Univerza v Mariboru
Ekonomsko-poslovna fakulteta

Letnik: 62 | Številka: 1 | 2016
Volume: | Number:

NG
OE

NAŠE GOSPODARSTVO
Revija za aktualna ekonomska in poslovna vprašanja

OUR ECONOMY
Journal of Contemporary Issues in Economics and Business

NAŠE GOSPODARSTVO

Revija za aktualna ekonomska in poslovna vprašanja

Letnik 62, št. 1, 2016

Izdajatelj:
Ekonomsko-poslovna fakulteta Maribor (EPF)

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Spletna stran:
http://www.ng-epf.si

Revija je indeksirana v ABI/INFORM Global, EconLit in ProQuest ter vključena v EBSCO in Ulrich's Periodicals bazo.

OUR ECONOMY

Journal of Contemporary Issues in Economics and Business

Vol. 62, No. 1, 2016

Published by:
Faculty of Economics and Business, Maribor (FEB)

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http://www.ng-epf.si

The review is indexed in ABI/INFORM Global, EconLit and ProQuest. It is included in EBSCO and Ulrich's Periodicals Directories.

Lektorji: mag. Darja Gabrovšek Homšak in ServiceScape Incorporated

Dtp: NEBIA, d. o. o.

Letno izidejo 4 (štiri) številke. Letna naročnina: za pravne osebe 46 €, za fizične osebe 29 € in za tujino 57,5 €.

ISSN 0547-3101

Revijo sofinancira Javna agencija za raziskovalno dejavnost Republike Slovenije.

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Spread and Liquidity Issues: A markets comparison

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ORIGINAL SCIENTIFIC PAPER

RECEIVED: SEPTEMBER 2015

REVISED: DECEMBER 2015

ACCEPTED: DECEMBER 2015

DOI: 10.1515/ngoe-2016-0001

UDK: 338.124.4:339.721

JEL: C19, E44, G01

Citation: Strašek, S., & Bricelj, B. (2016). Spread and Liquidity Issues: A markets comparison. *Naše gospodarstvo/Our Economy, 62*(1), 3–11. DOI: 10.1515/ngoe-2016-0001

Abstract

The financial crises are closely connected with spread changes and liquidity issues. After defining and addressing spread considerations, we research in this paper the topic of liquidity issues in times of economic crisis. We analyse the liquidity effects as recorded on spreads of securities from different markets. We stipulate that higher international risk aversion in times of financial crises coincides with widening security spreads. The paper then introduces liquidity as a risk factor into the standard value-at-risk framework, using GARCH methodology. The comparison of results of these models suggests that the size of the tested markets does not have a strong effect on the models. Thus, we find that spread analysis is an appropriate tool for analysing liquidity issues during a financial crisis.

Key words: liquidity, financial crisis, GARCH VaR models

1 Introduction

Traditionally, liquidity risk in financial crisis stemmed from the possibility of bank runs. One can find a number of these episodes. Strahan (2012) pointed out that, more recently, liquidity risk has come less from deposit outflows and more from exposure to a range of lending and interbank financial arrangements. These include undrawn loan commitments, obligations to repurchase securitized assets, margin calls in the derivatives markets, and the withdrawal of funds from wholesale short-term financing arrangements.

The global crisis has brought forward concerns that the lack of funding liquidity can have serious negative consequences, which can range from firms' inability to sell commercial papers to finance their business models to borrowers' inability to obtain funding for home mortgages. Falling home and stock prices are then unavoidable effects. Unconventional measures have been introduced to mitigate this problem: The Fed's decision to purchase unsecured 90-day commercial paper directly from corporations in late October 2008 and the $1,25 trillion home mortgage bond purchase program in 2010 are examples of solving the balance sheet channel (Bernstein, Hughson, & Weidenmeier, 2011).

In searching for other important effects of changes in funding liquidity on financial markets, Brunnermeier and Pedersen (2009) explored the relationship between

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funding liquidity and market liquidity. Their analysis suggested that market liquidity is likely to be low when funding liquidity is low. The sub-prime mortgage crisis and global crisis are examples in which funding constraints have played an important role in the onset and spread of the financial crisis.

A disagreement exists among economists as to whether the global crisis was a liquidity crisis or a solvency crisis. We could also find ample evidence that liquidity risk is incorporated into asset prices that allows the possibility that illiquidity and insolvency are not as distinct phenomena as we usually think (Viral & Pedersen, 2004).

The idea that the crisis was a liquidity crisis is based on the Diamond–Dybvig model of bank runs, where repo customers conducted a fire sale of repo securities, preventing banks from being able to borrow for the short term. The opposite argument states that banks' liquidity dried up simply because the market realized that the banks were insolvent.

Mehrling (2013) warned of the risk of over-simplification, where we tend to think of the financial crisis as a credit crisis concentrated in the banking system when in fact the global crisis was a liquidity crisis that prompted a solvency crisis on the dealer market. Far more important than a bank-based lending system for global financial markets is market liquidity, which can be defined as the ability to buy or sell securities in large quantities with virtually no effect on the price.

In the run-up to the crisis, huge incentives existed to set up or expand shadow banks because interest rates were low and there was a growing flow of available assets. The problem was that riskier assets in the form of securitized subprime mortgages filtered into the system (Mehrling, 2013). Forced sales provoked declining prices and, at one point, only the Fed's intervention prevented huge implications for the dealer funding market.

The global crisis of 2008 developed momentum and transformed to the euro area sovereign bond crisis. It is interesting that liquidity played a minor role in bond yield determination until 2008, after the Lehman crisis, and this role was quickly reduced after late 2009 (Bai, Julliard, & Yuan, 2012). In other words, during the early stage of the euro sovereign crisis, the market was characterized by flight to liquidity, but in later stages, credit risk was the main driver of bond yields and the market was characterized by flight to quality.

VAR analyses (Bai et al., 2012) also indicated that the euro sovereign bond crisis was less of a liquidity crisis and instead a crisis induced by common fundamentals. Imprudent fiscal policies (Greece) and lax regulation in the private sector like imprudent banking policies (Ireland and Slovenia), housing booms (Spain), and other fundamental factors provoked bad domestic macroeconomic behaviour. The liquidity crisis was an inevitable implication of such fundamental disequilibria.

2 Spread Considerations

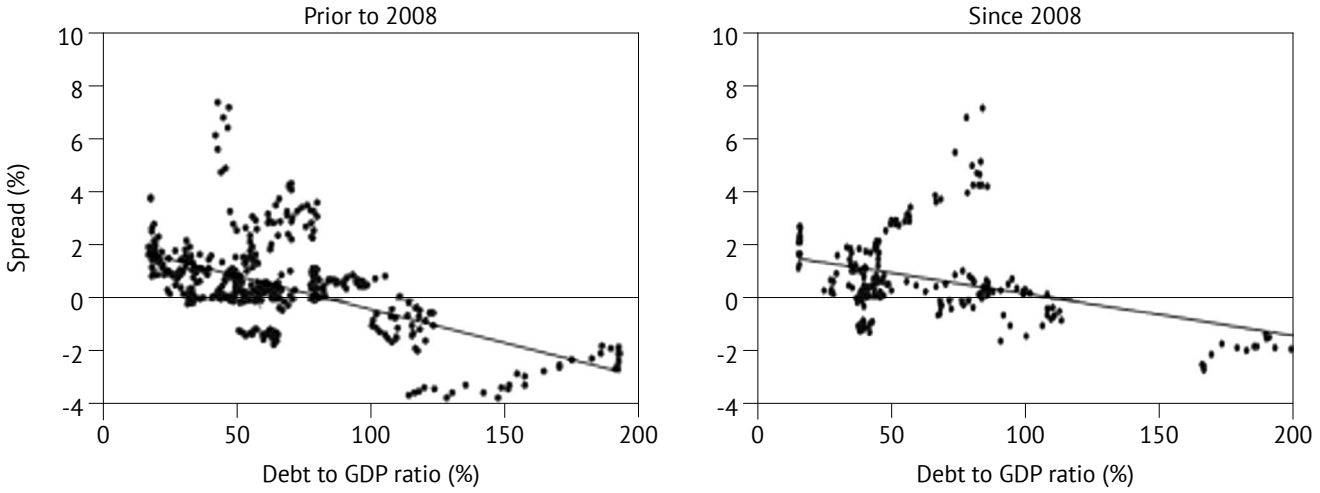
In line with existing empirical literature, the financial crises are closely connected with spread changes. Here we have in mind different types of spreads, like sovereign bond yield spreads, credit spreads of various financial instruments, and bid-ask spreads on asset prices.

It is not surprising that, in this environment, the crisis spreads were not only widening but also reaching record highs. The dimensions of risk measured by spreads may be many, but they can be grouped as being either default or liquidity risks. The empirical evidence has identified three main common drivers of bond yields and yield spreads: (i) credit risk (comprising the default risk, the credit spread risk, and the downgrade risk), (ii) liquidity risk, and (iii) global risk aversion. The euro sovereign crisis revealed that all three types of risk are reflected in the yields and yield spreads on government bonds.

Research on the determinants of sovereign bond yields differentials in the euro area has shown that government bond yields have risen sharply since the beginning of the financial crisis. Differences between euro area countries have become more pronounced as the spreads of some countries widened much more that those of other countries. Attinasi, Checherita, and Nickel (2009) found that sovereign bond yield spreads in the Eurozone reflect concerns about a country's credit risk and liquidity risk as well as higher international risk aversion. Higher expected budget deficits and/or higher expected government debt relative to Germany have contributed to higher government yield spreads in the Eurozone between the end of July 2007 and the end of March 2009. Empirical findings (Barrios, Iversen, Lewandowska, & Setzer, 2009) confirmed that international factors, particularly general risk perception, play a major role in explaining government bond yield differentials. The role played by domestic factors is smaller, but non-negligible. The impact of domestic factors on bond yield spreads increased significantly during the crisis, when international investors started to discriminate more between countries.

Empirical studies (De Grauwe & Ji, 2013) tested the hypothesis that government bond markets in the eurozone are more fragile and more susceptible to self-fulfilling liquidity crises than in stand-alone countries. A key difference exists between EMU member countries and stand-alone countries in terms of countries issuing debt in their own currency:

Figure 1: Spreads and debt-to-GDP ratios of stand-alone countries



Source: De Grauwe and Ji (2013).

Empirical data show that, despite the fact that in stand-alone countries' debt-to-GDP ratios and fiscal space variables were equally high and increasing, the spread movement did not follow the member countries' scenario.

The trap for members of a monetary union is that they issue debt in a currency over which they have no control and cannot give a guarantee that the cash will always be available to pay out bondholders at maturity. De Grauwe and Ji (2013) warned that such a liquidity crisis in a monetary union also makes it possible for the emergence of multiple equilibria. Undoubtedly, a great contrast exists between the eurozone and the stand-alone countries: Since the start of the financial crisis, the line between spreads and debt-to-GDP ratios has remained equally weak for stand-alone countries; furthermore, financial markets appear to punish eurozone countries more for the same imbalance. These conclusions are in line with De Grauwe's (2011) findings, which support the idea that government bond markets are more fragile and more susceptible to self-fulfilling liquidity crisis than stand-alone crisis.

The large relevance is associated with the combination of high risk aversion and large current account deficits, as the latter tends to magnify the incidence of deteriorated public finances on government bond yield spreads. Barrios et al. (2009) found that countries with large current account deficits experience an 11-base-point increase in government bond yield spread for each additional percentage point deterioration in public deficit. A high interaction occurs between general risk aversion and domestic fiscal conditions. In countries with large current account deficits and high debt, the latter experience the highest bond yield increases as a consequence of deteriorating public finances and increases in general risk aversion.

Different authors have also suggested that differences in government bond market liquidity have also been found to be significant for many euro area countries. Beber, Brand, and Kavajez (2006) found that, although credit risk matters for bond valuation in normal times, liquidity becomes more important in times of financial stress. The global crisis confirmed that the liquidity of government bond markets played a role in the widening of sovereign bond yield spreads. Countries with a more liquid bond market seem to enjoy relatively lower bond yield spreads during periods of financial turmoil (Attinasi et al., 2009).

The information contained in spreads is important because it may be indicative of an important channel through which financial prices affect the real side of the economy. The econometric analyses of the changing dynamic properties of a number of commonly reported yield spreads series (Guidolin & Tam, 2010) confirmed the use of spreads in timing breakpoints of selected financial crises. These findings suggest that, in non-crisis periods and especially in the aftermath of the crisis, yield spreads tend to adjust upward for yields on high (low) default (liquidity) risk bonds and downward for yields on high (low) default (liquidity) risk bonds.

Calculations on the relative contribution of explanatory variables to the change in average sovereign bond spreads relative to Germany show (Checherita, Attinasi, & Nickel, 2010) that the liquidity proxy amounts to 14%. The other proportions are: international risk aversion at 56%, expected fiscal position (expected budget balance and debt) at 21%, and the announcement of bank rescue packages at 9%. The authors also found that the announcement of bank rescue packages proved to be a robust and statistically significant determinant of the differential between sovereign credit

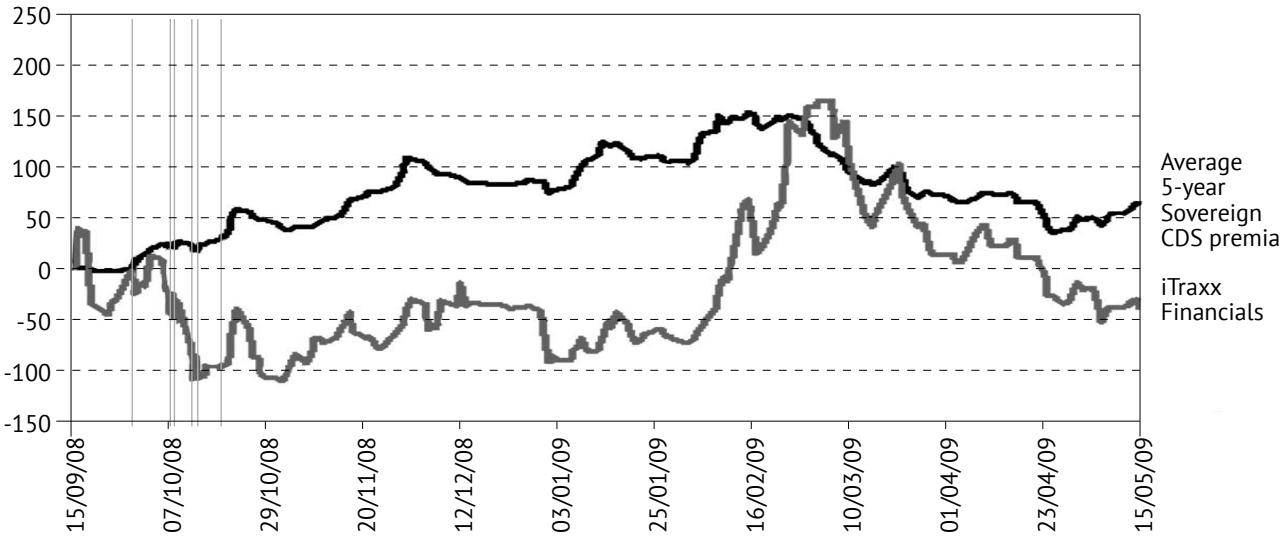
default swap premia and the iTraxx financials. This finding suggests that government commitments to support ailing financial institutions led to a re-assessment of sovereign credit risk on the part of the investors through a transfer of risk from the banking sector to the government (Checherita et al., 2010).

Gilchrist and Zakrajsek (2012) found that, as a feature of a business cycle, the number of yield spreads tends to widen shortly before the onset of recessions and to narrow again before recoveries. This phenomenon is due to the fact that credit risk spreads measure the default risk on private (relatively risky) debt. Hence, if private lenders can accurately assess increased default risks for individual firms or industries, these changes will be reflected by increases in the spreads. On the other hand, broad-based bank rescue packages alleviate some credit risk in the banking sector and bring about a transfer of credit risk from the private financial to the public sector. This fact was best seen in the global crisis, when a sharp increase in sovereign credit default swap (CDS) premia for most euro area countries was realized, whereas the CDS premia for European financial corporations (i.e., those covered by iTraxx financial index) reversed their upward trend and started to decline (ECB, 2009).

As illustrated in Figure 3, major investment banks experienced spreads that widened dramatically through the second half of 2007 and continued to widen still further through 31 October 2008. This corresponded to the movement of the spread between Libor and the overnight index swap (OIS) rate, which increased from less than 14 base points in July 2007 to 346 points on October 2008. Another argument for widened spreads represents the spread between Libor and the Treasury bill rate (TED), which widened from an average of 38 base points in the pre-crisis period to 464 points on 10 October 2008. Moreover, the same scenario could be observed on the yield spreads of short-term commercial paper of both non-financial and financial firms over the Treasury rate and spreads between 3-month Eurodollar deposits and the Treasury. Finally, the yield spreads of both MBS and high-yield bonds over the 10-year bond also rose considerably after July 2007. Pringle and Carver (2009) suggested that the spreads indicate that the market considered MBS to be even riskier than high-yield bonds, which was not the case prior to that time.

Liquid markets tend to exhibit five characteristics: tightness, immediacy, depth, breadth, and resiliency. Tightness refers to low transactions costs, such as the difference between buy and sell prices, like the bid-ask spreads in quote-driven markets. Several factors contribute to the difference between the bid and ask prices—namely, the security's liquidity, volatility, and stock price. The global liquidity crisis that started in 2007 could be explained through bid-ask spreads as a measure for the evolution of market liquidity. Pedersen (2009) highlighted the close co-movement between bid-ask spreads and VIX throughout the crisis as well as the visible connection to the TED spreads, indicating a link among market liquidity, funding, and volatility.

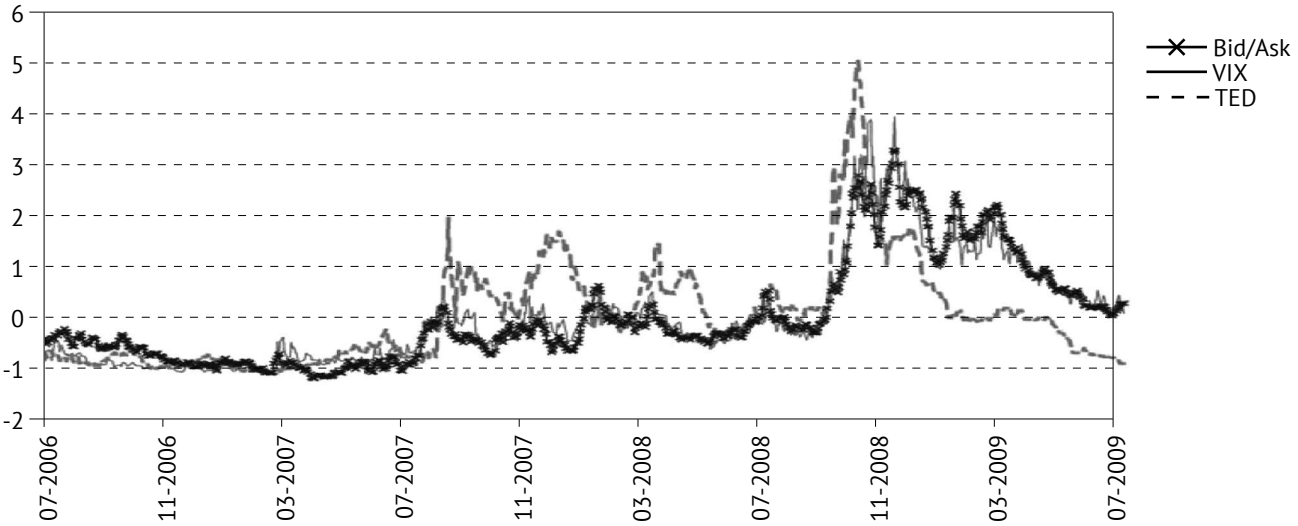
Figure 2. Cumulative changes in average five-year sovereign credit default swap premia for Eurozone countries and iTraxx financial index (15 September 2008 to 25 March 2009; bps)



Note: The vertical bars indicate the dates on which bank rescue packages were announced in Eurozone countries. Countries included in the analysis: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, and Spain.

Sources: Datastream and ECB staff calculations.

Figure 3: Bid-ask spreads during the global liquidity crisis



Note: The chart shows average bid-ask spread for large-cap U.S. stocks, the equity volatility index VIX, and the interest rate spread between LIBOR and Treasury bills (TED) from July 2006 to July 2009. Each of the series has been scaled to have a zero mean and a unit standard deviation.

Source: Pedersen (2009).

3 Methodology

As in our previous paper (Bricelj, Strašek, & Jagrič, 2013), we first describe the concept of liquidity. Jorion (2007) defined three different forms of liquidity. The first form is defined as the ability of a company to pay its debts. The second form is used to describe the characteristics of a portfolio (asset liquidity) or a market (market liquidity). The third form defines the state of an economy from the monetary perspective. The relevant form for our research is the second form—that is, the definition of how readily available a certain asset is for trade.

From the discussion thus far, we can further define market liquidity as costs associated with trading an asset relative to its mid-price. Stange and Kaserer (2009) defined possible degrees of liquidity of an asset as "fully liquid", "continuously tradable", "disruptively tradable", and "illiquid".

The availability of data often defines the methodology used in the research. Consequently, some models that incorporate liquidity risk are purely theoretical (Ernst, Stange, & Kaserer, 2009), including models based on optimal trading strategies. The authors classified the applied models into three groups: models based in bid-ask-spread data, models based on transaction or volume, and models based on weighted spread data.

In our research, we used data on relative spread. Our models were based on those documented in the articles of Bangia Diebold, Schuermann, and Stroughair (1998, 1999) and upgraded according to Ernst, Stange, and Kaserer (2012) with the Cornish-Fisher expansion to estimate the quantiles of the distribution of spread and mid-price:

$$\tilde{z}_\alpha = z_\alpha + 1/6\,(z_\alpha^2 - 1)\gamma + 1/24\,(z_\alpha^3 - 3z_\alpha)\kappa - 1/36\,(2z_\alpha^3 - 5z_\alpha)\gamma^2, \quad (1)$$

where γ and κ represent the skewness and kurtosis of a distribution. Considering the multiplicative effects of worst spread on mid-price returns, they proposed the following LVaR model:

$$LVAR = 1 - e^{(\tilde{z}_\alpha(r)\,\sigma_r)}\,(1 - 1/2\,(\mu_S + \tilde{z}_\alpha(S)\,\sigma_S)), \quad (2)$$

where $\tilde{z}_\alpha(r)$ represents the quantile of the distribution of returns and $\tilde{z}_\alpha(S)$ represents the quantile of the distribution of spread.

In our research, we calculated the volatility of returns using GARCH (1, 1). We opted for this method because, according to Engle (2001) and Bollerslev (2009), this type of GARCH model is often used in praxis. To calculate the dynamic variance, we used the following econometric model:

$$\sigma_t^2 = \omega + \alpha_i\,\varepsilon_{(t-1)}^2 + \beta_i\,\sigma_{(t-i)}^2. \quad (3)$$

The crucial part of our research after the implementation of VaR and LVaR models was the testing for accuracy of these

models using out-of-sample diagnostics, known as backtests. It can be assumed that, if a model does not pass these backtests, it is not sufficiently accurate, although it must be noted that the results of backtests vary depending of the characteristics of a portfolio (Alexander, 2008). Backtests are based on historical data with a fixed estimation period, which defines the sample used to estimate the VaR model parameters.

4 Data Collection and Results

We tested the effects of the global economic crisis on spreads with an ad-hoc ANOVA analysis of securities from four markets: the United States, Germany, Slovenia, and Korea. Using the ANOVA procedure we tested if the relative bid-ask spreads of securities changed in times of crisis—that is, if the change of the mean of those spreads was statistically significant. We calculated relative bid-ask spreads as the spreads between best ask and bid prices of securities, divided by the mid-prices of the observed securities:

$$S = \frac{P_{ask} - P_{bid}}{P_{mid}} \quad (4)$$

The table reports the *p*-values of ANOVA tests for our chosen securities. It is evident from the results that the relative bid-ask spreads differ in times of crisis. For 18 of the 20 chosen securities, we identified a statistically significant difference between the mean values of spreads before and after the start of the crisis, calculated as a *p*-value less than 0.05. In one case (GRVG) the *p*-value is marginal, but only because the data cover a short time before the crisis, due to the security splitting. Furthermore, a closer examination of results of our tests indicated that the spreads are larger in times of economic crisis than in times of economic stability.

Our database is comprised of four sets of securities, corresponding to the stock exchanges on which they are traded: Slovenian dataset, German dataset, Korean dataset, and American dataset. We summarized the characteristics of the chosen stock exchanges in Table 1.

Table 1 clearly shows how much the capital markets differ from one another. Some of the biggest stock exchanges operate on the foreign capital markets and are significantly larger than the Slovenian one.

In our research, we included five assets from each of the four capital markets—that is, five stocks from the Slovenian Prime Market Shares, five from the DAX 30 Index, five from the Dow Jones Industrial Average Index, and five from the KOSPI Composite Index. The data on assets consisted of price data (opening and closing maximum and minimum prices), volume data, and spread data (best bid/ask prices from the limit order book). We obtained the data for the Slovenian assets from the Ljubljana Stock Exchange and the data for foreign assets from Bloomberg. The data covered the period from January 2000 to April 2012 on a daily frequency.

Table 2 presents the data analysis. We based the analysis on mid-price logarithmic returns. The reason we chose the mid-price returns is because they are used in VaR and LVaR models as well as in most types of backtests we applied. In Table 2, *n* is the number of trading days, μ is the mean of logarithmic returns, Max and Min are the maximum in minimum value of returns in the sample, σ is the standard deviation of returns, γ is the coefficient of skewness, κ is the coefficient of kurtosis, and JB is the *p*-value of the Jarque-Bera test.

We chose the assets for our research in such a way that they best represented the economic landscape of a chosen economy while being diversified at the same time. We also tried to harmonize the choice of assets among the four capital markets. Two particular criteria were used in the choice of the final five. First, the data on the assets must cover a long enough period to encompass times of economic upturn and downturn. Second, the data must not contain bigger anomalies, such as stock splits or longer periods of no trading activity. In one case (KRKG), there was a stock split in September 2007. We chose to incorporate into our research only the data after the split as the other Slovenian stocks not chosen were far less traded and, therefore, presumed far less liquid than the one with the anomaly.

Table 1. *General characteristics of the chosen stock exchanges in 2011*

	Deutsche-Boerse	Ljubljana Stock Exchange[a]	Korea Exchange	New York Stock Exchange
Market capitalization [US$bn]	1185	6,316	996	11796
Number of listed companies	746	76	791	2308
Trade value [US$bn]	1758	0,511	2029	18027

Notes: [a] Data for Slovenia are converted to USD using the closing exchange rate on 30 December 2011: EUR/USD = 1,29610.
Sources: http://www.ljse.si, http://www.world-exchanges.org/

Table 2. *Data Analysis of Logarithmic Mid-price Returns*

Code	Description	n	μ	Max	Min	σ	γ	κ	JB
GRVG	Gorenje, d.d.	3045	-0,00023	0,097	-0,094	0,016	-0,041	7,721	0,000
KRKG	Krka, d.d.	1122	-0,00078	0,084	-0,113	0,017	-0,380	8,863	0,000
LKPG	Luka Koper, d.d.	3045	-0,00014	0,108	-0,098	0,016	-0,104	8,044	0,000
MELR	Mercator, d.d.	3034	0,00021	0,110	-0,094	0,016	0,142	9,157	0,000
PETG	Petrol, d.d.	3047	0,00012	0,128	-0,106	0,015	0,277	13,501	0,000
BAYN.DE	Bayer AG	3102	0,00006	0,334	-0,189	0,022	0,803	25,922	0,000
BMW.DE	BMW AG	3087	0,00026	0,135	-0,126	0,022	0,055	6,623	0,000
DAI.DE	Daimler AG	3098	-0,00021	0,175	-0,143	0,023	0,175	8,059	0,000
TKA.DE	ThyssenKrupp AG	3086	-0,00018	0,165	-0,174	0,024	-0,108	7,205	0,000
SIE.DE	Siemens AG	3112	-0,00006	0,166	-0,165	0,024	-0,068	7,312	0,000
000120.KS	CJ Korea Express Co.	2714	0,00007	0,254	-0,627	0,039	-1,360	33,409	0,000
000210.KS	Daelim Industrial Co.	2862	0,00076	0,465	-0,274	0,038	0,440	13,747	0,000
000240.KS	Hankook Tire Co.	2877	0,00093	0,154	-0,141	0,031	0,254	4,833	0,000
000270.KS	Kia Motors Corp.	2837	0,00085	0,214	-0,296	0,032	-0,258	8,487	0,000
005930.KS	Samsung Electr. Co.	2925	0,00054	0,140	-0,146	0,026	0,029	6,689	0,000
BA	The Boeing Co.	2967	0,00019	0,180	-0,173	0,024	-0,039	8,613	0,000
HPQ	Hewlett-Packard Co.	2920	-0,00020	0,203	-0,285	0,031	-0,363	13,250	0,000
KO	The Coca-Cola Co.	2959	0,00008	0,100	-0,144	0,016	-0,116	9,164	0,000
PFE	Pfizer Inc.	2920	-0,00012	0,116	-0,161	0,020	-0,228	8,596	0,000
XOM	Exxon Mobil Corp.	2840	0,00027	0,172	-0,160	0,019	-0,046	12,794	0,000

Source: Authors' calculations.

Regarding the start of the crisis, in our analysis, we defined the start of the American crisis in August 2007 and the start of the European crisis and the rest of the world in September 2008. The results are shown in Table 3.

We analysed the collected data and corrected smaller anomalies than those discussed above. From the data on Slovenian stocks, we omitted those days where errors occurred in the calculation of mid-price. These occurred due to either the lack of trading on a particular day or mismatches in limit order data. From the data on foreign stocks, we omitted non-tradable days. Finally, we applied an automatic filter, which omitted the days with a recorded negative bid-ask spread as well as days where the bid-ask spread exceeded the mean bid-ask spread of the sample by five standard deviations. We assumed that such bid-ask spread outliers cannot be part of the data but must be caused by errors in the limit order data.

To produce the VaR and LVaR estimates in our research, we used the following procedures. We used a 20-day rolling procedure to produce the mean values of returns and spread. For the GARCH variances, we used a 250-day rolling procedure. The reason behind the larger data window was that our tests of GARCH coefficients showed that they are unstable when using a smaller data window. For the quantiles of the Cornish-Fisher expansion, we used a 500-day rolling procedure because estimates on smaller data windows are susceptible to effects of outliers in the data (Ernst et al., 2012).

We tested the accuracy of VaR and LVaR models using an unconditional coverage backtest. The exceedances in LVaR

Table 3. *ANOVA Analysis of the Relative Bid-ask Spread Pre- and Post-crisis*

GRVG	KRKG	LKPG	MELR	PETG
0.00000	0.09300	0.00000	0.00000	0.00000
BAYN.DE	BMW.DE	DAI.DE	TKA.DE	SIE.DE
0.00000	0.58100	0.00920	0.00000	0.04520
000120.KS	000210.KS	000240.KS	000270.KS	005930.KS
0.00000	0.00000	0.00000	0.00000	0.00000
BA	HPQ	KO	PFE	XOM
0.00000	0.00000	0.00000	0.00000	0.00000

Source: Authors' calculations.

models were identified by comparing model forecasts with realized losses that were calculated as realizable net returns when liquidating a position (Ernst et al., 2012):

$$[rnet]_t=\ln (P_t/P_{(t-1)})-\ln (1-1/2\, S_t). \quad (5)$$

5 Conclusions

The analysis of market spreads confirmed that the financial crisis affected markets deeply and over the whole spectrum of finance, from actual spreads on tradable assets to arising liquidity issues on bond markets during the crisis as well as to firms' funding liquidity. Furthermore, the crisis accentuated the problems associated with bond yields from Eurozone country bonds and their inherent susceptibility to self-fulfilling crises.

The analysis of the spreads also confirmed that the effects of the financial crisis radiated from the United States and manifested in European markets with a delay of more than a year, as seen in the analysis of spreads. This is also well documented in the accuracy of LVaR and VaR models tested on select markets.

The results from the LVaR models were accurate for four out of five Slovenian stocks, but the VaR models underestimated risk in all cases. LVaR models overestimated risk for all five German stocks, but VaR models showed a high degree of accuracy. The results of unconditional coverage tests for the Korean stocks showed that the LVaR and VaR models were accurate in three out of five cases. Finally, LVaR models were accurate for all five of the American stocks, according to unconditional coverage tests, but VaR models were less accurate.

Backtests for the GARCH LVaR models showed that they were accurate on four out of five Slovenian stocks whereas GARCH VaR models underestimated the risk. GARCH LVaR models were accurate for three German stocks; GARCH VaR models also underestimated the risk. The results for the Korean stocks showed that the GARCH LVaR models were accurate in 80% of the cases and the GARCH VaR models in 60%. For the American subset, the GARCH LVaR models were accurate for two of the five American stocks while the GARCH VaR model backtests showed similar results as in all the prior stocks.

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Problematika likvidnosti in cenovnih razponov – primerjava kapitalskih trgov

Izvleček

Finančne krize so tesno povezane z likvidnostnimi težavami, ki izhajajo iz sprememb poslovanja na borzah. V tem članku analiziramo likvidnostne težave v času ekonomskih kriz. Likvidnostne učinke analiziramo na podlagi informacij o cenovnem razponu med ponujeno in povpraševano ceno naložbe. Predpostavljamo, da v času kriz obstaja pozitivna povezava med prevzemanjem tveganj in večanjem cenovnih razponov. V članku uvedemo likvidnost v standardno analizo tvegane vrednosti, pri tem pa za izračune volatilnosti uporabimo metodo GARCH. O primerjavi rezultatov po naborih delnic ugotavljamo, da velikost kapitalskih trgov ne vpliva na rezultate modelov, zato ugotavljamo tudi, da se po likvidnostnih modelih VaR ob upoštevanju predpostavk raziskave primerno ocenjujejo tržna tveganja.

Ključne besede: likvidnost, finančne krize, modeli GARCH VaR

ORIGINAL SCIENTIFIC PAPER

RECEIVED: OCTOBER 2015

REVISED: FEBRUARY 2016

ACCEPTED: FEBRUARY 2016

DOI: 10.1515/ngoe-2016-0002

UDK: 311.21:658.7

JEL: C22, C40, G11

Citation: Žmuk, B. (2016). Capabilities of Statistical Residual-Based Control Charts in Short- and Long-Term Stock Trading. *Naše gospodarstvo/Our Economy, 62*(1), 12–26. DOI: 10.1515/ngoe-2016-0002

Capabilities of Statistical Residual-Based Control Charts in Short- and Long-Term Stock Trading

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Abstract

The aim of this paper is to introduce and develop additional statistical tools to support the decision-making process in stock trading. The prices of CROBEX10 index stocks on the Zagreb Stock Exchange were used in the paper. The conducted trading simulations, based on the residual-based control charts, led to an investor's profit in 67.92% cases. In the short run, the residual-based cumulative sum (CUSUM) control chart led to the highest portfolio profits. In the long run, when average stock prices were used and 2-sigma control limits set, the residual-based exponential weighted moving average control chart had the highest portfolio profit. In all other cases in the long run, the CUSUM control chart appeared to be the best choice. The acknowledgment that the SPC methods can be successfully used in stock trading will, hopefully, increase their use in this field.

Key words: Zagreb Stock Exchange; investments; statistical process control; autocorrelation; residual-based control charts

1 Introduction

The stock market is recognized as a vital part of a country's economy, finances, and growth. Tachiwou (2010) considered the stock market as an indicator of an economy's financial health and as a base for economic growth in the short and long run. The positive effects of stock markets on economic growth have also been recognized by other authors (Caporale, Howells, & Soliman, 2004; Manas, 2005). In order to be capable of adopting the role of investors and being included in stock trading, individuals need to be financially literate (Almenberg & Dreber, 2012; Guiso, Sapienza, & Zingales, 2008, van Rooij, Lusardi, & Alessie, 2011) and have developed computer and Internet skills (Bogan, 2008).

The filter trading rules were introduced by Alexander (1961, 1964). Alexander's work on the filter trading rules presented one of the earliest academic works focused on the investigation of stock prices trends using statistical rules (Venkataramani, 2003). His work was followed by the works of Fama and Blume (1965) and Dryden (1969) and further developed by Sweeney (1988) and Corrado and Lee (1992). The filter-trading rule is defined as a sequence of buy and sell signals. These signals are given according to a mechanical rule. For instance, the buy signal is given if the daily closing price of an observed stock moves up at least F percent from a subsequent low. After the stock is bought, the investor holds the stock and awaits the sell signal. The sell signal is given when the closing prices drops at least F percent from a subsequent high. The

NG
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OUR ECONOMY**

Vol. 62 No. 1 2016

pp. 12–26

subsequent lows and highs can be defined in different ways (Sullivan, Timmermann, & White, 1999) whereas the *F* value is the filter size for the trading rule and represents the minimally acceptable percentage change of the observed stock value for the investor.

The research question is this study is whether statistical control charts, as a statistical process control (SPC) method, could be useful in trading stocks—that is, whether control charts are capable of giving signals for buying, holding, and selling stocks. Control charts were introduced by Shewhart in 1924 (Best & Neuhauser, 2006). Over the years, control charts, and other statistical control process methods, have found their use in different fields not only in mass production. For instance, control charts could be used in the financial analysis also. Right before the appearance of filter trading rules, H. V. Roberts (1959) was one of the first to suggest the use of statistical quality control methods for the study of market price levels and changes. Hubbard (1967) studied Moody's Composite 200 Stock Average from 1950 to 1967 and used logarithmic monthly values in order to construct control charts, which he used to determine the price trend and compare it with gross national product and personal income trends. Most importantly, he identified ways to recognize signs for buying or holding stocks. According to Hubbard (1967), small price differences edging up and down the centre line have no recognizable pattern; consequently, such differences contain no useful information for helping an investor decide whether to buy or sell stocks. On the other hand, significant departures from the centre line signals stock price overvaluation or undervaluation.

Statistical control charts are rarely explored as a technique in stock trading and portfolio analysis (Gandy, 2012; Rebisz, 2015). According to McNeese and Wilson (2002), one of the main reasons for rarely using statistical control charts in financial analysis is managers' attitude that control charts are inappropriate for their kind of work. However, Kovarik and Sarga (2014) used cumulative sum (CUSUM) and exponentially weighted moving average (EWMA) control charts to deal with the corporate cash flow control. Meanwhile, Gandy (2012) used CUSUM control charts in credit portfolio analyses. Therefore, in all analyses the focus is on the analysis based on individual (I), exponentially weighted moving average (EWMA), and cumulative sum (CUSUM) control charts. These control charts are also chosen because their application is intuitive and not too complex for an average investor. Furthermore, what is also important is that the selected control charts can give immediate signals to an investor.

According to the above stated research questions and literature review, three research hypotheses are defined:

H1: Statistical control charts are useful for making decisions about stock trading.

H2: Stock trading based on the individual (I) control chart overall gives a portfolio profit that is higher than the profit achieved by using the exponentially weighted moving average (EWMA) control chart or the cumulative sum (CUSUM) control chart.

H3: Stock trading based on opening prices overall results in higher portfolio profit than the trading based on average prices.

In order to test these research hypotheses, data from the Zagreb Stock Exchange were used. Four parallel analyses were conducted. The analyses used open and average prices of stocks from the CROBEX10 market index in the short and long run. The observed data and used methods are explained in Section 2. The conducted short-run analysis is given in Section 3, whereas the long-run analysis is provided in Section 4. Section 5 compares and discusses the obtained results. Final conclusions and suggestions for further research are given in Section 6.

2 Data and Methodology

The Zagreb Stock Exchange (ZSE) is the only regulated modern stock exchange in the Republic of Croatia (Benić & Franić, 2008; Zagreb Stock Exchange, 2014b). In 2013, 208 stocks were listed (Zagreb Stock Exchange 2014a) as well as 9 stock (equity) indices (Zagreb Stock Exchange, 2014e). The analysis included only the CROBEX10 index, which includes 10 stocks with the highest free float market capitalization and turnover (Zagreb Stock Exchange, 2014d) and that are traded in more than 90% trading days (Zagreb Stock Exchange, 2014c). This approach ensured the use of appropriate and quality data series with enough data points for the analysis without long breaks. The CROBEX10 index composition is shown in Table 1.

It has to be emphasized that the CROBEX10 index has two regular revisions during a year: on the third Friday in March and in September (Zagreb Stock Exchange, 2014d). Thus, the CROBEX10 index composition can be considered very unstable and changeable, which has to be taken into account in the long-run analyses of the CROBEX10 index.

Selected stocks were observed through two different periods. The first period was from 1 January to 31 December 2012 while the second period includes the period from the stocks' initial listings on ZSE to 29 August 2014. The first period will show control charts' capabilities for stock trading in

Table 1. *CROBEX10 Index Stock Members on 1 September 2014 and the Number of Trading Days*

Stock symbol	Enterprise	Total number of trading days in 2012	Overall number of trading days*
ADPL-R-A	AD Plastik d.d.	248	2,147
ADRS-P-A	Adris grupa d.d.	240	2,761
ATGR-R-A	Atlantic Grupa d.d.	245	1,676
ERNT-R-A	Ericsson Nikola Tesla d.d.	250	3,817
HT-R-A	Hrvatski Telekom d.d.	250	1,740
INA-R-A	INA-industrija nafte d.d.	246	1,721
KORF-R-A	Valamar Adria Holding d.d.	250	2,809
LEDO-R-A	Ledo d.d.	237	2,117
PODR-R-A	Podravka d.d.	247	4,474
PTKM-R-A	Petrokemija d.d.	249	2,505

Source: Zagreb Stock Exchange (2014d).
Note: *Includes the period from the stocks' initial listings on ZSE to 29 August 2014.

the short run; the second period will show their capabilities in the long run. Because the observed stocks have different dates of their initial listings on ZSE, the overall number of trading days among them differs much more than in the short-run analysis. The stocks ATGR-R-A (1,676 trading days) and INA-R-A (1,721 trading days) have the lowest overall number of trading days. According to Table 1, the stock PODR-R-A, which was initially listed on ZSE in 1995, has the highest overall number of trading days (4,474 trading days). Because the stock PODR-R-A has the longest trading tradition, the analysis for this stock is shown in more detail than for the other observed stocks.

In the analysis, the research variables include the opening price and the average price. Both variables are given in Croatian kuna (HRK). The variable opening price was used in the analyses mainly because of an investor's ability to react fast to the control chart signals to buy or to sell stocks. Thus, the first assumption in the opening price analyses is that the investor can trade on the same day the trading signal was received. The second assumption is that the investor can react fast, thereby securing a price equal to the opening price of that trading day.

As in the opening price analyses, in the average price analyses it is also assumed that the investor can react on the same day the trading signal was received. But contrary to the opening price analyses, in the average price analyses there is no need for the investor to be very fast in trading. In the opening price analyses, the investor has to trade right after the first or the opening price is announced whereas in the average price analysis, the investor can choose when to trade throughout the whole trading day. However, it is assumed that the investor will wait until the trading day ends, which means that the trade will be at the average price level of that trading day. More precisely, here it is assumed that the investor has an opportunity to make the last transfer of the day.

In order to emphasize that the main goal is to earn only the difference between the buy and sell price, no additional payments are considered in the analysis. Thus, it is assumed that no additional pay outs (e.g., dividends) are made to investors. Similarly, it is assumed that there are no additional costs for investors, such as trade commissions.

From the many available statistical control charts (Montgomery, 2013; Montgomery & Runger, 2011), it can be determined that the following control charts are the most appropriate to use in this case: control chart for individual units (I), exponentially weighted moving average (EWMA) control chart, and cumulative sum (CUSUM) control chart. The main criteria for control chart selection were intuitive approach, straightforward analysis, and sensitivity to a drift in the process. The "forgetfulness" parameter in the EWMA control chart is set to 0.3 because that is the value usually used (NIST/SEMATECH, 2013). In general, the choice of the parameter value is somewhat arbitrary (Lucas & Saccucci, 1990). Although the moving range (MR) control chart is presented, but it plays only a supportive role. The characteristics of the mentioned control charts are well described in existing literature (Box, Luceno, & Paniagua-Quinones, 2009; del Castillo, 2002; Dumičić & Žmuk, 2011a, 2011b; Hunter, 1986; Kovarik & Klimek, 2012; Liu & Tien, 2011; Montgomery & Friedman, 1989; Montgomery, Jennings, & Pfund, 2011; Page, 1954; S. W. Roberts, 1959; Ryu, Wan, & Kim, 2010; Riaz, Abbas, & Does, 2011; SAS Institute, 2014; Wild & Seber, 1999).

Financial data are very sensitive to mean shifting, and strong autocorrelation appears very often (Kovarik & Klimek,

2012), resulting in the high probability that the observed stock price data are also autocorrelated. The autocorrelation can have a huge impact on decision making based on control charts through the increased false alarm rates (Schmid, 1995; Schmid & Schone, 1997; Vanbrackle & Reynolds, 1997). Therefore, attention was given to developing different procedures in those cases (Alwan, 1991; Harris & Ross, 1991; Lu & Reynolds, 1999a, 1999b, 2001). The autocorrelation problem can be resolved by skipping data, adjusting the control limits of the existing control charts, and using the residual-based control chart analysis (Vasipulos & Stamboulis, 1978; Woodall & Faltin, 1993). Usually, the residual-based control charts are used to deal with the autocorrelation problem (Alwan & Roberts, 1988; Moskowitz, Wardell, & Plante, 1994).

It has been shown that economic and financial data could be autocorrelated (Levich & Rizzo, 1998; Sewell, 2011). Consequently, it is expected that this would be valid for stock data as well (Lewellen, 2002; Lillo & Farmer, 2004; Tolvi, 2002). If autocorrelation is present in open and average stock prices, the Autoregressive Integrated Moving Average (ARIMA) model is used (Box & Jenkins, 1976).

3 Short-run Stock Trading Analysis Based on Open and Average Prices

For the purpose of this paper, a short period is defined as the period of one year. Therefore, in the short-run stock trading analysis, only data from 2012 were used. First, the opening prices of CROBEX10 stocks were analysed. Afterwards, analyses based on the average prices of CROBEX10 stocks were conducted.

Control charts are most effective when the data are uncorrelated and are illustrated with stationary behaviour (Montgomery, 2013). Thus, the presence of data autocorrelation at the opening prices of CROBEX10 stocks was investigated. The analysis demonstrated that all observed stocks had an autocorrelation coefficient close to 1. As a result, it was concluded that the autocorrelation problem has a significant impact on the control charts.

In order to solve the autocorrelation problem, the *ARIMA*(*p*,*d*,*q*) modelling approach was used. If the skip data procedure had been used, some trading days would not have been observed. This does not seem to be logical and surely is not acceptable for an investor. Thus, the skip data procedure was not considered. Similarly, adjusting the control limits of the existing control charts—another recommended technique for dealing with the autocorrelation problem in such cases—was not considered either because this technique assumes a low autocorrelation level, which was not the case here. Given the strong autocorrelation, significant adjustments of control limits would be required, which is not acceptable.

In order to determine the *p* and *q* levels, the auto-correlation function (ACF) and the partial auto-correlation function (PACF) were used. If the ACF cut-off after *q* and if at the same time the PACF showed infinite tails off dominated by damped exponential waves and cosine waves, the moving average model of order *q* or the model *ARIMA*(0,0,*q*) was chosen. If the ACF showed infinite tails off dominated by damped exponential waves and cosine waves and if the PACF cut off after *p*, the autoregressive model of order *p* or the model *ARIMA*(*p*,0,0) was chosen. If exponential waves and cosine waves were present in both the ACF and the PACF, then an appropriate *ARIMA*(*p*,0,*q*) model was chosen. Before determining the *p* and *q* levels, the presence of the polynomial trend was checked and the value of *d* was chosen accordingly.

In order to estimate parameters of the *ARIMA*(*p*,*d*,*q*) models for CROBEX10 stocks, the approximate maximum likelihood method introduced by McLeod and Sales (1983) was used. Once the parameters were estimated for the selected *ARIMA*(*p*,*d*,*q*) model, the adequacy of the selected model for the data was checked. If the fitted model was adequate, the residuals should be approximately white noise, which means they should have zero mean and be uncorrelated. The key instruments are the ACF and the PACF of the residuals. If the model is appropriate, most of the coefficients of the ACF and the PACF should be close to zero. If the coefficients of the ACF and the PACF were not close to zero, the new *ARIMA*(*p*,*d*,*q*) model was chosen and the adequacy procedure was repeated. In the process of finding the best appropriate *ARIMA*(*p*,*d*,*q*) model, the parsimony principle was used. In other words, if two *ARIMA*(*p*,*d*,*q*) models had similar statistical characteristics, the simpler model was chosen (Hyndman, 2001).

After the ACF and the PACF confirmed the selected *ARIMA*(*p*,*d*,*q*) model adequacy, the statistical significance of estimated parameters was checked. If all estimated parameters were statistically significant at the 5% level, the final decision was made to accept the selected *ARIMA*(*p*,*d*,*q*) model as adequate. When some statistically non-significant estimated parameters existed, a new *ARIMA*(*p*,*d*,*q*) model was chosen.

After identifying the initial *ARIMA*(*p*,*d*,*q*) model and estimation of its parameters, Noskievičová (2007) recommended identifying outliers, inspecting their causes, and realizing adequate corrective actions. Due to the simplification of the

Table 2. *Explorative Analysis of Opening Prices of CROBEX10 Stocks in HRK in 2012 and Chosen Adequate ARIMA(p,d,q) Models*

Share	k	Min.	Max.	Mean	Median	Std. dev.	Var. coef. (in %)	*ARIMA*(*p*,*d*,*q*) model
ADPL-R-A	248	100.99	128.94	111.52	108.73	7.42	6.66	(1,0,0)
ADRS-P-A	240	202.01	256.98	222.67	217.00	13.29	5.97	(2,0,0)
ATGR-R-A	245	454.00	550.00	492.05	492.02	19.77	4.02	(2,0,0)
ERNT-R-A	250	880.01	1,374.99	1,158.10	1,175.05	109.64	9.47	(1,1,0)
HT-R-A	250	193.00	244.40	211.00	205.99	13.89	6.58	(1,1,0)
INA-R-A	246	3,550.00	4,500.00	3,858.21	3,728.02	265.83	6.89	(1,1,0)
KORF-R-A	250	70.61	110.99	94.30	95.57	11.58	12.28	(1,0,0)
LEDO-R-A	237	4,900.00	7,720.00	5,836.94	5,701.04	660.84	11.32	(1,0,0)
PODR-R-A	247	206.01	276.50	239.94	242.99	19.73	8.22	(1,0,0)
PTKM-R-A	249	184.80	340.00	229.27	226.73	31.17	13.60	(7,2,0)

Source: Author's calculations.

procedure and the nature of the process, outliers were not further inspected in the analysis. Namely, investors are interested in having a simple and fast procedure for everyday use. In addition, omitting outliers or some other outlier corrective actions could have a significant impact on stocks' history and trade decisions. The selected adequate *ARIMA*(*p*,*d*,*q*) models for opening prices of CROBEX10 stocks in 2012 are summarized along with the basic explorative analysis results in Table 2.

After the adequate *ARIMA*(*p*,*d*,*q*) models were chosen and the models' parameters were estimated, residuals for each CROBEX10 stock were calculated. In the further analysis, the residual-based control chart approach was used (Montgomery, 2013). In this approach, instead of using the original data, the residuals are used in order to construct the control chart. Because of the use of residuals, the analysis results are less intuitive and interpretable than the results of the analysis in which the original data were used; however, these disadvantages of using residuals in the control chart analysis can be neglected because in this case the aim is not to interpret the results, but to observe whether a significant difference of a residual from the other residuals exists. If such a significant difference exists between real and model values from the other residual differences, the residual falls outside the control limits. In that case, if the residual is above the upper control limit, the real stock price is significantly higher than it was anticipated by the model incorporating all previous prices. This situation results in investors' motivation to sell stocks because they can achieve a significantly higher price than expected. On the other hand, investors are encouraged to buy stocks if the price is significantly lower than expected; in other words, this situation results in investors' motivation for buying. In this case, the residual is under the lower control limit.

After the selected residual-based control charts of opening prices were constructed for each CROBEX10 stock in 2012, investor trading was simulated according to the control charts' signals. In the trading simulations I, EWMA (with λ=0.3), and CUSUM control charts were used. The moving range (MR) control chart was omitted from the analysis because of its inability to provide buying signals—namely, by definition, a range cannot be negative. It is very likely that the lower control limit needs to be set at 0, and no data can have a value lower than that value. In this way, this case leads to an absence of buying signals. Furthermore, an investor's trading was simulated based on these three selected residual-based control charts with 2-sigma and 3-sigma control limits separately. Six trading simulations were conducted for each CROBEX10 stock.

It was assumed that an investor bought stocks at the very beginning of the year at the price equal to the first opening price in 2012. Similarly, it was assumed that the investor did not want to have any stocks at the end of the year. If investors had any stocks in their portfolios at the end of the year, they would have sold all stocks at the last opening price in 2012. All investors' transactions were made at the opening price level in HRK. In order to keep the analysis simple, no trade commission was considered. The investor bought only one stock for each buy signal. The buy signal was given when a residual fell below the lower control limit. On the other hand, if a residual was above the upper control limit, the sell signal was given. In that case, the investor sold all stocks in the portfolio. Table 3 provides the stock trade simulation results based on opening prices for all CROBEX10 stocks in 2012.

Table 3 shows the results of 60 stock trade simulations conducted based on opening prices for all CROBEX10 stocks in 2012. According to the results provided in Table 3, 51 stock trade simulations gave a positive investor score whereas 9

Table 3. *Trade Simulation of CROBEX10 Stocks Based on Opening Prices Using the Residual-based Control Chart for Individual Units (I), the Residual-based Exponentially Weighted Moving Average (EWMA) Control Chart (λ=0.3), and the Residual-based Cumulative Sum (CUSUM) Control Chart, 2012*

Stock	Control chart	Control limits: +/- 2 std.		Control limits: +/- 3 std.	
		Number of trades	Investor score, HRK	Number of trades	Investor score, HRK
ADPL-R-A	*I*	12	1.63	4*	7.62
	EWMA	8	6.11	2	13.50
	CUSUM	20	4.89	14	11.65
ADRS-P-A	*I*	13	97.63	4*	12.39
	EWMA	8*	54.37	2	17.51
	CUSUM	12	34.19	4*	20.19
ATGR-R-A	*I*	7	66.98	2	36.00
	EWMA	5	143.97	2	36.00
	CUSUM	15	276.37	6	106.00
ERNT-R-A	*I*	15	560.87	7	187.00
	EWMA	15	600.83	9	314.78
	CUSUM	40	2,510.96	34	1,750.19
HT-R-A	*I*	9	-29.76	5	-42.56
	EWMA	12	-54.16	7	-61.96
	CUSUM	31	-119.25	21	-120.64
INA-R-A	*I*	22*	523.70	10*	137.95
	EWMA	14*	1,013.96	10*	712.96
	CUSUM	45*	1,207.41	33*	2,010.20
KORF-R-A	*I*	9	3.80	2	25.54
	EWMA	7*	91.86	2	25.54
	CUSUM	11	31.06	6*	73.26
LEDO-R-A	*I*	12	3,576.52	2	1,840.00
	EWMA	4	1,347.78	2	1,840.00
	CUSUM	10	2,163.44	4	2,759.89
PODR-R-A	*I*	11*	-7.24	5*	2.93
	EWMA	11*	7.14	5*	19.05
	CUSUM	22*	0.39	10*	36.64
PTKM-R-A	*I*	14*	189.97	8	131.47
	EWMA	11*	-33.07	7*	-278.41
	CUSUM	38*	426.26	32*	276.81

Notes: The number of trades includes initial buying.

*The stocks were sold on the last trading day.

Source: Author's calculations.

trade simulations led to a negative score. Thus, using residual-based control charts based on opening prices and according to stated assumptions, an investor could achieve profit in 85% of the cases. Looking at the investor score according to the residual-based control charts, it can be concluded that the residual-based CUSUM control charts achieved the highest investor score in most cases. Of the 20 cases, the residual-based CUSUM control chart had the highest investor score in 12 cases, the residual-based EWMA control chart in 4 cases, and the residual-based I control chart also in 4 cases. Meanwhile, looking at the investor score according to different control limit levels, in most cases better scores were achieved when 2-sigma control limits were used. In 19 cases, higher investor scores were achieved with the use of

Table 4. *Explorative Analysis of Average Prices of CROBEX10 Stocks in HRK in 2012 and Chosen Adequate ARIMA(p,d,q) Models*

Stock	k	Min.	Max.	Mean	Median	Std. dev.	Var. coef. (in %)	*ARIMA*(*p*,*d*,*q*) model
ADPL-R-A	248	101.02	128.35	111.46	108.50	7.38	6.62	(2,1,2)
ADRS-P-A	240	203.37	253.57	222.71	216.50	13.32	5.98	(1,0,0)
ATGR-R-A	245	456.23	548.01	492.37	493.15	20.45	4.15	(1,0,0)
ERNT-R-A	250	880.09	1,378.76	1,159.19	1,175.19	109.83	9.47	(5,2,0)
HT-R-A	250	193.64	243.76	210.89	205.92	13.83	6.56	(1,0,0)
INA-R-A	246	3,550.00	4,499.37	3,867.06	3,747.93	266.97	6.90	(1,0,0)
KORF-R-A	250	71.00	110.85	94.33	95.36	11.51	12.20	(2,1,1)
LEDO-R-A	237	4,947.40	7,839.72	5,849.52	5,748.19	664.09	11.35	(7,2,0)
PODR-R-A	247	205.17	276.53	240.21	244.05	19.78	8.24	(1,0,0)
PTKM-R-A	249	185.07	354.87	228.98	226.46	31.21	13.63	(2,1,2)

Source: Author's calculations.

2-sigma control limits than with the use of 3-sigma control limits. On the other hand, the use of 3-sigma control limits, rather than 2-sigma control limits, resulted in higher investor scores in only 11 cases.

As with the opening price analysis, the average price analysis also highlighted the autocorrelation problem. The analysis indicated that the autocorrelation problem is present in all the observed stocks. In order to solve the autocorrelation problem, the *ARIMA*(*p*,*d*,*q*) modelling approach was used. The selected adequate *ARIMA*(*p*,*d*,*q*) models for average prices of CROBEX10 stocks in 2012 are given next to the explorative analysis results in Table 4. The *ARIMA*(*p*,*d*,*q*) modelling enabled estimating residuals for each CROBEX10 stock. In the next step, these residuals were used to form residual-based control charts (I, EWMA, and CUSUM), which enabled the introduction of the investor's CROBEX10 stock trade simulation. The investor scores based on the trade simulation of CROBEX10 stocks in 2012 can be obtained from the author upon request.

4 Long-run Stock Trading Analysis Based on Opening and Average Prices

In a long-run analysis, data are observed over a long period—namely, more than one year. In this long-run analysis, prices of CROBEX10 stocks were observed from their initial listings on ZSE to 31 August 2014. The prerequisite of being on ZSE for more than a year was fulfilled by all the observed stocks.

Table 5. *Explorative Analysis of Opening Prices of CROBEX10 Stocks in HRK in the Period from Stocks' Initial Listings to 31 August 2014 and Chosen Adequate ARIMA(p,d,q) Models*

Stock	k	Min.	Max.	Mean	Median	Std. dev.	Var. coef. (in %)	*ARIMA* (*p*,*d*,*q*) model
ADPL-R-A	2,147	32.00	284.89	125.05	118.00	51.34	41.05	(1,0,1)
ADRS-P-A	2,761	135.65	611.99	312.21	281.03	96.68	30.97	(9,4,1)
ATGR-R-A	1,676	320.00	1,060.00	653.47	682.26	135.34	20.71	(2,1,1)
ERNT-R-A	3,817	59.00	4,250.00	1,259.05	1,295.00	895.26	71.11	(9,4,2)
HT-R-A	1,740	141.60	402.00	237.49	230.02	51.37	21.63	(3,1,2)
INA-R-A	1,721	960.00	4,500.00	2,825.24	2,852.00	1,021.40	36.15	(2,0,1)
KORF-R-A	2,809	21.00	250.00	106.10	104.01	56.59	53.33	(1,1,0)
LEDO-R-A	2,117	100.00	20,800.00	6,789.39	6,000.00	3,539.97	52.14	(1,0,0)
PODR-R-A	4,474	60.00	639.00	253.23	245.00	109.23	43.13	(3,0,2)
PTKM-R-A	2,505	12.85	340.00	165.36	163.00	70.86	42.85	(2,0,1)

Source: Author's calculations.

Table 6. *Trade Simulation of CROBEX10 Stocks Based on Opening Prices Using the Residual-based Control Chart for Individual Units (I), the Residual-based Exponentially Weighted Moving Average (EWMA) Control Chart (λ=0.3), and the Residual-based Cumulative Sum (CUSUM) Control Chart, the Period from Stocks' Initial Listings to 31 August 2014*

Stock	Control chart	Control limits: +/- 2 std.		Control limits: +/- 3 std.	
		Number of trades	Investor score	Number of trades	Investor score
ADPL-R-A	*I*	131*	-20.08	61*	18.84
	EWMA	95	-165.19	42*	441.89
	CUSUM	359	-166.87	273*	-1,099.36
ADRS-P-A	*I*	162*	368.22	68	-229.54
	EWMA	79	-590.02	39*	6,298.52
	CUSUM	351	17,679.61	257	26,780.99
ATGR-R-A	*I*	77*	-1,494.22	39*	-1,007.04
	EWMA	73	612.43	34	-154.51
	CUSUM	189*	1,200.04	133*	1,385.55
ERNT-R-A	*I*	285*	10,528.37	136	8,673.67
	EWMA	233	12,610.56	120*	18,318.30
	CUSUM	697*	-20,773.40	548	-12,336.46
HT-R-A	*I*	102*	-147.13	62*	4.37
	EWMA	131	405.99	78*	-446.14
	CUSUM	347	1,044.53	310*	929.33
INA-R-A	*I*	120	26.02	49	2,904.31
	EWMA	80	-9,679.52	44	-3,755.11
	CUSUM	252	2,887.18	185	17,384.00
KORF-R-A	*I*	179	214.74	62*	13.03
	EWMA	129*	-266.56	62*	-83.73
	CUSUM	421*	252.28	305*	-296.70
LEDO-R-A	*I*	130	11,186.31	79	14,851.54
	EWMA	108	10,593.40	60	-18,205.58
	CUSUM	221*	62,296.22	187	60,163.02
PODR-R-A	*I*	282	1,792.96	109	1,093.27
	EWMA	189	-659.43	79*	25.95
	CUSUM	538	3,536.01	337	3,671.00
PTKM-R-A	*I*	138*	-565.05	44*	114.60
	EWMA	121*	-415.85	58*	689.78
	CUSUM	358*	2,650.81	266*	4,070.07

Notes: The number of trades includes initial buying.

*The stocks were sold on the last trading day.

Source: Author's calculations.

A long-run analysis based on opening prices was conducted first, followed by an analysis based on average prices. The long-run stock trading analysis based on opening prices began with an explorative analysis. According to results provided in Table 5, as opposed to the short-run analysis, the stocks show a higher variability level in the long run. The lowest coefficient of variation in the long run is roughly one-third higher than the highest coefficient of variation in the short run. In the long run, ATGR-R-A (20.71%) and HT-R-A (21.63%) had the lowest coefficient of variation of opening prices.

Despite different variability data levels, the autocorrelation problem was also present in the long run. In order to solve the autocorrelation problem, *ARIMA*(*p*,*d*,*q*) modelling was used again. The selection of *ARIMA*(*p*,*d*,*q*) models was

Table 7. *Explorative Analysis of Average Prices of CROBEX10 Stocks in HRK in the Period from Stocks' Initial Listings to 31 August 2014 and Chosen Adequate ARIMA(p,d,q) Models*

Stock	k	Min.	Max.	Mean	Median	Std. dev.	Var. coef. (in %)	*ARIMA* (*p*,*d*,*q*) model
ADPL-R-A	2,147	32.34	286.74	124.99	118.14	51.35	41.08	(1,1,1)
ADRS-P-A	2,761	134.84	613.55	312.12	281.53	96.58	30.94	(3,0,0)
ATGR-R-A	1,676	320.70	1,068.53	653.79	684.98	135.42	20.71	(1,1,0)
ERNT-R-A	3,817	59.01	4,278.96	1,259.07	1,287.90	894.20	71.02	(7,4,2)
HT-R-A	1,740	142.46	397.50	237.52	229.91	51.28	21.59	(2,1,0)
INA-R-A	1,721	965.22	4,499.37	2,829.47	2,851.01	1,025.32	36.24	(1,1,1)
KORF-R-A	2,809	21.15	248.54	106.22	104.15	56.73	53.41	(6,4,2)
LEDO-R-A	2,117	100.00	20,612.26	6,795.14	5,999.99	3,534.16	52.01	(5,4,2)
PODR-R-A	4,474	60.00	635.79	253.44	245.00	109.14	43.06	(1,1,1)
PTKM-R-A	2,505	12.85	354.87	165.16	162.51	70.73	42.82	(4,4,0)

Source: Author's calculations.

conducted in the same way as described earlier within the short-run analysis. The selected *ARIMA*(*p*,*d*,*q*) models are given in Table 6.

After the selection of *ARIMA*(*p*,*d*,*q*) models, the residuals were calculated and trade simulations were performed. The results of the conducted trade simulations for CROBEX10 stocks for the period from their initial listings to 31 August 2014 are given in Table 8. In addition to the investor score achieved using I, EWMA, and CUSUM control charts and 2-sigma and 3-sigma control limits, Table 8 also provides the number of trades. Out of 60 trade analyses conducted, the investor score was positive in 38 and negative in 22 cases. Consequently, it could be concluded that using residual-based control charts with opening prices and according to the trading simulation assumptions, an investor could achieve profit in 63.33% of the cases. Looking at the investor scores according to the used residual-based control charts, the use of the residual-based CUSUM control chart resulted in the highest investor score in most (i.e., 15) cases. The residual-based I control chart had the highest investor score in 2 cases, while the residual-based EWMA control chart had the highest in 3 cases. Looking at the investor score according to different control limits levels, in most cases better scores were achieved when 3-sigma control limits were used. In 19 cases, higher investor scores were achieved with the use of 3-sigma control limits than with the use of 2-sigma control limits. In 11 cases, the use of 2-sigma control limits resulted in a higher investor score than the use of 3-sigma control limits.

The basic explorative statistics of CROBEX10 stocks' average prices in the long run are very similar to the statistics of opening prices. Table 7 shows that only ATGR-R-A (20.71%) and HT-R-A (21.59%) had coefficients of variation under 30%.

The autocorrelation analysis of average prices revealed high autocorrelation presence for all CROBEX10 stocks. The autocorrelation problem was solved using the *ARIMA*(*p*,*d*,*q*) modelling. The selected *ARIMA*(*p*,*d*,*q*) models are given in Table 9. The *ARIMA*(*p*,*d*,*q*) models enabled the calculation of residuals used in the construction of residual-based I, EWMA, and CUSUM control charts. These residual-based control charts and different control limits levels (2-sigma and 3-sigma level) were the basis for conducting stock trading simulations. The trade simulation results can be obtained from the author upon request.

5 Discussion

This paper attempted to emphasize the ability of control charts to achieve profit rather than to quantify it. This ability was observed according to used residual-based control charts (I, EWMA, CUSUM), observed periods (short run, long run), and stock prices (opening price, average price). The numbers of positive and negative investor scores according to these three variables are given in Table 8.

Looking at prices of CROBEX10 stocks, the opening price analysis is more successful than the average price analysis. In the opening price analysis, 89 of 120 cases had a positive investor score. In other words, in 74.17% of the cases, the investor who used an opening price analysis profited. The profit rate obtained from the average price analysis was 61.67%, which is lower than the rate obtained from the opening price analysis, although still remarkably high.

The profit rate difference is more evident when, instead of stock prices, periods of different length are compared.

Table 8. *Positive (Profit) and Negative (Loss) Investor Scores Achieved in the Short-run and the Long-run Trade Simulation of CROBEX10 Stocks Based on Opening and Average Prices Using the Residual-based Control Chart for Individual Units (I), the Residual-based Exponentially Weighted Moving Average (EWMA) Control Chart (λ=0.3), and the Residual-based Cumulative Sum (CUSUM) Control Chart*

Observed stock price	Control chart	No of cases: Short-run*		No of cases: Long-run**		No of cases: Overall	
		Profit	Loss	Profit	Loss	Profit	Loss
Opening price	*I*	17	3	14	6	31	9
	EWMA	16	4	9	11	25	15
	CUSUM	18	2	15	5	33	7
	Total	51	9	38	22	89	31
Average price	*I*	16	4	10	10	26	14
	EWMA	14	6	11	9	25	15
	CUSUM	15	5	8	12	23	17
	Total	45	15	29	31	74	46
Overall	*I*	33	7	24	16	57	23
	EWMA	30	10	20	20	50	30
	CUSUM	33	7	23	17	56	24
	Total	96	24	67	53	163	77

* Short run includes the period from 1 January to 31 December 2012.

** Long run includes the period from stocks' initial listings to 31 August 2014.

Source: Author's calculations.

The control charts showed a considerably higher ability to achieve profit in the short run (80%) than in the long run (55.83%). In the context of stock trading, the I control chart has proven to be the most successful control chart in achieving profit with a profit rate of 71.25%, followed by the CUSUM control chart (70%) and the EWMA control chart (62.50%).

Examining the overall level, of 240 performed trade simulations, the investor achieved a profit in 163 and a loss in 77 cases, resulting in an overall profit rate of 67.92%. This rate is rather high, suggesting that the control charts provide a good quality basis for making decisions about trading on the stock market. The conducted statistical test confirmed the initial conclusion—namely, at the 5% significance level, $\alpha = 0.05$, the null hypothesis that control charts will be successful and result in a profit of 50% or less cases can be rejected (standard error = 0.0323, z-value = 5.55, p-value = 0.0000). Thus, the first research hypothesis was accepted.

In addition to examining trade simulation cases and whether profit or loss was realized, an investor would also be interested in the total portfolio profit and investment rates. Because each trade simulation began by buying stocks at the same initial price, only the total portfolio profit was examined. The portfolio profits for given residual-based control charts, observed periods, stock prices, and different control limit deviations are shown in Table 9.

In the short run, the highest portfolio profit was achieved by using the residual-based CUSUM control chart in all possible cases. On the other hand, regardless of the observed stock prices, if the 2-sigma control limits were used, the residual-based I achieved a higher portfolio profit than the residual-based EWMA control chart. But when the 3-sigma control limits were used, then in the short run, regardless of the observed stock prices, the residual-based EWMA control chart had a higher portfolio profit than the I control chart.

In the long-run, the supremacy of the residual-based CUSUM control chart was violated when trading stocks at average prices and using 2-sigma control limits. In all other cases the residual-based CUSUM control chart achieved the highest portfolio profit. The portfolio profit difference among the residual-based CUSUM control chart and the other two control charts used was especially noticeable if the stock trading was based on opening prices. As opposed to the short run, in the long run the difference between the residual-based I and the EWMA control charts is presented according to the observed stock prices and not according to different control limits levels. Thus, in the short run, the residual-based I control chart achieved a higher portfolio profit by using opening prices as basis for trade simulations than the residual-based EWMA control chart regardless of the control limits level. On the other hand, the residual-based EWMA control chart achieved a higher portfolio profit than the residual-based I control chart when the average price was used.

Table 9. *Portfolio Profits Achieved in the Short-run and the Long-run Trade Simulation of CROBEX10 Stocks Based on Open and Average Prices Using the Residual-based Control Chart for Individual Units (I), the Residual-based Exponentially Weighted Moving Average (EWMA) Control Chart (λ=0.3), and the Residual-based Cumulative Sum (CUSUM) Control Chart with Different Control Limit Deviations (2 and 3 standard deviations), in HRK*

Observed stock price	Control chart	Portfolio profit					
		Short-run*		Long-run**		Overall	
		+/-2 std.	+/- 3 std.	+/-2 std.	+/- 3 std.	+/-2 std.	+/- 3 std.
Opening price	*I*	4,984.10	2,338.34	21,890.14	26,437.05	26,874.24	28,775.39
	EWMA	3,178.79	2,638.97	12,445.81	3,129.37	15,624.60	5,768.34
	CUSUM	6,535.72	6,924.19	70,606.41	100,651.44	77,142.13	107,575.63
	Total	14,698.61	11,901.50	104,942.36	130,217.86	119,640.97	142,119.36
Average price	*I*	5,595.57	3,024.09	-25,289.59	-4,184.89	-19,694.02	-1,160.80
	EWMA	4,695.74	4,261.15	49,322.79	15,154.20	54,018.53	19,415.35
	CUSUM	6,838.92	7,527.93	-44,103.06	17,936.77	-37,264.14	25,464.70
	Total	17,130.23	14,813.17	-20,069.86	28,906.08	-2,939.63	43,719.25
Overall	*I*	10,579.67	5,362.43	-3,399.45	22,252.16	7,180.22	27,614.59
	EWMA	7,874.53	6,900.12	61,768.60	18,283.57	69,643.13	25,183.69
	CUSUM	13,374.64	14,452.12	26,503.35	118,588.21	39,877.99	133,040.33
	Total	31,828.84	26,714.67	84,872.50	159,123.94	116,701.34	185,838.61

* Short run includes the period from 1 January to 31 December 2012.

** Long run includes the period from stocks' initial listings to 31 August 2014.

Source: Author's calculations.

Table 10 lists residual-based control charts with which the highest portfolio profit was achieved according to observed stock prices, investment length, and different control limits deviations. If stocks' opening prices and 3-sigma control limits were used, the best choice was to use the residual-based CUSUM control chart in order to achieve the highest portfolio profit through stock trading. The residual-based CUSUM control chart was the best choice in short-run investments, but because of poor scores achieved in the long run when using the average price as the basis for stock trading and 2-sigma control limits as limits for trading signals, the residual-based CUSUM control chart cannot unambiguously be recommended for use in the stock trading process. The drastically bad results of the residual-based CUSUM control chart led to the choice of the residual-based EWMA control chart as the best one for achieving the highest portfolio profit when stocks' average prices were observed and 2-sigma control limits used. Furthermore, the residual-based EWMA control chart proved to be the best choice when 2-sigma control limits were used overall.

Table 10. *Recommended Residual-based Control Charts for Stock Trading According to Observed Stock Prices, Investment Length, and Different Control Limit Deviations*

Observed stocks' price	Short-run		Long-run		Overall	
	+/-2 std.	+/- 3 std.	+/-2 std.	+/- 3 std.	+/-2 std.	+/- 3 std.
Opening price	*CUSUM*	*CUSUM*	*CUSUM*	*CUSUM*	*CUSUM*	*CUSUM*
Average price	*CUSUM*	*CUSUM*	*EWMA*	*CUSUM*	*EWMA*	*CUSUM*
Overall	*CUSUM*	*CUSUM*	*EWMA*	*CUSUM*	*EWMA*	*CUSUM*

Source: Author's calculations.

The second research hypothesis assumed that the use of the I control chart would lead to higher portfolio profits compared to profits gained by the EWMA and the CUSUM control charts. The results in Tables 9 and 10 indicate that the I control chart was never the best choice; indeed, in most cases, it was the worst choice to use in stock trading. Therefore, research hypothesis H2 was rejected.

The results indicated that an investor should use the EWMA and/or the CUSUM control charts in the stock trading, whereas the I control chart should be omitted because of inferior results. Another consideration for investors is whether they should use opening or average prices as the starting point of the trade analysis. The portfolio profits gained by opening and average prices can be compared using data from Table 12. In the short run and when using the control chart and different control limit levels, stock trading based on average prices achieved higher portfolio profits overall and individually than stock trading based on opening

Table 11. *Comparison of "Pick-and-hold" Strategy and Control Charts Approach Portfolio Results, in HRK*

Observed stocks' price	Short-run		Long-run	
	Pick-and-hold	Control charts	Pick-and-hold	Control charts
Opening price	3,082.92	6,924.19	11,850.35	100,651.44
Average price	3,152.50	7,527.93	11,796.19	17,936.77

Source: Author's calculations.

prices. On the other hand, in the long run, stock trading based on opening prices achieved higher profits overall than the trading based on average prices. However, whereas the portfolio profits achieved in the short run favoured only one certain stock price, in the long run the portfolio profits of the I and the CUSUM control charts favoured the opening price analysis and the EWMA control chart favoured the analysis based on average prices.

If the portfolio profits in the short and long run are examined together, a significantly higher portfolio profit is achieved through the use of opening prices than the use of average prices. What played a crucial role in designating the opening price analysis better than the average prices analysis on the overall level was its far better performance in the long run. Consequently, the third research hypothesis was accepted.

Table 11 compares portfolio results for the "pick-and-hold" strategy and the control charts approach. In the "pick-and-hold" strategy, it is assumed that an investor bought stocks on 1 January 2012 (short run) or on the day of the initial stock's listing (long run) and kept them until 31 December 2012 or 29 August 2014, respectively. In order to compare the control charts, it was assumed that an investor bought only one share of each observed stock. For the portfolio results in the control charts approach, the scores for CUSUM control charts using three standard deviation limits were used because they were the best (see Table 9).

The results in Table 11 show that the control charts approach resulted in higher portfolio profits in all cases compared to the "pick-and-hold" strategy. However, in the control charts approach, costs like transaction and analysis costs were excluded.

6 Conclusions

The paper investigated the ability to use statistical control charts in stock portfolio analyses. The preliminary analyses showed the presence of the autocorrelation problem in relation to all opening and average prices of CROBEX10 stocks on which the analyses were based. In order to overcome the autocorrelation problem, the *ARIMA*(*p*,*d*,*q*) modelling was applied. Consequently, residual-based control charts were used in the analysis. The analysed variables demonstrated the need to base the analysis on the residual-based I, EWMA (), and CUSUM control charts. Therefore, in order to research the statistical control charts' ability to ensure successful stock trading in periods of different lengths, two periods were introduced. The first, short-run, period covered from 1 January to 31 December 2012 whereas the second, long-run, period included the stocks' initial listings to 31 August 2014. The explorative analysis showed that the short-run data had significantly lower variability than the long-run data. Therefore, the short-run analysis also represented the low data variability case whereas the long-run analysis was the high data variability case.

Although the overall profit rate was 67.92%, which can be considered rather high and successful and led to the first research hypothesis being accepted, further developments of the procedure used are expected to lead to an even higher profit rate. Additional information about stocks, not included in the procedure, could significantly improve the profit rate. An investor is interested in achieving not only portfolio profit through stock trading, but also the highest portfolio profit possible. In the short run, the analysis based on the residual-based CUSUM control chart led to higher portfolio profits than analyses based on the residual-based I and EWMA control charts. In the long run, the highest portfolio profit, based on opening prices, was gained by the residual-based CUSUM control chart; if average prices were considered, then the highest portfolio profit was achieved by the residual-based EWMA control chart. Thus, the I control chart was not the most appropriate choice to use in the stock trading process. Consequently, the second research hypothesis was rejected. Despite lower portfolio profits in the short run, using the opening price instead of the average price in stock trading was justified by overall higher portfolio profits. As a result, the third research hypothesis was accepted.

This paper analysed the use of control charts in stock trading by employing a completely new approach. Therefore, much room for improvement remains. In addition, because the paper introduced a new approach, some limitations are evident. First, only very liquid stocks were observed in this paper. The potential use of control charts with rarely traded (e.g., once a week, once a month) stocks needs to be researched. Second, because the stocks from the CROBEX10 index were analysed, only those stocks in which investors were the most interested were observed. In other words, investors believed in these stocks and were convinced that the enterprises in question have a bright future. However, it would be of interest to examine control charts' profit rates for

enterprises that are not so successful. The off-line approach to the analysis is another significant drawback of the analysis. In practise, the on-line approach was used, resulting in new analyses each day because of the new data, which could lead to a different *ARIMA*(*p*,*d*,*q*) model selection and consequently to different trading signals. Still, if the amount of data is large, it is not likely that one new data point would lead to a different *ARIMA*(*p*,*d*,*q*) model specification. In the long run. possible data seasonality was not considered in the paper; this should be taken into account in further research as well. When the residual-based EWMA control chart was used, the choice of the weight parameter was provisional in accordance with the literature reviewed. In future research, more attention should be given to the choice of the parameter for each stock separately. In order to keep the analysis as simple as possible, trade commissions were not included in the analyses. This drawback should also be corrected in further research. For simplicity, only one stock market was observed. Future studies should observe more stock markets and compare results and conclusions.

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Zmožnosti nadzornih diagramov, ki temeljijo na statističnih rezidualih, pri kratkoročnem in dolgoročnem trgovanju z delnicami

Izvleček

Namen tega prispevka je predstaviti in razviti dodatna statistična orodja za podporo odločitvenega procesa pri trgovanju z delnicami. Uporabljene so vrednosti delniškega indeksa CROBEX10. Izvedene simulacije trgovanja, ki temeljijo na nadzornih diagramih, temelječih na rezidualih, so v 67,92 % primerov vodile v dobiček investitorja. Kratkoročno je nadzorni diagram kumulativne vsote (CUSUM) vodil v najvišje portfeljske dobičke. Dolgoročno je imel najvišji portfeljski dobiček nadzorni diagram, temelječ na eksponentni uteženi drseči aritmetični sredini rezidualov, pri čemer so bile uporabljene povprečne cene delnic in nadzorne meje 2-sigma. V vseh drugih primerih so se na dolgi rok nadzorni diagrami CUSUM izkazali za najboljšo izbiro. Pričakovati je, da bodo dognanja o možni uspešni uporabi pri trgovanju z delnicami dvignila raven uporabe metod SPC.

Ključne besede: Zagrebška borza vrednostnih papirjev, naložbe, statistični nadzor procesov, avtokorelacija, nadzorni diagrami, temelječi na rezidualih

The Examination of Factors Relating to the Leadership Style of Nursing Leaders in Hospitals

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ORIGINAL SCIENTIFIC PAPER

RECEIVED: JULY 2015

REVISED: DECEMBER 2015

ACCEPTED: DECEMBER 2015

DOI: 10.1515/ngoe-2016-0003

UDK: 005.32:614.2

JEL: I10, M54, M12

Citation: Lorber, M., Treven, S., & Mumel, D. (2016). The Examination of Factors Relating to the Leadership Style of Nursing Leaders in Hospitals. *Naše gospodarstvo/Our Economy, 62*(1), 27–36 DOI: 10.1515/ngoe-2016-0003

Abstract

Theories often describe leadership with different classifications, based on personality and behaviour, and have been used to establish the traits and behaviours that determine an effective leadership style. We used the quantitative methodology to investigate the determinants of the leadership style among nursing leaders in Slovene hospitals. Based on the results, we determined that demographic characteristics such as gender, age, length of employment, and level of education do not affect the choice of the leadership style. Internal organizational characteristics such as job position, emotional intelligence, communication, personal characteristics, and the decision-making process are positively associated with the leadership style. Personal characteristics are considered important when it comes to using specific leadership styles, regardless of the choice of the leadership style, which also depends on the situation and external influences.

Key words: decision-making process, personal characteristics, communication, emotional intelligence, leadership style

1 Introduction

The importance of effective leadership in health care has been emphasized by a number of authors (Carney, 2006; Greenfield, 2007; Hewison, & Griffiths, 2004; Sutherland & Dodd, 2008), and nursing leadership is pivotal because nurses represent the most extensive discipline in health care (Marquis & Huston, 2009; Oliver, 2006; Roussel, Swansburg, & Swansburg, 2009; Sullivan & Garland, 2010). Lombardi and Schemerhorn (2007) stated that a leader can be anyone in the organization who supports and is responsible for the work performance of one or more persons. Later, Huber (2013) noted that the leadership is defined as the process of working with individuals, groups, and other resources in order to achieve the objectives of the organization.

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OUR ECONOMY

Vol. 62 No. 1 2016

pp. 27–36

In recent years, many theories and styles of leadership have been developed. Various styles of leadership demonstrate how to lead nurses in hospitals (Huber, 2006). Goethals, Sorenson, and Burns (2004) noted that transactional leadership was founded on the theory that employees are motivated by rewards and discipline. The transformational leadership styles focus on team-building, motivation, and collaboration with employees at different levels of the organization to accomplish change for the better. Leaders focus on encouraging all of the staff to set a good example and portray an optimistic personality. This style of leadership is based on the premise that employees are motivated to perform their job through the positive rather than negative incentives. Both types of the leadership style have benefits and drawbacks (Goethals et al., 2004; Marquis & Huston, 2009). The laissez-faire leadership style is one style in which the leader provides little or no direction or supervision and prefers to take decisions alone. The changes occur rarely, and the quality improvement is typically low. This leadership style is most often used by new and inexperienced leaders or by those at the end of their career (Goethals et al., 2004; Skogstad, Einarsen, Torsheim, Aasland, & Hetland, 2007).

The leadership style is a construct associated with the number of employees and organizational variables. A few of the verified connections are discussed here. The leadership style associated with the personality (Brown & Reilly, 2009), organizational commitment (Avolio, Gardner, Walumbwa, Luthans, & May, 2004; Geijsel, Sleegus, Lithwood, & Jantzi, 2003; Leach, 2005), emotional intelligence (Barling, Kelloway, & Slater, 2000; Downey, Papageorgiou, & Stough, 2006; Vrba, 2007), organizational learning and adaptation (Castiglione, 2006), stress and burnout (Gill, Flaschner, & Shacha, 2006; Kanste, Kyngas, & Nikkila, 2007; Zopiatis & Constanti, 2010), job satisfaction (Failla, & Stichler, 2008; Mancheno-Smoak, Endres, Potak, & Athanasaw, 2009; Sellgren, Ekvall, &Tomson, 2008; Wu, 2009), work performance (Kozak & Uca, 2008; MacKenzie, Podsakof, & Rich, 2001; Vigoda-Gadot, 2007), motivating employees (Mehta, 2000) organizational culture (Bass & Avolio, 1994; Kozak & Uca, 2008; Sellgren et al., 2008), and well-being (Kuoppala, Lamminpää, Liira, & Vainio, 2008; Nielsen, Yarker, Randall, & Munir, 2008; Skakon, Nielsen, Borg, & Guzman, 2010). Kouzes and Posner (1997) found that there is no the best leadership style; rather, leaders must choose the way of leading depending on the situation and circumstances. Effective leadership can encourage employees to take tasks, effectively solve problems, and make decisions that improve the efficiency of the team and the entire organization (Bennett, 2009).

Nursing leaders currently face many challenges (new roles, new technology, financial constraints, greater emphasis on participation, cultural diversity, and education). In every health care institution, the leadership must act to encourage effecting changes and achieving high standards of the patient care (Sullivan & Garland, 2010). Heller and colleagues (2004) noted that nurses are not adequately prepared for the role of the leader during their nursing education programmes. Because of the importance of the leadership in nursing, we wanted to determine which leadership style is most frequently used by the nursing leaders in Slovene hospitals and which factors are associated with the leadership style.

2 Methods

The study used quantitative methodology. The data were collected in a cross-sectional survey among the employees in nursing in Slovene hospitals using an anonymous structured questionnaire.

2.1 Instruments

In the study, we used two questionnaires: one for the leaders and another for other employees in nursing. Leaders at the execution level of management, which act directly on the department or unit, participated in the study. Their emphasis is on the management and leadership of the unit, department, or team and the scope of the operation control, including the efficient provision of services, achieving better quality of care and patient satisfaction. It is important to recognize that the success of the organization depends on the success of individual units or departments of the organization. The questionnaires contained 50 closed-type questions that covered demographic data (gender, age, job position, years of employment, years of employment in a leading position, and the level of education) and, in the second part, 21 items for the leadership style, 10 characteristics of successful leaders, 6 items for the emotional intelligence, 7 items for the decision-making process, and 10 for the communication. Job position was used to describe a specific group of performed tasks (professional leader of department, team leader, nurses with diploma degree, nursing assistant). For the leadership style, we used the Multifactorial Leadership Questionnaire (Bass & Avolio, 1994), which contains 12 items for the transformational leadership (Cronbach's alpha = 0.960), 6 items for the transactional leadership (Cronbach's alpha = 0.937), and 3 items for the laissez-faire leadership style (Cronbach's alpha = 0.977). For communication, we used 10 items prepared in cooperation with O.K. Consulting (an education and transformational management company) and based on a theoretical background (Marquis & Huston, 2009; Zidar Gale, 2004). The Cronbach's alpha was 0.977. For the decision-making process, we used 7 items prepared in

cooperation with O.K. Consulting and based on a theoretical background (Dickson, Den Hartog, & Mitchelson, 2003; Skela Savič, 2002). The Cronbach's alpha was 0.958. For emotional intelligence, we used 6 items prepared in the cooperation with O.K. Consulting and based on a theoretical background (Goleman, 2001; Goleman & Boyatzis, 2008). The Cronbach's alpha was 0.974. For personal characteristics, we used 10 characteristics of successful leaders (decisiveness, communicativeness, honesty, self-confidence, reliability, responsibility, objectivity, cooperation, organizing, ambitious). The Cronbach's alpha was 0.943. The leaders self-assessed their leadership style, personal characteristics, emotional intelligence, communication, and decision-making process using a 6-point Likert scale ranging from 1 (strongly disagree) to 6 (strongly agree). The employees assessed the leadership style, personal characteristics, emotional intelligence, communication and decision making of their direct leader on a 6-point Likert scale ranging from 1 (strongly disagree) to 6 (strongly agree). The questionnaires were tested in a pilot study (10 leaders and 40 employees).

2.2 Sample

In the current study, 8 of the 12 Slovene hospitals with internal medicine and surgery departments were included. We asked all 12 hospitals to participate, but four refused. The questionnaires were distributed to the morning shift by the author and the research coordinator in the participating hospitals. The nursing leaders were not selected randomly. The questionnaire was sent only to those with the job position relevant to the research, which means that purposive sampling was used. We distributed 1100 (85 to leaders and 1015 to other employees in nursing) questionnaires; 640 questionnaires were correctly and comprehensively filled out (response rate = 56%).

The study included 640 employees in nursing from Slovene hospitals, of which 75 (12%) were nursing leaders and 565 (88%) were other employees in nursing. Participants included 87 (14%) men and 553 (86%) women. There were 346 (54%) employees from the surgery department and 294 (46%) employees from the internal medicine department. Of the participating employees, 24% were younger than 30 years old, 64% were between 30 and 50 years of age, and 12% were older than 50 years old. On average, the leaders had been in a leadership position for 8.6 years (from 0.5 to 32 years).

2.3 Data Analysis

We received written permission for the study from all participating hospitals and the National Medical Ethics Committee of the Republic of Slovenia (No.157/09/13). Before the research, we informed the respondents about the aim of the study, and participation in the study was voluntary and anonymous. The questionnaire took approximately 20 minutes to complete, and the study was conducted in the year 2014 (from April to September 2014).

For the statistical analysis, SPSS version 20.0 (IBM; SPSS Inc., Chicago, IL, USA) was used. The differences between individual variables were analysed using the Mann-Whitney test, while the Spearman correlation coefficient was used to identify the relationship between the studied variables. The linear regression analysis was used to determine the impact of gender, age, level of education, personal characteristics, communication, decision-making process, and emotional intelligence (independent variables) on the leadership style (dependent variable). A p-value of less than 0.05 was considered to be statistically significant.

3 Results

Table 1 shows that the leaders in nursing indicated that the most widely used leadership style is transactional ($\bar{x}$ = 4.22, s = 0.72); however, their employees assessed that their leaders most often use the laissez-faire leadership style ($\bar{x}$ = 3.83, s = 1.327). Significant differences occurred between the leaders' and other employees' perceptions of only the transactional leadership styles (Z = -2.736; p = 0.006). Table 1 highlights significant differences in the assessment of the leaders' communication (Z = -3.377; p = 0.001), leaders' emotional intelligence (Z = -3.544; $p < 0.001$), decision-making process (Z = -3.963; $p < 0.001$), and leaders' personal characteristics (Z = -5.823; $p < 0.001$).

The Spearman correlation analysis (Table 2) showed a strong positive correlation between the leadership style and the leaders' communication, decision-making process, leaders' emotional intelligence, and leaders' personal characteristics.

In order to establish the factors' impact on transformational, transactional, and laissez-faire leadership styles, a regression analysis was conducted. For independent variables, we used gender, age, years of employment, level of education, job position, leaders' decision-making, leaders' emotional intelligence, leaders' communication, and leaders' personal characteristics. Because we intended to build the regression model, the residuals were tested for normality. The results of the Shapiro-Wilk indicated that, for the first regression model (df = 474; p = 0.008), the values of the residuals were not normally distributed. Despite the fact that residuals were not normally distributed, we built the first regression model. This represents a limitation of the research. We take this into account when presenting the results of this model. When we

Table 1. *Results of the Mann-Whitney Test*

Variables	x̄ (L)	s (L)	x̄ (E)	s (E)	Z	*p*
Transformational leadership	4.16	0.755	3.72	1.407	-1.928	0.054
Transactional leadership	4.22	0.711	3.56	1.407	-2.736	0.006
Laissez-faire leadership	4.04	0.748	3.83	1.327	-0.879	0.379
Leaders' communication	4.40	0.907	3.37	1.723	-3.377	0.001
Leaders' emotional intelligence	4.50	0.843	3.28	1.874	-3.544	<0.001
Leaders' decision-making process	4.33	0.943	3.16	1.800	-3.963	<0.001
Leaders' characteristics	5.42	0.827	4.21	1.396	-5.823	<0.001

Note: L = leaders; E = other employees; x̄ = average; s = standard deviation; Z = value of Mann-Whitney test; *p* = statistically significant at 0.05 or less

Table 2. *Results of the Spearman Correlations for the Studied Variables*

	TL	TS	LF	CO	DM	EI	PC
TL	1	0.860**	0.685**	0.794**	0.783**	0.837**	0.733**
p	/	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
TS	0.860**	1	0.720**	0.801**	0.797**	0.861**	0.726**
p	<0.001	/	<0.001	<0.001	<0.001	<0.001	<0.001
LF	0.685**	0.720**	1	0.642**	0.644**	0.637**	0.498**
p	<0.001	<0.001	/	<0.001	<0.001	<0.001	<0.001
CO	0.794**	0.801**	0.642**	1	0.842**	0.882**	0.744**
p	<0.001	<0.001	<0.001	/	<0.001	<0.001	<0.001
DM	0.783**	0.797**	0.644**	0.842**	1	0.839**	0.720**
p	<0.001	<0.001	<0.001	<0.001	/	<0.001	<0.001
EI	0.837**	0.861**	0.637**	0.882**	0.839**	1	0.775**
p	<0.001	<0.001	<0.001	<0.001	<0.001	/	<0.001
PC	0.733**	0.726**	0.498**	0.744**	0.720**	0.775**	1
p	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	

Note: TL = transformational leadership; TS = transactional leadership; LF = laissez-faire leadership; CO = communication; DM = decision making; EI = emotional intelligence; PC = personal characteristics

tested the assumptions for the presented regression model, we excluded the problem of autocorrelation, multicollinearity, and heteroscedasticity. The results of these assumptions are presented below.

When we tested residuals for normality for the second (df = 20; $p = 0.316$) and the third (df = 72; $p = 0.941$) regression models, we found that the values of the residuals are normally distributed. We also checked the assumption of autocorrelation, multicollinearity, and heteroscedasticity for the second and the third regression models. To verify autocorrelation, we used the Durbin-Watson test, which returned values of 1.721, 1.656, and 1.621 for the first, second, and third regression models, respectively. The Durbin-Watson statistics for all three regression models are within the acceptable range (i.e., from 1.50 to 2.50). The values of the Durbin-Watson test show slightly positive, but acceptable correlations. Tables 3, 4, and 5 indicated that all the values of VIF factors are less than 10 and all values of the tolerance factors are higher than 0.2. Therefore, we can conclude that our models did not present a problem of multicollinearity. We also checked the problem of heteroscedasticity using the Breusch-Pagan test, which is a hypothesis test of whether the pattern of the residuals is consistent across the range of predicted values. The results from all three models (first: F = 1.630; $p = 0.125$; second: F = 1.741; $p = 0.251$; third: F = 0.598; $p = 0.440$) showed that heteroscedasticity is not a problem in this study.

The regression analysis demonstrated that job position ($\beta = 0.103$; $p < 0.001$), nursing leaders' decision-making process ($\beta = 0.173$; $p = 0.018$), leaders' communication

Table 3. *Results of the Regression Analysis for the Transformational Leadership Style*

	B	SE	β	t	*p*	PART	TOL	VIF
Gender	0.013	0.031	0.009	0.420	0.675	0.062	0.929	1.076
Age	0.001	0.003	0.014	0.263	0.793	0.031	0.605	1.654
Years of Employment	0.001	0.003	0.020	0.373	0.709	0.023	0.633	1.580
Level of education	0.009	0.010	0.021	0.918	0.354	0.008	0.828	1.207
Job position	0.160	0.034	0.103	4.681	<0.001	0.195	0.772	1.295
Leaders' communication	0.223	0.050	0.223	4.424	<0.001	0.266	0.137	7.301
Leaders' decision-making	0.173	0.045	0.173	2.365	0.018	0.331	0.143	7.004
Leaders' emotional intelligence	0.500	0.047	0.501	7.975	<0.001	0.681	0.246	4.086
Leaders' personal characteristics	0.079	0.013	0.220	5.938	<0.001	0.018	0.240	4.168

Note: B = unstandardized coefficient; SE = standard error; β = standardized regression coefficient; t = t-test value; *p* = statistically significant at 0.05 or less; PART = partial correlations; TOL = tolerance; VIF = variance inflation factor

Table 4. *Results of the Regression Analysis for the Transactional Leadership Style*

	B	SE	β	t	*p*	PART	TOL	VIF
Gender	0.012	0.029	0.009	0.426	0.670	0.083	0.923	1.084
Age	0.003	0.03	0.051	1.011	0.312	0.081	0.615	1.623
Years of Employment	0.001	0.002	0.016	0.321	0.749	0.031	0.644	1.553
Level of education	0.004	0.009	0.008	0.403	0.687	0.049	0.837	1.194
Job position	0.002	0.033	0.001	0.049	0.961	0.146	0.772	1.295
Leaders' communication	0.242	0.045	0.241	5.318	<0.001	0.169	0.136	7.377
Leaders' decision-making	0.116	0.041	0.116	2.470	0.014	0.397	0.143	7.013
Leaders' emotional intelligence	0.502	0.044	0.501	9.358	<0.001	0.669	0.242	4.137
Leaders' personal characteristics	0.062	0.012	0.175	5.121	0.021	0.034	0.233	4.285

Note: B = unstandardized coefficient; SE = standard error; β = standardized regression coefficient; t = t-test value; *p* = statistically significant at 0.05 or less; PART = partial correlations; TOL = tolerance; VIF = variance inflation factor

Table 5. *Results of the Regression Analysis for the Laissez-faire Leadership Style*

	B	SE	β	t	*p*	PART	TOL	VIF
Gender	0.008	0.082	0.003	0.099	0.921	0.049	0.952	1.050
Age	0.004	0.008	0.039	0.540	0.590	0.041	0.615	1.626
Years of Employment	0.001	0.007	0.009	0.117	0.907	0.088	0.933	1.071
Level of education	0.012	0.029	0.014	0.406	0.585	0.023	0.849	1.178
Job position	0.066	0.092	0.021	0.713	0.476	0.128	0.792	1.262
Leaders' communication	0.228	0.144	0.116	1.582	0.114	0.121	0.134	7.478
Leaders' decision-making	0.756	0.120	0.385	6.318	<0.001.	0.395	0.137	7.308
Leaders' emotional intelligence	0.488	0.145	0.248	3.365	0.001	0.576	0.222	4.507
Leaders' personal characteristics	0.029	0.038	0.041	0.760	0.448	0.068	0.220	4.540

Note: B = unstandardized coefficient; SE = standard error; β = standardized regression coefficient; t = t-test value; *p* = statistically significant at 0.05 or less; PART = partial correlations; TOL = tolerance; VIF = variance inflation factor

($\beta = 0.223$; $p < 0.001$), leaders' emotional intelligence ($\beta = 0.501$; $p < 0.001$), and leaders' personal characteristics ($\beta = 0.220$; $p < 0.001$) impacted the use of the transformational leadership style. The regression analysis can explain 78% of the total variability of the transformational leadership style with the studied independent variables.

The regression analysis also showed that leaders' communication ($\beta = 0.241$; $p < 0.001$), leaders' decision-making process ($\beta = 0.166$; $p = 0.014$), leaders' emotional intelligence ($\beta = 0.501$; $p < 0.001$), and leaders' personal characteristics ($\beta = 0.175$; $p < 0.021$) affected the use of the transactional leadership style. The regression analysis explained 73% of the total variability of the transactional leadership style with the studied independent variables.

The regression analysis also showed that the decision-making process ($\beta = 0.385$; $p < 0.001$) and leaders' emotional intelligence ($\beta = 0.248$; $p = 0.248$) impacted the use of the laissez-faire leadership style. The regression analysis explained 62% of the total variability of the laissez-faire leadership style with the studied independent variables.

4 Discussion and Conclusion

We found that the leaders most widely use the transactional leadership style. We also identified statistically significant differences in the assessment of the transactional leadership style between leaders and other employees in nursing. Kleinman (2004) found that nursing leaders consistently perceived that they used the transformational leadership style compared to the perceptions among their staff. Kleinman (2004) also found that nursing leaders and other nurses do not agree about the frequency of use the transformational leadership style; however, they do agree about the frequency of use the transactional leadership style. In addition, Hendel, Fish, and Galon (2005) found that the nursing leaders perceive themselves as transformational leaders much more often than as transactional leaders. Hospitals and other health care institutions, by nature, tend to be bureaucratic organizations in which the transformational leadership may not be fostered to the greatest possible degree. Ramey (2002) noted that a contingent reward is a feature of the transformational leadership style for nurses.

In the research, the employees in nursing perceived their leaders as mostly using the laissez-faire leadership style. Findings from previous studies indicate that the laissez-faire leadership style is the least effective form of leaders' behaviour (Khan, Ramzan, Ahmed, & Nawaz, 2011) and is likely to have a negative relationship with job satisfaction (Rowold & Wolff, 2009). Skogstad and colleagues (2007) found that the laissez-faire leadership style is positively correlated with role conflict, role ambiguity, and conflicts with co-workers. They further noted that their results support the assumption that the laissez-faire leadership is a destructive leadership behaviour. As we found in our research, nursing leaders continue to use the transactional and laissez-faire styles, which may be causing nurses to leave the profession. In contrast to the transactional leadership style, the transformational leadership style and team development have a positive effect on communication and team building. We further identified that transformational, transactional, and laissez-faire leadership styles have a positive correlation, and we agree with previous research (DuBrin, 2004; Goleman, 2001; Northouse, 2001; Scott, Bishop, & Chen, 2003) that noted that effective leaders conduct their work using different styles of leadership and successfully adapt to co-workers, situations, and the environment in which they work.

The research demonstrated that, for leadership styles, leaders' communication, emotional intelligence, decision-making, and personal characteristics are important. Nursing leaders set an example—either positive or negative—for others. AANAC (2013) noted that, regardless of the leadership activity, it is important for leaders to act with integrity, set realistic goals, communicate clearly, encourage others, recognize the successes of team members, and inspire them to provide the best patient care.

Emotional intelligence is an important quality of leaders in nursing and also has an impact on leadership styles. We agree with previous researchers (Chiva & Alegre, 2008; Clarke, 2010; Kafetsios & Zampetakis, 2008; Kerr, Garvin, Heaton, & Boyle, 2006; Mittal & Sindhu, 2012; Naidu, 2014), who found that—for the leaders' success—it is essential to have a high degree of emotional intelligence. Another important factor is the leaders' communication. In order to maintain good interpersonal relationships, the leaders should master a variety of communication skills and have the ability to understand the needs of others. Some studies (Fix & Sias, 2006; Kim, 2002; Madlock, 2008; Mueller & Lee, 2002) have found that leaders' communication is a strong predictor of employees' satisfaction. According to some researchers (Lorber & Skela Savič, 2011; Skela Savič, 2007; Yazbeck, 2004), hierarchy and leaders' power represent the biggest problem of effective communication in a hospital. But Zidar Gale (2004) noted that leaders with well-developed communication skills contribute to greater productivity and employees' satisfaction.

Another factor determining the leadership style that cannot be ignored is the personality of an individual who leads a group of employees. We found that leaders' personal characteristics have an impact on leadership styles. Leaders' behaviour affects employees. According to previous research

(Cimerman, Jerman, Klarič, Ložar, & Sušanj, 2003; DuBrin, 2004; Holden Leadership Center, 2009; Mayer, 2003), leaders' personal characteristics are important for successful leadership.

Leaders' behaviour is reflected through their employees in the care they give to their patients each day, regardless of the leadership style used. The leaders must recognize the importance of their role and that younger employees rely on their leadership in developing their own professional skills. Leaders must also use behaviour to positively influence organizational outcomes and must appreciate the interconnectedness among developing nursing practice, improving quality of care, and optimizing patient outcomes. Health care organizations need nursing leaders who can improve nursing care, are an advocate for the nursing profession, and have a positive effect on health care.

This study has some limitations. The research framework was based on the theoretical findings discussing leadership style, communication, emotional intelligence, and decision-making process, so we only studied the influence of some predictors on a leadership style. Because some questionnaires were sent by mail and a researcher was not available in all participating hospitals, the respondents did not get any help if they did not understand the items. Another limitation of the study is that residuals were not normally distributed for one of the created regression models.

The studied topic provides opportunities for further research. It could be conducted in all health care institutions in Slovenia. Our results emphasize the possible contribution and utility of programs especially designed to improve communication skills, emotional intelligence, and decision-making skills among leaders and other employees in nursing.

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Proučevanje dejavnikov, ki se povezujejo s slogom vodenja vodij zdravstvene nege v bolnišnicah

Izvleček

V literaturi je zaslediti različne teorije vodenja na osnovi značilnosti in vedenja vodij. Uporabljajo se za določitev značilnosti, ki pripomorejo k uporabi učinkovitega sloga vodenja. V raziskavi smo uporabili kvantitativno metodologijo za proučitev dejavnikov sloga vodenja vodij zdravstvene nege v slovenskih bolnišnicah. Na podlagi rezultatov smo ugotovili, da demografske značilnosti, kot so spol, starost, leta zaposlitve in stopnja izobrazbe, ne vplivajo na izbiro sloga vodenja. S slogom vodenja se pozitivno povezujejo čustvena inteligenca, komunikacija, osebnostne značilnosti in proces odločanja. Za uporabo izbranega sloga vodenja so pomembne osebnostne značilnosti vodij, izbira sloga vodenja pa ja odvisna od situacije in zunanjih vplivov.

Ključne besede: proces odločanja, osebnostne značilnosti, komunikacija, čustvena inteligenca, slog vodenja

Determinants of Entrepreneurial Intentions in ICT Industry: Gender and country of origin perspective

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ORIGINAL SCIENTIFIC PAPER

RECEIVED: NOVEMBER 2015

REVISED: DECEMBER 2015

ACCEPTED: DECEMBER 2015

DOI: 10.1515/ngoe-2016-0004

UDK: 658:001.895

JEL: L26

Citation: Pejić Bach, M., Merkač Skok, M., & Suša, D. (2016). Determinants of Entrepreneurial Intentions in ICT Industry: Gender and country of origin perspective. *Naše gospodarstvo/Our Economy, 62*(1), 37–45. DOI: 10.1515/ngoe-2016-0004

Abstract

Although many researchers agree that environmental and personal characteristics are important for becoming an entrepreneur, it is still not clear if their influence is equally significant. Numerous authors have pointed out unresolved matters regarding the relationship among innovativeness, gender, and entrepreneurial intensions. The aim of this paper is to explore the impact of gender and country of origin in relation to entrepreneurial intentions and innovative cognitive style. Research was conducted using a sample of students majoring in information and communication technologies from Croatia and Slovenia. The results revealed the influence of gender, country, attitudes toward entrepreneurship, and innovative cognitive style on entrepreneurial intentions.

Key words: entrepreneurship, gender, innovation, cross-country, entrepreneurial intentions, ICT, Croatia, Slovenia

1 Introduction

Entrepreneurship is one of the main drivers of economic development and growth (Bjørnskov & Foss, 2013). The significance of fostering entrepreneurial activities is confirmed by the continually increasing trend of various governmental and non-governmental organizations' actions towards promoting and encouraging entrepreneurship. Due to the importance of entrepreneurship, defining determinates of entrepreneurial intentions is crucial for future economic development.

Previous research regarding entrepreneurial intentions has revealed the impact of various factors. Lee, Wong, Der Foo, and Leung (2011) found that entrepreneurial intentions are affected by individuals' personal attraction to entrepreneurship, social norms among the micro and macro environments that shape beliefs and attitudes towards entrepreneurship, and perceived self-efficacy of an

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OUR ECONOMY**

Vol. 62 No. 1 2016

pp. 37–45

individual as a future entrepreneur. However, the theory of entrepreneurship has still not shed light on the question as to whether environmental and personal characteristics are equally significant to entrepreneurial intentions.

Taking gender and country of origin into account, we considered if innovative cognitive style might have a significant influence on entrepreneurial intentions. This paper's aim is to investigate a gender approach to entrepreneurial intentions and innovative cognitive styles based on a cross-country survey carried out in Croatia and Slovenia. This work contributes to the existing body of knowledge regarding entrepreneurial intentions by providing confirmation of existing research. Moreover, this is the first study to investigate the influence of innovative cognitive style on information and communication technologies (ICT) students' entrepreneurial intentions in Croatia and Slovenia and can serve as a basis for future studies.

This paper consists of five parts. After the introduction, a literature review is presented on the topic, followed by a description of the methodology used. The fourth part gives the results of the employed logistic regressions, while at the end there is a short discussion with a conclusion emphasizing the most important findings and contributions of this paper.

2 Literature Review

No universally accepted definition for entrepreneur or entrepreneurship has achieved consensus (Carland, Carland, & Carland, 2015; Klapper, Amit, & Guillén, 2010). Gartner (1990) used the Delphi method to identify two main perspectives when trying to define entrepreneurship. The majority of Gartner's respondents (79%) focused on entrepreneurship characteristics, while the rest (21%) had entrepreneurship outcomes in their focus (Gartner, 1990). Summing up the various attempts to define entrepreneurship, it is the process and capacity of perceiving and exploiting good business opportunities in order to create business value while accepting risks in this regard (Dahalan, Jaafar, &Rosdi, 2013; Landstrom, 2007; Sharif, 2015). By the same principle, an entrepreneur is an innovative and proactive person with a specific mind-set and vision who recognizes business possibilities, makes crucial decisions, and is willing to take risks in order to make a profit (McQuaid, 2002; Obembe, Otesile, & Ukpong, 2014). In addition, some authors emphasize innovativeness as a very important characteristic of entrepreneurs (Drucker, 2014; Owoseni, 2014).

A number of studies have observed and investigated the personality of entrepreneurs. Numerous studies have demonstrated that entrepreneurship is a process that includes the identification and taking advantage of business chances, a predisposition for making decisions autonomously, risk taking, and innovativeness as well as a determination against competitors (Di Zhang & Bruning, 2011; Lumpkin & Dess, 1996). Mitchell et al. (2007) distinguished entrepreneurial cognition as a unique and special mixture of knowledge structures that help entrepreneurs efficiently use windows of opportunities by making adequate choices and decisions. Krueger, Reilly, and Carsrud (2000) indicated that entrepreneurial activities cannot be predicted by modelling only personal or situational factors and emphasized the importance of investigating entrepreneurial intentions in order to gain an understanding and prediction ability of entrepreneurial activity.

As previously mentioned, innovation plays an important role in entrepreneurial processes. Innovation and entrepreneurship complement and encourage each other, contribute to the success of an organization, and are both essential in enduring organizational sustainability in today's dynamic and turbulent global economy (Zhao, 2005). Moreover, a growing body of literature recognizes entrepreneurs as key enablers of making innovations available to the market; thus, the strong connection of entrepreneurship with innovation is evident (Szirmai, Naudé, & Goedhuys, 2011). Individual innovative behaviour is influenced by many characteristics, such as individual problem-solving style, leadership skills, and work group relationships (Scott & Bruce, 1994). Innovative cognitive style is a strongly ingrained style of decision-making, creativity, and problem solving (Beeftink, Van Eerde, Rutte, & Bertrand, 2012). The Kirton Adaption-Innovation Inventory (KAI) is broadly used for measuring problem-solving cognitive style (Kirton, 2003; von Wittich & Antonakis, 2011), which furthermore forms innovative behaviour (Beeftink et al., 2012).

The issue of gender influence on entrepreneurial intentions has been a matter of interest in numerous studies (Dahalan et al., 2013; Sasu & Sasu, 2015; Wilson, Kickul, & Marlino, 2007). Furthermore, a great number of studies have focused on barriers that women face along their path to becoming entrepreneurs (Harrison, Leitch, & McAdam, 2015; Heilman & Chen, 2003; Lynn & Len, 2005). A recent study reported that women do not see themselves as highly capable in becoming and succeeding as entrepreneurs (Thébaud, 2010).

The use of ICT is an important part of entrepreneurial participation in the global economy, especially in creating a competitive advantage. Moreover, ICT usage helps female entrepreneurs equally take part in today's business world (Mathew, 2010). Martin and Wright (2005) pointed out the scarcity of literature regarding female ICT entrepreneurship

and proposed further research on that topic. Based on the research conducted in ICT businesses, O'Connor, Hamouda, McKeon, Henry, and Johnston. (2006) reported a positive relationship between complementary skills in the co-entrepreneurial, mixed-gender founding teams and exploration of new business opportunities.

3 Methodology

Research questions

The research presented in this paper is based on the following research questions: (1) RQ1: Does the country of origin influence entrepreneurial intentions? (2) RQ2: Does the gender influence entrepreneurial intentions? (3) RQ3: Do attitudes towards entrepreneurship influence entrepreneurial intentions? (4) RQ4: Does innovative cognitive style influence entrepreneurial intentions? And (5) RQ5: What are the differences in gender regarding the influence of attitudes towards entrepreneurship and innovative cognitive style on entrepreneurial intention?

Sample Description

Our survey was conducted on a sample of students in an informatics study programmes of Croatian and Slovenian business and economic colleges ranging from second-year to graduate students. Student-based samples as well as cross-country samples have previously been used by other researchers in similar entrepreneurial intention studies (Ahmed et al., 2010; Mueller & Thomas, 2001). Our sample consists of 541 respondents, of which 60.81% are Croatian students and 39.19% are Slovenian students. Table 1 presents the entrepreneurial intentions of respondents by their characteristics: country of origin, year of study, and gender. The majority of respondents at both the undergraduate (77.78%) and graduate (72.77%) levels of study are planned to start an enterprise. In addition, the majority of both male (89.29%) and female (67.02%) respondents planned to start an enterprise. The Chi-square revealed a statistically significant difference between the group of students planning to start an enterprise and those who were not, in terms of gender with a *p*-value below 0.01.

Research Instrument

The research instrument was developed based on previous studies. The binomial dependent variable measured respondents' serious consideration of becoming an entrepreneur. Participants indicated agreement with the independent variables and constructs using a 7-point scale (1 = completely disagree, 7 = completely agree). There are two main groups of constructs. First, attitudes toward entrepreneurship together comprised the selected variable groups (personal attraction, social norms, and perceived self-efficacy) of entrepreneurial intentions (Liñan & Chen, 2009). Second, cognitive abilities comprised innovative cognitive style (willingness to try, creative-original and opinion-leader, and ambiguities/problems) measured by KAI (Goldsmith, 2011).

Statistical Methods

In order to check the validity of an instrument, a validity analysis was carried out. We have used items from existing

Table 1. *Entrepreneurial Intentions*

Respondents' characteristics	Total (N = 541)		Planning to start an enterprise (N = 400)		Not planning to start an enterprise (N = 141)		Chi-square
	Freq.	%	Freq.	%	Freq.	%	
I. Country							
Croatia	329	60.81%	242	73.56%	87	26.44%	0.801
Slovenia	212	39.19%	158	74.53%	54	25.47%	
II. Year of study (ICT as major)							
Undergraduate	126	23.29%	98	77.78%	28	22.23%	1.288
Graduate	415	76.71%	302	72.77%	113	27.23%	
III. Gender							
Male	168	31.05%	150	89.29%	18	10.71%	29.788**
Female	373	68.95%	250	67.02%	123	32.98%	

Note: (two-tailed) ** $p < 0.01$

Source: Authors' survey

studies, so we based the instrument content validity on that fact. For the sake of testing the reliability of using average values of items grouped into six variable groups, a reliability analysis was conducted using Cronbach's alpha coefficients. Feldt and Kim (2008) recommended using a cut-off value of 0.70 or higher for the Cronbach's alpha coefficient. As all of the calculated coefficients were higher than the cut-off value, we concluded that the item scales were internally consistent. A logistic regression was employed in order to investigate the relationship between dependent and independent variables. The validity of logistic regression models has been investigated using Nagelkerke R Square.

Results

Table 2 presents the results of logistic regressions conducted using entrepreneurial intention as the dependent variable based on the total sample. The results of the logistic regression employed in the total sample model revealed that entrepreneurial intentions are strongly affected by gender and personal attraction ($p < 0.01$) as well as social norms and creative-original ($p < 0.05$). Nagelkerke R Square shows that 46.1% of the variance in the response variable can be explained by the explanatory variables.

Table 3 presents the results of the logistic regression employed in the female-only sample and male-only sample. When focusing on gender, only personal attraction affected entrepreneurial intentions in both the male ($p < 0.05$) and female ($p < 0.01$) samples. Male entrepreneurial intentions were also influenced by the country of origin and social norms ($p < 0.10$), whereas females are influenced by the creative-original factor ($p < 0.05$). On the other hand, in neither the female nor male samples did the year of study, perceived self-efficacy, willingness to try, or opinion-leader and ambiguities/problems factors have any significant influence on entrepreneurial intentions of the respondents. The male sample model explained 29.1% of the variance, while the female sample model explained 48.2% of the variance, as calculated by the Nagelkerke R Square.

Table 4 presents the results of the logistic regression according to the country of origin. In both the Croatian and Slovenian sample, gender and personal attraction had a strong impact on entrepreneurial intentions ($p < 0.05$ in the Croatian sample and $p < 0.01$ in the Slovenian sample). Furthermore, the impact of social norms ($p < 0.05$) and creative-original ($p < 0.10$) group of constructs on entrepreneurial intentions was identified in the Croatian sample model. However, the year of study, perceived self-efficacy, willingness to try, and opinion-leader and ambiguities/problems constructs had no statistically significant impact on entrepreneurial intentions in either Croatia or Slovenia. The Croatian sample model explained 48.5% of the variance, while the Slovenian sample model explained 47.3% of the variance, as calculated by the Nagelkerke R Square.

Table 2. *Logistic Regression Results with Entrepreneurial Intention as Dependent Variable, Total Sample Results*

	Total sample	
	B	*P*-value
Respondent's characteristics		
Gender	-1.365	0.000***
Year of Study	-0.065	0.842
Country	0.193	0.499
Attitudes towards entrepreneurship		
Personal Attraction	-0.798	0.000***
Social Norms	-0.186	0.035**
Perceived Self-Efficacy	-0.114	0.320
Innovative cognitive style		
Willingness to Try	-0.043	0.653
Creative-Original	-0.292	0.035**
Opinion-Leader & Ambiguities/Problems	-0.118	0.379
Constant	5.862	0.000***
Nagelkerke R Square	0.461	

Note: (two-tailed) * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Source: Authors' survey

Table 3. *Logistic Regression Results with Entrepreneurial Intention as Dependent Variable, According to Gender*

	Male		Female	
	B	*P*-value	B	*P*-value
Respondents' characteristics				
Year of Study	0.100	0.871	-0.213	0.592
Country	1.646	0.073*	-0.049	0.877
Attitudes towards entrepreneurship				
Personal Attraction	-0.494	0.043**	-0.862	0.000***
Social Norms	-0.361	0.077*	-0.148	0.140
Perceived Self-Efficacy	-0.309	0.345	-0.117	0.358
Innovative cognitive style				
Willingness to Try	0.016	0.941	-0.065	0.549
Creative-Original	0.008	0.984	-0.387	0.012**
Opinion-Leader & Ambiguities/Problems	-0.122	0.758	-0.137	0.352
Constant	1.921	0.289	6.799	0.000***
Nagelkerke R Square	0.291		0.482	

Note: (two-tailed) * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$
Source: Authors' survey

Table 4. *Logistic Regression Results with Entrepreneurial Intention as Dependent Variable, According to Country*

	Croatia		Slovenia	
	B	*P*-value	B	*P*-value
Respondents' characteristics				
Gender	-0.821	0.029**	-2.870	0.000***
Year of Study	-0.277	0.428	1.050	0.328
Attitudes towards entrepreneurship				
Personal attraction	-0.807	0.000***	-0.761	0.000***
Social Norms	-0.221	0.039**	-0.211	0.213
Perceived Self-Efficacy	-0.221	0.120	-0.035	0.874
Innovative cognitive style				
Willingness to Try	0.013	0.912	-0.153	0.375
Creative-Original	-0.342	0.066*	-0.286	0.184
Opinion-Leader & Ambiguities/Problems	-0.080	0.668	-0.150	0.454
Constant	6.464	0.000***	6.227	0.000***
Nagelkerke R Square	0.485		0.473	

Note: (two-tailed) * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$
Source: Authors' survey

4 Discussion and Conclusion

The purpose of the current study was to investigate if gender, year of study, country of origin, attitudes towards entrepreneurship, and innovative cognitive style affected entrepreneurial intentions. After employing logistic regressions in order to analyse the results of the survey conducted among Croatian and Slovenian ICT students, all previously stated research questions were answered.

The first research question (RQ1) asked if country of origin influences entrepreneurial intentions. The presented results revealed the influence of the country of origin on entrepreneurial intentions among male respondents. When referring

to the second research question (RQ2), which was focused on the possible gender influence on entrepreneurial intentions, the results indicated the strong influence of gender on entrepreneurial intentions. Furthermore, the next two research questions (RQ3 and RQ4) dealt with the possible influence of attitudes towards entrepreneurship and innovative cognitive style on entrepreneurial intentions. These research results suggest that the selected variables of attitudes towards entrepreneurship and innovative cognitive style have a significant impact on entrepreneurial intentions. The last research question (RQ5) sought to determine the differences in gender regarding the influence of attitudes towards entrepreneurship and innovative cognitive style on entrepreneurial intention. The results of our research highlight the notable differences between male and female ICT students concerning their motivation towards becoming entrepreneurs. These differences are mostly evident in respondents' attitudes towards entrepreneurship in the form of social norms affecting males more than females and in cognitive abilities where females are more driven to start a new venture by being original and creative.

Based on the presented results, it could be concluded that males are more driven to become an entrepreneur by extrinsic motivation whereas females are more driven to start their own business by intrinsic motivation. The findings of this research align with some of the previous findings regarding the impact of gender on entrepreneurial intentions and gender differences among entrepreneurs (Dahalan et al., 2013; Di Zhang and Bruning, 2011; Gupta, Turban, Wasti, & Sikdar, 2009; Mueller & Thomas, 2001; Sasu & Sasu, 2015; Thébaud, 2010). Entrepreneurial intentions are very strong among both Croatian and Slovenian students, with a statistically significant gender impact on students' entrepreneurial intentions.

As reported in Gupta et al. (2009), gender stereotypes regarding the perception of what an entrepreneur should be have a great impact on individuals' entrepreneurial intentions. Thus, the significant differences between males and females presented in this research are not surprising. These results could also be explained by the society's perception of entrepreneurship as a masculine domain, which influences females' concerns about if they could achieve success among male entrepreneurs. Nevertheless, ICT can help overcome this issue as many new possibilities are available for female entrepreneurs in terms of electronic businesses and virtual presence in which the gender distinction is often blurry. Khanka (2000) saw female entrepreneurs as confident, creative, and innovative women who are capable of achieving entrepreneurial success while balancing personal, family, and social life. Both males and females have a tendency to start or run a new business if they have the strong ability to solve problems and ambiguities as well as a high level of capacity to be the opinion leader of a group. On the other hand, Croats are still a traditionally raised society (Črpić, Sever, & Mravunac, 2010), which may explain the strong impact of social norms on entrepreneurial intentions among Croatian respondents.

The investigation of gender influence points to the fact that women are conscious of different glass-ceilings and barriers facing female entrepreneurs, especially in the areas dominated by men, like technology and innovation (Ranga & Etzkowitz, 2010). In addition, Kourilsky and Walstad (1998) indicated that men are much less aware of their knowledge insufficiencies and more self-assured in their abilities than women, which make females being more realistic about the matter. Based on these findings as well as ours, we could presume that education is highly important for females in terms of boosting their self-esteem as well as belief in success. In addition, females will probably count on their innovativeness and creativity in the process of becoming entrepreneurs as it is more likely that others will not be eager to cooperate due to the gender stereotypes. In their study, Martin and Wright (2005) indicated that the emphasis in ICT small businesses run by females is on innovation, which is consistent with results presented in this paper regarding the creative-original factor being statistically significant for entrepreneurial intentions among the female sample. However, Tominc and Rebrenik (2004) found that, despite the relatively high social and cultural support for female entrepreneurs, Slovenian women do not benefit from business opportunities, but are more likely to be forced into a business activity due to necessity. The Global Entrepreneurship Monitor's 2012 Women's Report highlighted the global recognition of female entrepreneurship, but also emphasized the importance of enabling supporting activities like providing better access to education and training activities as well as undertaking targeted efforts (Kelley, Brush, Greene, & Litovsky, 2013). Another solution is given by Tominc and Rebrenik (2007) in the form of encouraging women to start a new business by the host society and not only family and friends (e.g., by lowering social services costs or offering niche funding loans for women entrepreneurs).

As this research was limited to students majoring in ICT in Croatian and Slovenian business and economic colleges, it was not possible to gain a large sample; thus, the sample size can be considered a limitation of the generalization of the results. Another limitation of this study is the uneven sample size regarding country of origin and the year of study. A larger part of the respondents were graduate students, which may have affected the high percentage of those planning to start an enterprise. Future research should repeat this study using larger and equal sample sizes in both countries and at the same level of studies. In addition, it would be interesting to include other countries in the region.

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Determinante podjetniških namer v IKT po spolu in državi izvora

Izvleček

Čeprav se mnogi raziskovalci strinjajo, da so okoljske in osebne karakteristike pomembne pri posameznikovi odločitvi, da postane podjetnik, še ni razjasnjeno, ali je vpliv teh karakteristik enako značilen. Številni avtorji opozarjajo na nerešena vprašanja, ki zadevajo povezavo med inovativnostjo, spolom in podjetniškimi namerami. Namen tega članka je raziskati vpliv spola in države izvora na povezanost podjetniških namer in inovativnega kognitivnega sloga. Raziskava je bila izvedena na vzorcu študentov IKT iz Hrvaške in Slovenije. Rezultati so pokazali vpliv spola, države, odnosa do podjetništva in inovativnega kognitivnega sloga na podjetniške namere.

Ključne besede: podjetništvo, spol, inovacija, meddržavne raziskave, podjetniške namere, IKT, Hrvaška, Slovenija

REVIEW PAPER

RECEIVED: NOVEMBER 2015

REVISED: FEBRUARY 2016

ACCEPTED: FEBRUARY 2016

DOI: 10.1515/ngoe-2016-0005

UDK: 711.451:001.895(437.3)

JEL: R11, O31

Citation: Klímová, V., & Žítek, V. (2016). Identification of Czech Metropolitan Regions: How to improve targeting of innovation policy. *Naše gospodarstvo/ Our Economy, 62*(1), 46–55. DOI: 10.1515/ngoe-2016-0005

Identification of Czech Metropolitan Regions: How to improve targeting of innovation policy

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Abstract

Concepts of national and regional innovation systems can serve as an analytical framework forming the empirical base for innovation policy creation. It is possible to distinguish various types of these systems. One of these typologies is based on the assessment of innovation deficiencies. There are three types of regions: metropolitan, peripheral, and old industrial. Metropolitan regions can be characterized by a high level of research, innovation, and patent activity. The aims of this paper are to find relevant indicators that can be used as the basis for defining metropolitan regional innovation systems and using them for the identification of Czech metropolitan regions. The results of the point method combined with the cluster analysis showed that the capital city, Prague, as well as the South Moravian, Pardubice, Central Bohemian, Pilsen, and Liberec Regions can be defined as metropolitan regions.

Key words: regional innovation system, knowledge, innovation, region, Czech Republic, metropolitan region

1 Introduction

Innovation is an essential prerequisite for economic prosperity and wealth creation, because it has a significant influence on socio-economic development and its long-term sustainability. We can say that innovation represents an important competitive advantage of regions in advanced countries. However, individual regions differ considerably in their ability to use innovation as a source of their development. On a theoretical level, the territorial significance of innovation is dealt with by national and regional innovation systems. Concepts of national and regional innovation systems also serve as an analytical framework, forming an empirical basis for innovation policy creation (Doloreux & Parto, 2005). Lundvall (2010), Cooke (1992), Edquist and Hommen (1999), Tödtling and Trippl (2005), Freeman (2002), and other researchers can be classified as the main representatives of these concepts. Generally, we can define innovation system as a group of players in the private and public spheres whose activities and interactions influence the development and diffusion of innovations in a particular territory (state, region).

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OUR ECONOMY**

Vol. 62 No. 1 2016

pp. 46–55

The innovation system concept emerged in the 1980s, and its purpose is to explain the disparities in innovation performance of industrial countries. Its proponents have claimed that the differences in economic and technological performance of individual states are given by the combination of institutions present and their interactions. Innovation performance depends on the institutional differences in the introduction, development, and diffusion of new technologies, products, and processes (Metcalfe & Ramlogan, 2008). In recent years, the innovation systems concept has become the primary approach in research into innovations (Kaufmann, 2007).

Initially, the innovation systems concept focused exclusively on the national level (see Tödtling & Kaufmann, 1999); within a short period, it started to be applied to the transnational and especially regional levels. It was affected by the idea that industrial branches are concentrated in some geographical areas, and the existing decentralized policy can be applied at the regional level (Buesa, Heijs, Pellitero, & Baumert, 2006). The innovation systems concept (together with the endogenous growth theory and the cluster-based theory of the national industrial competitive advantage) was also used for the construction of the concept of national innovative capacity. This concept explains the innovation ability using three building blocks: common innovation infrastructure (including science and technology policy), country's industrial clusters, and linkages between them (Furman, Porter, & Stern, 2002).

The innovation systems concept is characterized by an emphasis on cooperation (networking) and interactive learning. Interactive learning is a process whereby its participants cooperate on the creation and application of new and economically useful knowledge (Lundvall, 2007). This learning arises in a specific institutional context—namely, in a systematic environment influenced by (among other things) by regulations, laws, political culture and "game rules" of economics institutions (Mytelka & Smith, 2002). The innovation network is a network of various actors that helps introduce and diffuse innovations (Powell & Grodal, 2005). Activities practiced in these networks include creation, combination, exchange, transformation, absorption, and utilization of resources through a wide range of formal and informal relations (Fischer, 2001; Tijssen, 1998). Innovation networks can significantly contribute to the improvement of companies' innovation capabilities. Through such cooperation, companies can determine tasks in the innovation process and reach targets that would not be reached without others (Bučar, Jaklič, & Stare, 2010; Powell & Grodal, 2005).

We should distinguish between different types of regional innovation systems (RIS) because it can help further the development of economic theory and the better implementation of the economic policy. One of the approaches is to distinguish the roles of regional and innovation actors in innovation processes (Asheim & Isaksen, 2002); in this way, territorially embedded, regional networked, and regionalized national RIS are defined. Another way to classify the RIS (Cooke, 2004) is through the dimension of management (grassroots, networked, dirigiste) and the dimension of the innovation business (localist, interactive, globalised). A different approach is to classify the regions based on their innovation potential, including the creation and dissemination of knowledge, the ability to gain European funds to promote innovation, and the application and use of knowledge (Cooke, Boekholt & Tödtling, 2000; Doloreux, 2002).

The concepts influencing the identification of various RIS deficiencies, such as organizational thinness, negative lock-in, and fragmentation, were identified by Tödtling and Trippl (2005), who defined three types of RIS: peripheral, metropolitan, and old industrial. They based their classification on system failures, defined by Isaksen (2001) as failures inhibiting innovation activities (see Table 1).

Organizational thinness is the main deficiency of regional innovation systems in peripheral regions. It means that the key elements of RIS are missing or present only to a small extent. In particular, there is an insufficient presence of innovative companies, universities, research institutes, supporting organizations, and clusters. (Trippl, Asheim &

Table 1. *Classification of Barriers to Regional Innovation Systems*

The problem of the regional innovation system	The main problem	A typical problem region
Organizational thinness	Lack of relevant local actors	Peripheral areas
Fragmentation	Lack of regional cooperation and mutual trust	Metropolitan regions, some regional clusters
Lock-in	Regional industry specializes in obsolete technologies	Old industrial regions and peripheral areas built on the acquisition of raw materials

Source: Isaksen (2001), adapted

Miorner, 2015) Peripheral regions are also characterized by a low level of research and development, innovation, and patenting activities (Tödtling & Trippl, 2005). At the same time, these regions are not able to gain the offered resources (Klímová & Žítek, 2015).

Old industrial regions are characterized by a strong representation of industry that is declining or out of date (e.g., mining industry, metallurgy, heavy engineering) and the emergence of the lock-in effect. This innovation system is considered too embedded or specialized (Trippl et al., 2015; Tödtling, Skokan, Höglinger, Rumpel, & Grillitsch, 2013).

Metropolitan regions, which are the subject of this paper, are characterized by a high level of research, innovation, and patent activity and are considered to be the centres of innovation. These regions have sufficient representation of all types of organizations, such as top research institutions and universities, innovative enterprises, the headquarters of multinational companies, and trading services; they thus benefit from the knowledge externalities and agglomeration economies (Tödtling & Trippl, 2005). The innovation importance of metropolitan regions is strengthened by the fact that cities are becoming generators of economic development and a source of growth for the whole national economy (Mavrič, Tominc, & Bobek, 2014). However, we cannot definitively say that all metropolitan regions are centres of innovation. They may have experienced fragmentation of the innovation system and poor linkages among the different RIS elements. A low level of networking and knowledge exchange leads to insufficiently developed collective and interactive learning and lower systemic innovation activities (Trippl et al., 2015). Some metropolitan regions may lack dynamic clusters, even though there are individual high-tech companies and knowledge organizations in the region. However, a low level of cooperation (weak innovation networks) represents an innovation barrier, which results in the innovation activities being at a lower level than could be expected (Tödtling & Trippl, 2005).

Based on the theories described thus far, we can define the metropolitan regional innovation systems at the level of Czech regions. The aim of this paper is to find relevant indicators that can be used as the basis for the definition of metropolitan regional innovation systems and to use these indicators for the identification of metropolitan regions in the Czech Republic. The next chapter deals with the methodology and introduces the indicators that have been chosen as the characteristics or features of metropolitan regions. In the following sections, we present and discuss the results. All Czech regions were divided into six clusters, and it was determined which ones are metropolitan. The results achieved are summarized in the conclusion.

2 Methodology

In this paper, we define the metropolitan regional innovation systems in the Czech Republic. All other steps are inspired by the approach presented by Tödtling and Trippl (2005). The point method seems appropriate for the identification of the metropolitan regions as this method ranks the regions based on the cumulative score, in combination with the cluster analysis, through which it is possible to define groups of similar regions or to classify as metropolitan those regions where the result of the point method is not clear.

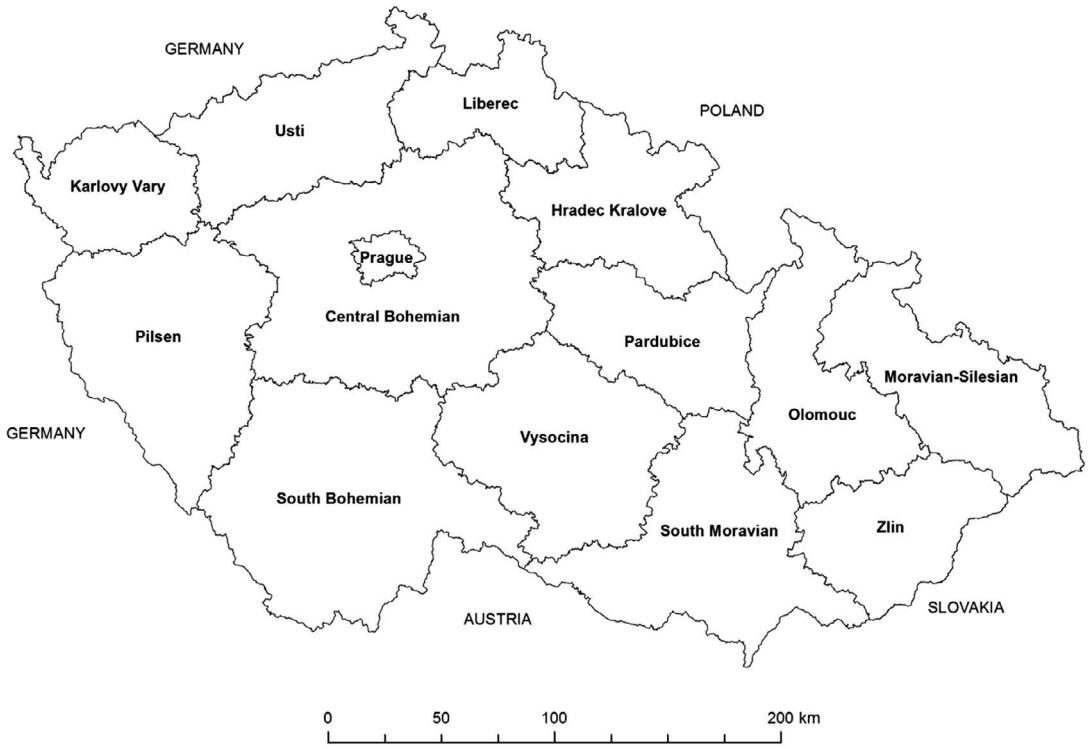
The Czech Republic is divided into 14 regions (NUTS3 regions,) which also represent administrative units within their own regional governments. The capital city of Prague (1.2 million inhabitants) is a self-governing region that is among the most developed regions in Europe based on the gross domestic product and other indicators. Brno (380,000 inhabitants) is the second biggest city in the Czech Republic and the capital of the South Moravian Region. These two cities are considered innovation centres of supranational significance. These regions include many universities, research institutes, innovative companies, and central government bodies. The position of the Central Bohemian Region is very specific, because it surrounds Prague and represents its natural centre. The most important Czech company, Škoda Auto, is located in this region. The economic structure of the Czech regions is affected by natural conditions, the quality of infrastructure, industrial structures, and also continuing structural problems in some cases (especially in the Moravian-Silesian, Karlovy Vary, and Usti Regions). Figure 1 shows all the Czech regions.

When selecting the indicators, we followed the theoretical knowledge provided in scientific literature (Tödtling & Trippl, 2005). We searched for indicators that express the presence of knowledge organizations (see NPF, RDC) and well-educated people (UDE). We also needed to evaluate the presence of innovative companies (TIS) and their research activity (BRD). In addition, it was necessary to find out whether the knowledge-intensive branches with high value added (HTI, HTS) are available. We wanted to know whether the knowledge organizations and innovative companies cooperate with each other (ECS). At the same time, all the indicators have to be accessible at the regional level.

The following eight indicators were chosen as the characteristics or features of metropolitan regions:

- the number of faculties of public universities (NPF)
- the number of research and development centres per 100,000 inhabitants (RDC)
- the share (%) of employees with university degrees among all those employed in the national economy (UDE)

Figure 1: Czech NUTS3 regions



Source: Authors

- the share (%) of businesses in high-tech industrial sectors (NACE 21 and 26) in all businesses in the manufacturing industry (HTI)
- the share (%) of businesses in high-tech service sectors (NACE 59-63 and 72) among all businesses in services (HTS)
- the share (%) of businesses that have implemented a technical innovation among all businesses with 10 or more employees (TIS)
- the business expenditures on research and development as a share (%) of GDP (BRD)
- the share (%) of external costs (purchase of R&D services, purchase of other external knowledge) of businesses of total expenditures on technical innovation (ECS)

All the indicators, excluding ECS, are assumed to reach high values ("more is better" principle) in terms of the characteristics of metropolitan regions; by contrast, ECS is assumed to reach a low value ("less is better"). All data are as of the end of 2012. The values of these indicators are presented in Table 2.

With regard to the aim and nature of indicators, which are expressed in different units and gain different values, it seems appropriate to use the point method. However, as its results are to a large extent affected by potential major differences in the values of one or more indicators, it can be further combined with the cluster analysis.

The point method is based on finding the region that, in the analysed indicator, reaches the maximum or minimum value. The minimum value is relevant if the indicator's decline is considered positive (the less, the better); the maximum value is the opposite case—namely, an increase in the indicator value is positive (Melecký & Staníčková, 2011).

The point value of the specific indicator is set as follows:
- in the case of the maximum:
- in the case of the minimum:

where B_{ij} is the point value of the i^{th} indicator for the j^{th} region, x_{ij} is the value of the i^{th} indicator for the j^{th} region, $x_{i\,max}$ represents the maximum value of the i^{th} indicator, and $x_{i\,min}$ is the minimum value of the i^{th} indicator.

The region with the maximum (minimum) value of the indicator is assigned with a certain number of points within the point evaluation of each (100 in the calculations carried out here); other regions are rated according to their indicator values (0–100). The main advantage of this method is the possible establishment of integrated indicators—a group of indicators

Table 2. *Indicators of RIS Typology Evaluation: Metropolitan regions*

Code	Region	NPF	RDC	UDE	HTI	HTS	TIS	BRD	ECS
CZ010	Prague	41	5.47	39.09	5.87	7.33	34.84	1.01	16.78
CZ020	Central Bohemian	1	1.94	19.79	2.97	4.02	34.10	1.10	53.57
CZ031	South Bohemian	10	1.76	17.55	2.85	4.11	35.41	0.64	10.65
CZ032	Pilsen	10	2.08	19.12	3.13	4.56	36.44	1.31	22.42
CZ041	Karlovy Vary	0	0.73	13.23	0.74	1.36	24.75	0.23	15.15
CZ042	Usti	8	1.24	13.76	2.27	2.93	33.54	0.28	6.98
CZ051	Liberec	6	2.05	16.41	2.95	4.47	45.30	0.96	17.30
CZ052	Hradec Kralove	6	2.42	17.43	5.81	4.03	28.67	0.60	14.91
CZ053	Pardubice	7	2.77	14.99	4.61	5.25	36.04	1.27	5.26
CZ063	Vysocina	1	1.72	15.78	1.53	3.35	40.76	0.47	5.38
CZ064	South Moravian	27	3.99	24.78	3.58	6.82	36.31	1.26	7.86
CZ071	Olomouc	8	2.10	17.68	2.05	6.34	32.73	0.56	19.15
CZ072	Zlin	6	2.92	16.64	3.11	6.36	44.43	0.83	14.02
CZ080	Moravian-Silesian	17	2.16	18.14	2.42	5.73	33.76	0.56	13.43

Source: Albertina Database (2014) and CZSO (2013a, 2013b, 2014), recalculated by authors

expressed in different units that is summarized in one characteristic, a dimensionless quantity (Kutscheraurer et al., 2010).

The point values of the individual parameters can further be used as data for the cluster analysis. By means of the cluster analysis, regions can be grouped into clusters based on their resemblances (e.g., Poledníková & Lelková, 2012). Non-hierarchical clustering is used; specifically, the method of *k*-means with Euclidean distances is appropriate for this purpose.

3 Results and Discussion

The values of the indicators are converted using the point method so that the maximum value of 100 points corresponds to the minimum or the maximum value, depending on the expected interpretation (whether less or more is the better) of the indicator for the metropolitan RIS. When the regions are ranked based on the point score (see Table 3), some results stand out.

Prague and the South Moravian Region achieved the highest values. Several differences are evident in the rate of achievement of the maximum values: Prague reaches the maximum in five out of eight cases, whereas the South Moravian Region dos not a single time. However, this is not surprising. Prague is one of the most advanced European regions, and the South Moravian Region—mainly due to the presence of Brno—is a region with a developed innovation infrastructure and a considerable concentration of knowledge and innovation activities. Furthermore, the Pardubice Region can be classified as metropolitan. In other regions within the ranking, we have to consider their similarities. The situation in the individual regions can be graphically presented using the icon graph (see Figure 2).

To decide which regions are metropolitan, it is necessary to conduct another analysis. For this purpose, the cluster analysis seems to be appropriate. It relatively reliably distributes regions into clusters based on their similarities. The hierarchical method of *k*-means was used. After distributing the regions into six clusters, the situation is as follows (the order of the clusters is subjected to the mean values of the point score of the sub-indicators in the individual clusters):

- 1st cluster: Capital city of Prague
- 2nd cluster: South Moravian and Pardubice Regions
- 3rd cluster: Pilsen, Liberec, and Central Bohemian Regions
- 4th cluster: Zlín, Hradec Králové, Olomouc, Moravian-Silesian, and South Bohemian Regions
- 5th cluster: Ústí nad Labem and Vysočina Regions
- 6th cluster: Karlovy Vary Region

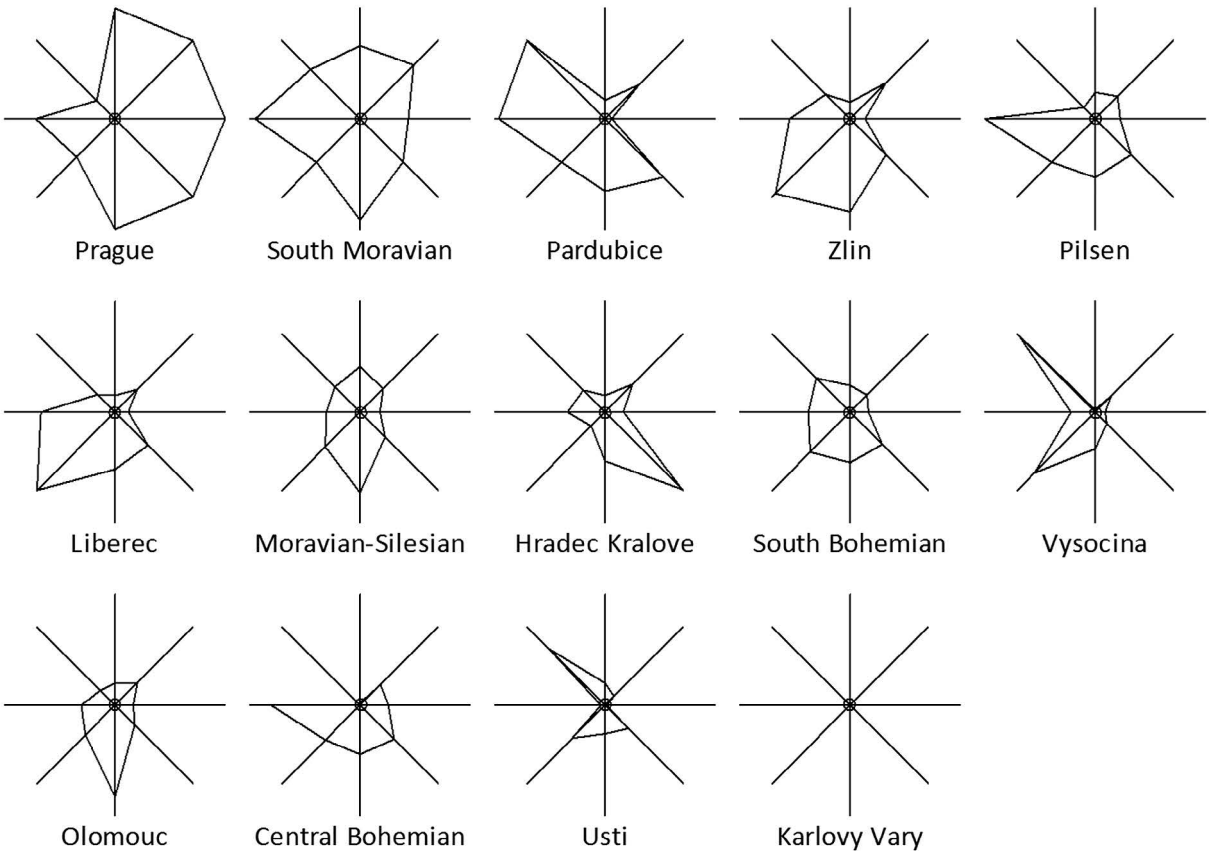
The results of the cluster analysis show that the regions in the first, second, and third clusters can be definitely considered metropolitan (see Figure 3). On the surface, the ranking of the Central Bohemian Region might be surprising; however, we have to consider its specific structure, in which the natural centre and regional capital, Prague, is at the same time a separate region. The fourth cluster consists of

Table 3. *RIS Typology Evaluation: Metropolitan regions (point method)*

Code	Region	NPF	RDC	UDE	HTI	HTS	TIS	BRD	ECS	Total
CZ010	Prague	100	100	100	100	100	77	77	31	685
CZ064	South Moravian	66	73	63	61	93	80	96	67	600
CZ053	Pardubice	17	51	38	78	72	80	97	100	533
CZ072	Zlin	15	53	43	53	87	98	63	38	449
CZ032	Pilsen	24	38	49	53	62	80	100	23	431
CZ051	Liberec	15	38	42	50	61	100	73	30	409
CZ080	Moravian-Silesian	41	39	46	41	78	75	43	39	403
CZ052	Hradec Kralove	15	44	45	99	55	63	46	35	402
CZ031	South Bohemian	24	32	45	49	56	78	49	49	383
CZ063	Vysocina	2	31	40	26	46	90	36	98	369
CZ071	Olomouc	20	38	45	35	86	72	43	27	367
CZ020	Central Bohemian	2	36	51	51	55	75	84	10	363
CZ042	Usti	20	23	35	39	40	74	21	75	327
CZ041	Karlovy Vary	0	13	34	13	19	55	18	35	185

Source: Authors

Figure 2: Icon graph of metropolitan region indicators



Note: The eight rays represent the individual indicators. The 12 o'clock position is occupied by NPF, the other indicators (RDC, UDE, HTI, HTS, TIS, BRD and ECS) are ordered clockwise.

Source: Authors

the regions that have some features of metropolitan regions, but cannot be considered as "clear" types. The Czech metropolitan regions lie on the three main developmental axes of national significance: Prague–Brno; Prague–Pardubice, and Liberec–Mlada Boleslav–Prague–Pilsen (Viturka, Halámek, Klímová, Tonev, & Žítek, 2010).

4 Conclusion

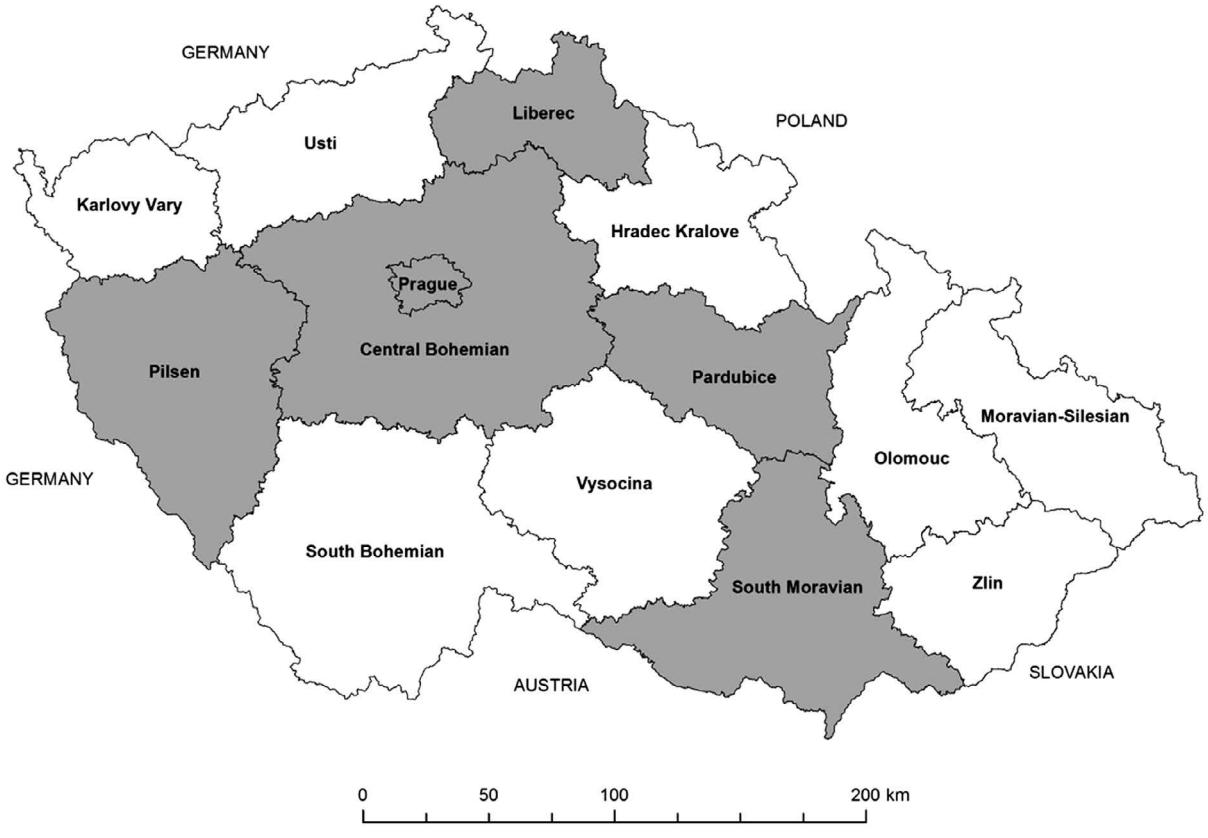
A higher level of innovation activity is typical characteristic of metropolitan regions due to two main factors: they have more resources for innovation and they have a more appropriate density of potential innovation partners (Kaufmann, 2007). This density brings various types of externalities, which can enhance innovation opportunities (Dautel & Walther, 2013).

This article identified the Czech metropolitan regions: the capital city of Prague, the South Moravian Region (including Brno, the second largest city of the Czech Republic), and the Pardubice Region. The other NUTS3 that can be considered metropolitan are the Central Bohemian, Pilsen, and Liberec Regions.

Prague's economic performance highly exceeds that of the other Czech regions. Prague is home to many multinational companies, research institutes, and universities. Innovation activity in the South Moravian Region is concentrated in Brno, which is a city often referred to as "university city". In addition to universities, it is home to numerous innovative companies, research institutes, and supporting organizations. In recent years, it has become a research leader, especially due to the large investments financed from the EU cohesion policy. Prague and Brno are considered innovation centres of supranational significance. The advantages of the Pardubice Region are well connected to Prague and the Central Bohemian Region, presence of an international airport, and the tradition of chemical research.

As previously stated, the identification of a regional type enables better targeting of the innovation policy. Metropolitan regions should strive for greater cooperation among regional actors (through the formation of innovation

Figure 3: Czech metropolitan regions



Source: Authors

networks and clusters) and connections to global networks. These regions have the potential to introduce radical innovations that they must develop permanently. They have to support the establishment and development of start-up and spin-off companies in knowledge-based fields. They also have to build high-quality universities and research institutes in order to support specialized qualifications and skills in relevant fields (Tödtling & Trippl, 2005).

We are of the opinion that the capital city of Prague should cooperate closely with the Central Bohemian Region. Both regions have strong mutual linkages, and the border between them is only formal. A very good transportation connection already exists between them, and a lot of people from the Central Bohemian Region commute to work and school in Prague. In turn, Prague's research organizations build their research facilities in Central Bohemia, where real estate is available and cheaper and the organizations can get more support from the EU's structural funds (in terms of the EU cohesion policy, Prague is a more developed region and Central Bohemia is a less developed region). Innovations do not represent the priority for regional governments there, so the political support for innovation is very low in both regions. Until 2015, none of them had their own regional innovation strategy. Furthermore, there is no special agency for innovation support. Therefore, we would recommend paying more attention to the regional innovation policy and establishing a special intermediary organization (innovation centre). To the contrary, the development of innovations in the South Moravian Region has strong political support. The first innovation strategy was approved in 2003 and has continued to be updated. It managed to build two renowned intermediary organizations: the South Moravian Innovation Centre and the South Moravian Centre for International Mobility. Yet the South Moravian Region needs a better air connection to other countries and a better road connection to Vienna. We do not recommend establishing new public research centres in the three regions mentioned, but it is necessary to develop the existing ones and attract foreign scientists and doctoral students. These three regions have the necessary prerequisites to participate in the Horizon2020 programme. The universities in the Pardubice, Pilsen, and Liberec Regions do not have as good of a tradition as those in Prague and the South Moravian Region, and such tradition cannot be built in the foreseeable future. Therefore, these latter regions have to cooperate more with universities in Prague and Brno and focus on the embeddedness of big innovative companies in their territories. In addition, they need stronger political support for innovation, and it is recommended that they establish intermediary organizations. The Pilsen Region should aim to cooperate with Germany (Bavaria). Poor cooperation represents a weakness of all metropolitan regions. Therefore, we recommend supporting collaborative research projects, innovation vouchers, pre-commercial public procurements projects, participation in international projects, and the like. It is suitable to focus on proof-of-concept projects to support radical innovations; these innovations can be supported through private equity as well (e.g., public venture capital funds).

Although our research study has certain limitations (e.g., availability of statistical data), the designed methodology has a strong research potential. Future research should verify these results over a longer period or compare them with regions in other countries.

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Opredelitev čeških metropolitanskih regij: kako izboljšati ciljanje inovacijske politike

Izvleček

Koncepti nacionalnih in regionalnih inovacijskih sistemov lahko služijo kot analitični okvir, ki tvori empirično osnovo za oblikovanje inovacijske politike. Razlikovati je mogoče več tipov teh sistemov. Ena izmed teh tipologij temelji na oceni inovacijskih primanjkljajev. Obstajajo trije tipi regij: metropolitanski, obrobni in staroindustrijski. Metropolitanske regije je mogoče označiti z visoko raziskovalno, inovacijsko in patentno dejavnostjo. Cilj tega članka je najti ustrezne indikatorje, ki jih je mogoče uporabiti kot osnovo za definicijo metropolitanskih regionalnih inovacijskih sistemov in jih uporabiti za opredelitev čeških metropolitanskih regij. Rezultati točkovne metode v kombinaciji s klastersko analizo so pokazali, da je mogoče regijo Praga ter Južnomoravsko, Pardubiško, Osrednječeško, Plzensko in Libereško regijo definirati kot metropolitanske.

Ključne besede: regionalni inovacijski sistemi, znanje, inovacija, regija, Republika Češka, metropolitanska regija

REVIEW PAPER

RECEIVED: AUGUST 2015

REVISED: JANUARY 2016

ACCEPTED: JANUARY 2016

DOI: 10.1515/ngoe-2016-0006

UDK: 005.336.3

JEL: M11, L15, N01

Citation: Ćwiklicki, M. (2016). Understanding management concepts through development of their tool box: the case of total quality management. *Naše gospodarstvo/Our Economy, 62*(1), 56–62. DOI: 10.1515/ngoe-2016-0006

Understanding Management Concepts through Development of their Tool Box: The case of total quality management

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Abstract

This paper offers an alternative approach to defining the management concept. The proposed methodology relies on the identification of tools supporting the given concept. The author assumed that the identification of tools' evolution gives clearer insights into circumstances of constant development of—by its nature—a more general concept. The tools' classification resembles a phylogenic tree and is based on the idea of an affinity diagram. To provide the proof for such reasoning, the total quality management (TQM) concept was chosen. This proposition can be useful for better understanding origins and the development of management thought. It clarifies relationships among methods constituting frameworks of quality management.

Key words: management concept, evolution, tools, total quality management

1 Introduction

In order to define a concept, general terms are used. Such definitions are especially difficult in the case of philosophies that have evolved over a long period. The nature of such philosophies changes as they develop in different surroundings. Therefore, another approach to defining a concept based on the details of the concept usually expressed by accompanying methods (tools) can be useful. A method is a systematic way of accomplishing something. Depending on how detailed the description is, one can treat it is as rules, guidelines, methodology, techniques, procedures, and algorithms. The author uses the word *tool* as an equivalent of these terms.

Tools are easy to describe, but this does not mean that they are easy to grasp in a manner that allows for a better understanding of the concept. The primary research objective of the paper is to describe the idea of a management concept by identifying its tools. The secondary objective is to test whether a classification based on phylogeny is suitable for the main purpose.

The applied methodology refers to evolutionism, which as a theory assumes the constant and continuous development of an idea, concept, paradigm, etc., rooted in the past and adapted to the present conditions of its application (Futuyma, 2005). Evolutionism is based on the Darwinian theory of biological evolution.

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OUR ECONOMY**

Vol. 62 No. 1 2016

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Such an approach offers a different point of view and permits the identification of the main characteristics of the concept through the reconstruction of its tools' evolution. This article made such an attempt using the total quality management (TQM) concept, which is a "management approach to long-term success through customer satisfaction. TQM is based on all members of an organisation participating in improving processes, products, services and the culture in which they work" (ASQ, n.d.). In this paper, the development of the TQM concept is described and contemporary sets of TQM tools are presented. An evolutionary perspective is applied to S. Shiba's (1995) thoughts on TQM development. The paper then proposes the classification of TQM tools from and evolutionary perspective. Finally, conclusions are given based on the presented analysis.

2 Development of the TQM Concept

There is no single or commonly accepted definition of the TQM concept. As a result, TQM has become a fashionable expression associated with multiple meanings (Dahlgaard, 1999). Interestingly, P. Crosby, W. E. Deming, and J. M. Juran—considered to be the contemporary TQM gurus—did not actually use the term (Martínez-Lorente, Dewhurst, & Dale, 1998). Martínez-Lorente et al. (1998) embarked on a search for the roots of TQM as a term and its changing interpretations. Based on their analysis of publications from 1986–1997 registered in the ABI-INFORM database, they found that the TQM concept did not appear until the second half of the 1980s, where it replaced total quality (TQ) and quality management (QM). Dahlgaard (1999) reached a similar conclusion. This analysis of the historical development of the TQM concept sheds some light on the differences in nomenclature and, at the same time, helps determine the first management system to possess the features with which TQM is currently endowed.

Initially, a statistical approach to quality control, called statistical quality control (SQC), was used. Its characteristic features became the focus of training courses in Japan, where the transformation of a narrowly conceived control tool into a broader concept occurred. The English phrase *quality control* was translated into Japanese as *hinshitsu kanri*. However, the word *kanri* has a different meaning in Japan than in the West. Xu (1994) explained that, in Japan, there is no separation of control and management (Witcher, 1995). In fact, *kanri* means control, administration, and management. It was the first harbinger of a change in terms from *control* to *management*.

Another premise was the observation that non-production workers have also had an impact on the creation of quality. In order to give it its proper expression and distinguish from the meaning of quality control as it has been used to date, the word *total* was added in order to underscore the global approach to quality within an organization. In this way, total quality control (TQC) was born. A. V. Feigenbaum was the first author to use and disseminate the term[1] (Witcher, 1995). According to his definition, TQC is an effective system for integrating the development of quality among various parts of a company, quality retention and quality improvement for economical production, and service that considers its goal to be complete satisfaction of customers (Akao, 1991).

TQC was officially introduced in Japan in 1960 during a series of seminars conducted by Feigenbaum. But Japanese managers perceived TQM differently. Apart from the companywide approach to quality control, of equal importance is the commitment[2] to quality as an organizational strategy (Akao, 1991). In response to the erroneous identification of the TQC concept with its Japanese version, the term *companywide quality control* (CWQC) was used as an alternative (Akao, 1991). In this way, the importance of the word *total* as an approach to management that involved the entire organization was underscored while simultaneously emphasizing its difference from Feigenbaum's approach. Therefore, interpreting TQC at the time as synonymous with CWQC is misguided. However, these concepts are considered similar or the contents of the PN-ISO 8402:1996 industrial standard[3] (item 3.7, comment 5).

The transition from statistical quality control to companywide or total quality control occurred in Japan in 1961–1965 in companies whose achievements in the area of quality earned them the Deming Prize in the first half of the 1960s, which contributed to the dissemination of best practices, including those regarding planning. These companies were Nissan Automotive (1960), Teijin and Nippon Denso (1961), Sumitomo-Denko (1962), Nippon-Kayaku (1963), Komatsu (1964), and Toyota Jiko (1965) (Akao, 1991).

The greatest propagator of CWQC was K. Ishikawa, who showed the differences between Feigenbaum's TQC and Japanese TQC (Ishikawa, 1985, 1986). Ishikawa defined quality control (quality management) as the development, design, production, and provision of a product and service qualities that are the most economical, are useful, and always satisfy the customer (Ishikawa, 1986). It should

[1] The first edition of A. V. Feigenbaum's book was titled *Quality Control* (1951), and the second one *Total Quality Control* (1961). Witcher (1995) argued that the change in the perception of quality control as management was presented by Feigenbaum in his article titled "Total Quality Control" published in *Harvard Business Review* in 1956.

[2] Hence, TQM is also synonymous with total quality commitment.

[3] In addition, total quality is mentioned in it as well.

be remembered that, when describing the PDCA cycle, Ishikawa used the term *control*, not *management*.

As a result, this very popular name conceals a number of interpretations and also different perceptions of the scope of the term. This stems from the fact that TQM combines three distinct strands: productivity (process analysis, operational management, statistical process control), the human factor (trained human resources), and strategic management (Costin, 1994; Dahlgaard, 1999). Depending on the researchers' approach, one of these strands tends to predominate, which results in different interpretations of the term.

Thus, taking into account the historical development of the concept, it can be assumed that the name TQM was applied to the first completely formed management system that came into existence in the late 1970s in Japan, in which the relevant methods were used. Such an approach partly converges with D. Garvin's model proposed in 1988, which is commonly accepted among theoreticians in the field (Dahlgaard, 1999). Garvin (1988) isolated four stages of evolution in the history of quality: inspection, statistical quality control, ensuring quality, and strategic quality management (Dahlgaard, 1999). Dahlgaard (1999) asserted that the current perception of TQM is too narrow because it does not include such issues as organizational learning, the sociological approach, or interpersonal relationships. Indeed, given the present standard of knowledge, the scope of TQM has significantly expanded, which is evident, for example, in Dahlgaard's works, with the beginning of the initial TQM concept dating back to the late 1980s—mainly in the United States. The term TQM was accepted by JUSE in the 90s. (JUSE, 2010).

3 Contemporary Sets of TQM Tools

The list of methods to support the implementation of quality management principles is continuously expanding. An example of such a trend is the compendium of management methods and techniques compiled by Kanji and Asher (1998). In addition, Zhang (2000), based on literature studies, identified 83 methods, although neither theoreticians nor practitioners in the field can agree on the number of existing TQM methods or their actual impact on performance. Due to their characteristics, a number of these belong to the group of TQM methods, although they were originally developed for the implementation of other objectives.

Their sheer number requires at least an attempt at classification. The proposed groups of methods—or families, as understood in biological classifications—usually correspond to the basic activities undertaken as part of TQM. The literature includes no agreement on the nomenclature; however, three types of such methods can be indicated. For example, Juran (1986) proposed a "trilogy" comprising quality planning, quality control, and quality improvement. A similar division was proposed by Duffin (1995), who also came up with three main groups: control, continuous improvement, and prevention. According to Duffin, the latter comprises quality function deployment (QFD) and policies, which may be interpreted as a reference to planning.

Consequently, those wishing to find out about the inventory of quality management tools are faced with a variety of classification proposals that are, at times, different from one another.

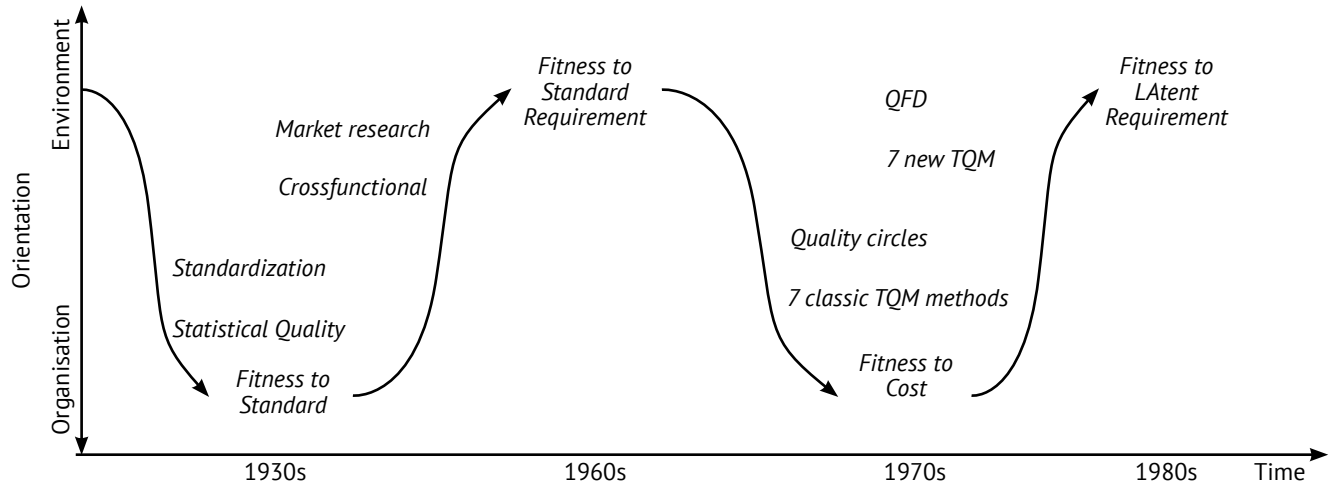
4 Evolution of Approaches and Management Methods According to Shoji Shiba

Shiba (1995) and Shiba and Walden (2001) enunciated the application of management methods in response to social and economic changes that have occurred in the business environment in the recent decades. Fitness to standard[4] constituted the first phase of quality management evolution, which came in response to an increased demand for mass-produced goods and contributed to the development of statistical quality control methods developed in the 1930s. The inspection function of management and standardization of tasks were accorded paramount importance as it was thought that only in this way could a product's conformance with the designer's criteria be ensured. This tendency, as indicated by Shiba, represents the development or improvement of methods for measuring and standardizing work (*Time and Motion Study*) in industrially developed countries, such as the United States and the United Kingdom. This is further supported by the sample observations method proposed by L. H. C. Tippett and explained in *Random Sampling Numbers* in 1927 and the methods–time measurement (MTM) method developed in the 1940s by H. B. Maynard, J. L. Schwab, and G. J. Stegemerten.

However, the separation of control from production did not solve the issue of defective products. Furthermore, in mass production, customers' needs were not fully addressed. Consequently, in the 1960s Japan saw the development of methods that would ensure fitness to use and fitness to market requirements (i.e., customers' needs). The ways of analysing them were developed (market research), and within organisations, the need to cooperate among various types of staff who fulfil different functions in the generally

[4] In the French edition of Shiba's book, the word *adéquation* was used.

Figure 1: Evolution of management methods according to Shiba



Source: Author's own idea (based on Shiba, 1995; Shiba & Walden, 2001).

conceived production process was underscored. This was accompanied by the drive to eliminate the variable quality of products.

The next phase reflected the focus on cost adjustment, which Shiba (1995) described as the retention of high quality and low costs. This was influenced by the perception that product price is determined by the market, not by costs and profits. In the 1970s, methods were developed to reduce production costs while maintaining or improving the quality of products. Methods such as quality circles or the seven classic QC methods (ASQ, 2011) were intended to improve the operation of the organization. Methods mentioned by Shiba (1995) could be supplemented by Toyota's development of one of the most important complete production management systems—namely, lean management—in 1973–1975. However, such solutions were copied by countries with smaller production costs. As a result, it was necessary to seek further sources of competitive advantage.

A search for new markets led to the emergence of a new approach that Shiba (1995) called the fitness to latent requirement. In the mid-1980s, methods were developed to enable the identification of these needs as well as the adjustment of organizational activity to develop new products. According to Shiba, they comprise the QFD method and the seven new TQM methods (ASQ, 2011). The author does not mention other approaches created at the same time to integrate company operation with a view of addressing customers' needs. H. Takeuchi and I. Nonaka (1986) called these ways *rugby*, which became the basis for the development in Japan of concurrent engineering.[5]

Shiba (1995) applied two dimensions to the previously identified phases: production focus (organization) and market focus (customer). The transitions among them demonstrate a logical consequence of an evolution in the approach to quality or, in other words, to customer satisfaction (Shiba & Walden, 2001). The diagram proposed by Shiba can be supplemented with a timeline, as shown in Figure 1.

5 Classification of TQM Methods: An evolutionary perspective)

The identified classifications of TQM tools have been generated from the contemporary perspective and are the result of the deductive process. In this part, the proposed division of TQM methods is developed along inductive lines. The number of methods considered is limited to those that were used as part of TQM in 1931–1978. They constitute the primary set of TQM methods. The justification for this timeline is the conclusion that TQM reached maturity as a management concept well grounded in practice and theory in the 1980s (ASQ, 2013). Since the 1990s, other management approaches, such as lean manufacturing and six sigma, have started to gain in popularity. The tools were chosen based on the results of the literature review that included journals and books published in the last 30 years and discussing TQM as a main topic and unified management approach towards quality. The detailed presentations of the chosen TQM tools were described by Ćwiklicki and Obora (2011). The authors divided them into two main time periods: 1920–1948 and 1948–1978.

I prepared the classification of TQM, based on the idea of an affinity diagram. It helps organize diverse qualitative data

[5] The emergence of the concept of *concurrent engineering* in the West has been related to the activities of the Concurrent Engineering Research Centre, West Virginia, since 1990.

into groups. Similarities between individual methods were detected along several parameters—namely, structure, target use, profile, inspiration, and context of its creation. Whenever it was impossible to find a correspondence between a given method and any other at a given level, similarities were sought at the level of previously combined methods.

The results are presented in the form of a tree (see Figure 2). The tree consists of three main families of methods. The first one comprises methods termed statistical quality control and approximately corresponds to the division into seven classic QC methods that make use of numerical data. The second family involves methods whose main focus is to analyse the reasons for the occurrence of problems and planning and includes several of the seven new QC methods. The third family consists of methods whose main focus is to improve and—more broadly—implement total, comprehensive management involving the entire organization, with its best example being the *hoshin kanri* method (King, 1989).

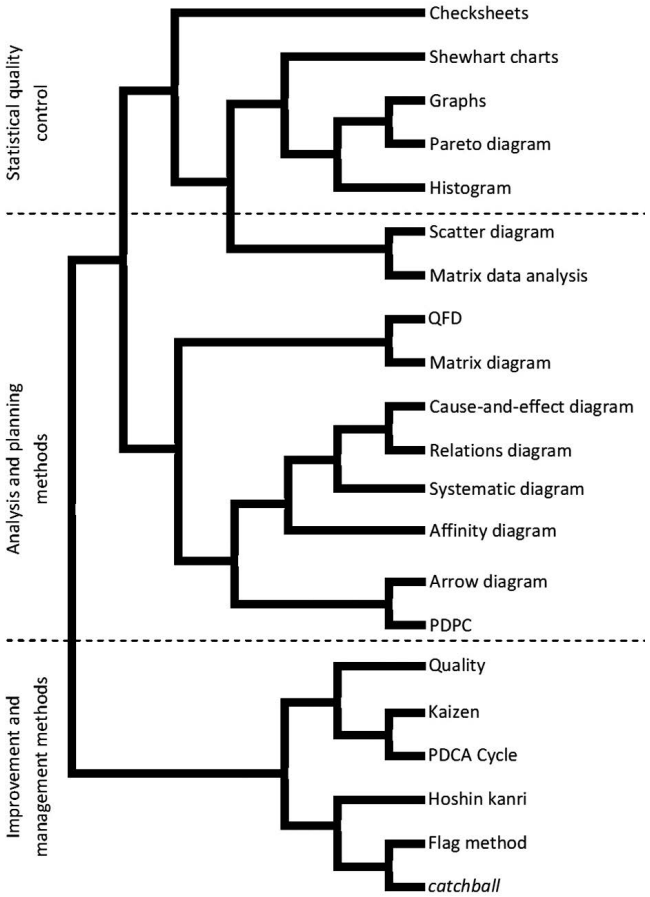
The families of methods described above can be called:
1.) Statistical control methods;
2.) Analysis and planning methods; and
3.) Improvement and management methods.

These three families of methods correspond with the evolution of the TQM concept. First, they applied to aspects of quality control supported by statistical methods. Next, the reasons for low quality were sought using analytical methods, such as the cause-and-effect chart or the matrix chart. The need to manage quality across the entire organization led to the development of appropriate methods, the key one being *hoshin kanri*. From the perspective of the latter phase of the formulation of TQM, this family can be termed TQM methods proper.

The classification presented above offers another attempt to precisely match methods to categories. A much clearer and more comprehensible division that illustrates the process of emergence of TQM is the division that takes into account the passage of time. Additional information on the place of origin or a significant modification of the method (marked with '*' in Figure 3) indicates the original influences within the three categories identified. A modified version of Figure 2 is shown in Figure 3; wherever possible, the first application of a given method is given in brackets.

For the most part, control methods originated in the West. Improvement methods—specifically, analysis methods—can be found in both the West and Japan. However, planning methods, or more broadly, management methods implemented or applied to quality management have been developed by Japanese practitioners and researchers, who frequently drew their inspiration from Western management concepts.

Figure 2: Families of TQM methods

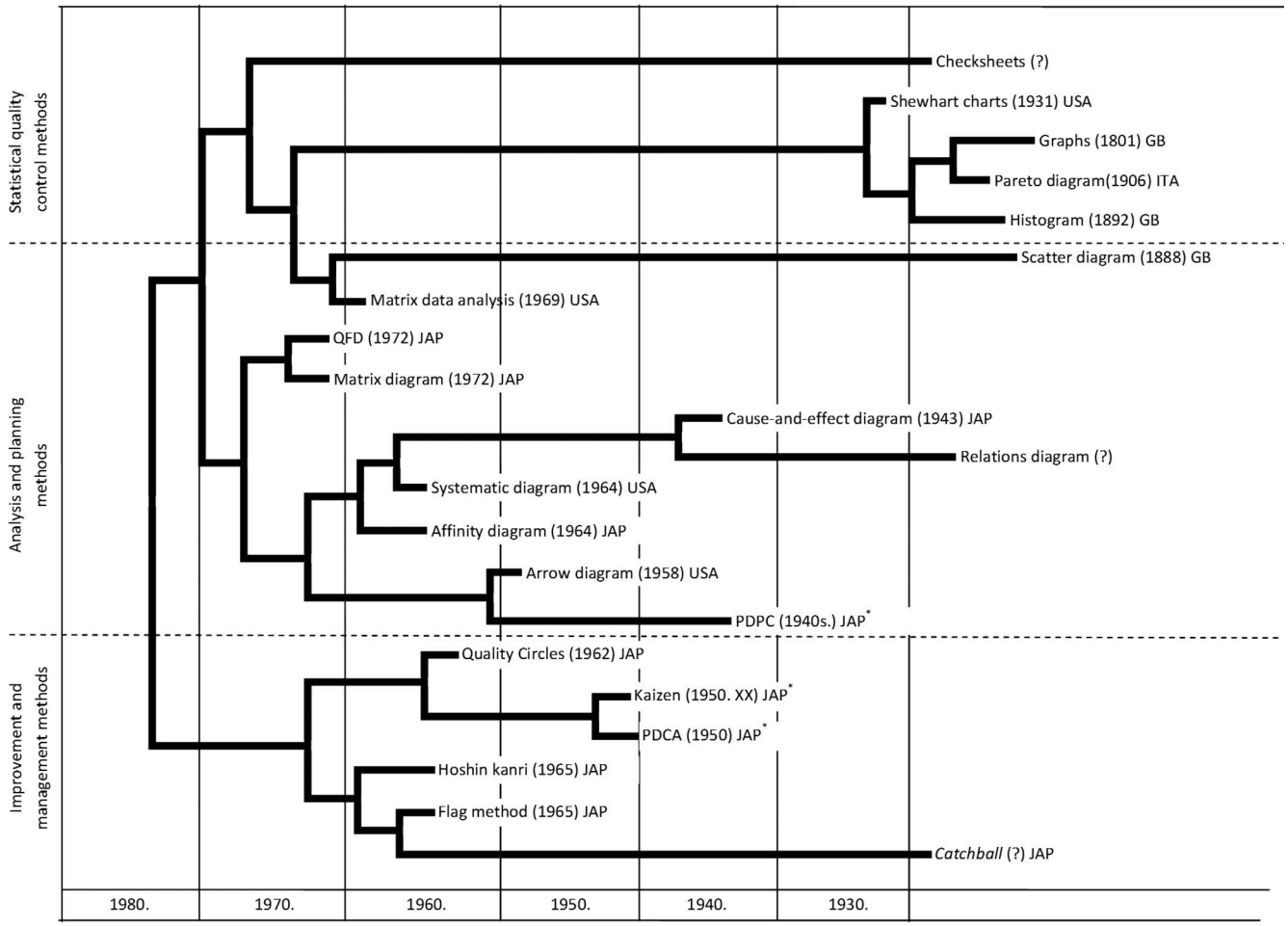


Source: Author's own analysis.

6 Conclusions

The presented analysis gives a solid basis for identifying the main changes within the TQM concept. The tools clearly indicate parts of the concept that could be separately studied. All of them create a unified view and allow for understanding how the given concept evolved. Thanks to identification of its small pieces (i.e., tools), it is possible to present the major aspects that shaped and created a contemporary shape of the management concept. Thus, the primary research objective—namely, to describe the idea of a management concept by identifying its tools—were achieved. The second research objective referring to testing classification based on phylogeny as suitable for the previous objective was also achieved. Using an affinity diagram proved to be not only useful, but also efficient. The obtained result indicates that it can also be applied to identifying other management concept, especially those consisting of many supporting tools.

Figure 3: Families of TQM methods viewed from the perspective of time and place of origin



Source: Author's own analysis.

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Razumevanje konceptov menedžmenta s pomočjo razvoja njihove „orodjarne“: primer menedžmenta celovite kakovosti

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