EUROPEAN JOURNAL OF BUSINESS SCIENCE AND TECHNOLOGY

CONTENTS

CHALLENGES AND VULNERABILITIES OF ANALYSING CYBERCRIME COSTS

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ABSTRACT

Recent studies have underlined a limited scope of research published with regard to the impact of cybercrimes, which is investigated by applying the scientific literature analysis and surveys. This paper focuses on in-depth research on cybercrime costs by analysing the information from selected online materials in order to reveal a research gap. To support the contributions of the research in the field, two methods, namely, literature review and statistical analysis were employed. The findings reveal that several interested parties such as independent IT companies, governmental and non-governmental institutions have conducted various surveys to identify the impact of cyberattacks. The main challenges and vulnerabilities of analysing cybercrime costs can be overcome by further investigations.

KEY WORDS

cybercrime cots, cyber attack, OLS regression

JEL CODES

M21, K24

1 INTRODUCTION

A rapid technological progress has enabled power imbalance and anonymity in electronic environment, which encourages cybercrime activities. Cybercriminals use various means of information and communication technologies (ICTs), networked computers, mobile telephones, bots, and other devices. In the effort to reduce computer-focused digital deviance (Reyns, 2010) and negative outcomes, it is essential for academics, practitioners and criminologists to understand the impact of cybercrimes. Bossler and Holt (2009) point out that individuals' cyber deviance and the absence of social guardianship have increased the chances of dataloss due to a malware infection, whereas physical guardianship (the usage of an antivirus

software) has had no expected protective impact because of the lack of information.

In recent years, scientists as well as practitioners have shown an increased interest in cyber incidents and their effects. Cyber activities have been recognised as a destructive phenomenon in private and public enterprises (de Werra and Studer, 2017; Van Niekerk, 2016; Hills and Batchelor, 2015; Kawanaka et al., 2014; Ventre, 2013; Kim et al., 2011; Luo and Liao, 2009). Moreover, the major threat of cyberattacks, which have occurred in the last decade, has showed the vulnerabilities in cyber defence of the North Atlantic Treaty Organization (NATO), the European Union (EU), and the United Nations (UN). The number of studies in the field is sufficient, however, in order to shed light on the spread and the impact of cyberattacks and provide important information to policymakers and practitioners, a deeper analysis is necessary. Cybercrime entails a variety of costs for enterprises, e.g. system repair expenditure, compensations for customers, legal costs, lost revenues, and a reputational damage.

It should be noted that a viral spread of cybercrime has started increasing threats of digital challenges. It has motivated the interested parties to create prevention tools (Saxena et al., 2017), cyber security strategies (Miao and Li, 2017), and an intrusion detection system to reduce the number of cybercrimes. Nevertheless, when analyzing the effect of cyberattacks, some academics have highlighted extreme challenges related to the issue under discussion (Furnell et al., 2015; Leeuw and Leeuw, 2012; Musman et al., 2010; Fletcher, 2007).

It should be pointed out that many recently conducted studies measuring the economic effect of cybercrime costs in a contemporary workplace has remained ambiguous. The paper aims to contribute to in-depth research of cybercrime costs by analysing the information from selected online materials using the statistical package IBM SPSS version 20 and MS Excel 2012. The paper concludes with final remarks on the contributions of the research, its limitations and insights for future implications.

2   THEORETICAL BACKGROUND

Recent theoretical and practical advances have produced alternative views of forms, prevention and recovery costs of cybercrime (Ponemon Institute, 2016). In 2016, cybercrime cost the global economy more than $450 billion. Due to such a situation and an increasing operational risk, it is vital to understand the importance of the investment in the information security. Smith et al. (2011) estimated that cybercrime news story has a significant impact on the average stock price of companies in a short term.

Cybercrime costs are one of the biggest issues; however, they have been defined differently in the last decades. Center of Strategic and International Studies (2014) emphasizes three kinds of opportunity costs, which determine the losses after cyberattacks: (1) reduced investment in R&D, (2) risk averse behavior by businesses, and consumers that limit the

Internet use, and (3) increased spending on the network defence. Ponemon institute (2016) divides internal cybercrime costs of organizations into three groups: (1) direct costs such as the main expense outlay to accomplish the given activity; (2) indirect costs such as time, effort and other organizational resources; (3) opportunity costs such as a negative reputation and lost opportunities. External costs include the loss of information assets, business disruption, equipment damage and revenue loss, which have been captured using shadow-costing methods. However, Jardine (2015) broaden the understanding of damage by operationalizing cyberattacks via: (1) the average cost per data breach; (2) overall organizational cost from data breaches; (3) the cost of detecting a data breach and escalating; (4) post-breach reaction costs; (5) lost business cost; and (6) victim notification costs.

Findlay (2015, pp. 4–5) emphasizes that measuring the degree of cybercrime harm addresses vulnerabilities – "analysts are required to postulate various scenarios of exploit and their immediate and secondary, or down-stream, impacts". Such harm is related to the cost (dollar value) of recovery procedures after data breaches. Immediate impact is defined as data loss, credibility, liability and intangible assets associated with financial or national security inferences.

3 METHODOLOGY AND DATA

In order to achieve the aim of the investigation, different methodological techniques were used. Firstly, the review of literature was done in order to create a unique dataset. To be more specific, information from previous researches carried out on behalf of governmental and non-governmental organizations and reports of independent IT companies and institutes were taken into consideration in this study. The search was accomplished in the scientific databases such as Web of Science, Scopus, JSTOR, Springers, Emerald, Science Direct, Sage, EBSCO, and Google Scholar. In addition, a snowballing technique was employed for the initial sample including relevant materials and the latest references. Thus, bibliometric review helped to reveal interests of Internet users, who search for specific keywords related to the impact of cyberattacks. The data of Google Trends was analysed.

Tab. 1: The type of selected materials

Type	Frequency	Percent	Cumulative percent
Articles	94	27.9	27.9
Scientific papers	1	0.3	28.2
Reports	217	64.4	92.6
Working papers	24	7.4	100.0
In total	337	100.0	

By reviewing a large number of published articles, reports and working papers from various scientific journals and online sources (Tab. 1), the research gap as well as challenges and vulnerabilities related to the analysis of cyberattacks were identified. To keep the research up-to-date, the recent materials were included and the collected data was analysed using statistical package IBM SPSS version 20 and MS Excel 2012. The collected data was used to develop a unique dataset for an empirical research analysing cybercrime costs.

Moreover, eight components or meta-clusters were chosen to estimate cybercrime costs using ordinary least squares (OLS) regression models. Based on a relative small sample and the violation of normality assumption of OLS regressions, the bias corrected and accelerated (BCa) bootstrapping technique was employed (Levi and Leighton Williams, 2013). Bootstrapping is a nonparametric resampling procedure to estimate the sampling distribution of an indirect effect (Bollen and Stine, 1990).

The investigation was based on the equation by cluster (Woolridge, 2006):

$$y_{gm} \quad = \quad \alpha + x_g\beta + z_{gm}\gamma + v_{gm}, \qquad (1)$$

where $m = 1, \ldots, M_g$ and $g = 1, \ldots, G$.

The estimation in the equation depends on the factor and effects of aggregate variables (β) or individual specific variables (γ). For the cluster sampling, it is important whether the vgm contains a group effect.

The first set of the meta-cluster consists of macroeconomic factors. The annual statistics from the World Bank database were taken into consideration in order to estimate GDP growth and growth of Internet users. The second set of items was collected by employing a snowballing technique to select relevant data and check if there is any bias among institutions. Two governmental companies, namely, the CSI and FBI were chosen as the control group. Another meta-cluster focused on the cybercrime costs: notification costs, data breach costs, privacy violations, stolen devices, thefts, opportunity costs, and phishing. The sets of predictor variables and the control group were regressed

and eight models were generated. In order to assert which set of variables was the most predictive in retaliation to each model, a sub-model analysis was conducted. R^2 statistic was used to evaluate the sub-models.

The hypothesis was made that the number of Internet users is significant in OLS regression. Kleiner et al. (2013) stated that Internet users are largely concentrated in North America and Western Europe. The Council of Europe Convention on Cybercrime and London Action Plan propose actions to develop global cyber security and policy initiatives. This study also suggests that the growth of Gross Domestic Product (GDP) has impact on cybercrime costs. The same hypothesis was applied for Microsoft researches in 2013.

4   RESULTS

To address the research gap, institutions which conduct surveys to measure the effect of cybercrime in different contexts and wide institutionalization were taken into account. The main contribution is that the analysis of cybercrime costs might be framed by specific institutions and authors, which provides directions or solutions to curtail cyber incidents (Tab. 2).

It could be unrealistically promising for a private sector to use services of independent IT firms such as Rand Corporation, IBM (sponsor investigation of Ponemon institute), Cisco (sponsor analysis of Government & Finance Divisions), PwC (sponsor surveys of HM Government), and others. It could be noted that private IT companies play the central role among relevant stakeholders because they have more capabilities or resources to conduct specialized surveys than any other actor (Tab. 2). There is also a difference in institutions influencing the understanding of the main factors that affect a control system and cyber security policy. While an institution is diffused in different cases of cybercrimes, the priorities are defined by stakeholders, the analysis focuses on governments and companies.

Tab. 3 shows the most common location of authors or institutions. Only one country, the USA, has more than 200 online materials, i.e. almost five times more materials than the United Kingdom, which is the second country in the list. It suggests that a few players have taken the lead in the empirical investigation of cybercrime costs, with the USA as the top-ranking country, which reflects the efforts to develop and implement a cyber security policy. This offers contributed identification of the used sample that should be investigated in depth through extensive econometric analysis in order to capture emerging trends. The lack of published reports in the world reveals another vulnerability.

Fig. 1 illustrates steep increases in the number of the selected online materials in 2003, 2013 and 2016. The main tendency is also obvious: most of scientific analyses, reports or working papers are published in the United Kingdom and the United States of America. This reveals the main vulnerability in the field of cybercrimes. The number of countries whose institutions focus on cyberattacks is very small; therefore, there is a great need for other countries to develop cyber security policy or create research institutes to curtail cyber incidents or analyze their impact on private and public sectors.

Cyberattacks gained interest in 1988. According to the NATO (2013), the Morris worm, which is one of the first recognised worm to affect the world's nascent cyber infrastructure, spread around computers largely in the US in 1988. The worm used weaknesses in the UNIX system Noun 1 and replicated itself regularly. It slowed down computers to the point of being unusable. It was reported that 6000 computers were affected causing an estimated 10–100 million dollars for repair costs. This type of a cyberattack encouraged to develop methodology and create distributed denial-of-service (DDOS) attacks which were committed by MafiaBoy (Michael Calce) and targeted at

Tab. 2: Institutions which analyse the impact of cyber attacks

Institution	Frequency	Percent	Cumulative percent
Cardiff School of Social Science	7	2.1	2.1
CSI / FBI	12	3.6	5.6
Government & Finance Divisions (USA)	22	6.5	12.2
HM Government	8	2.4	14.5
Internet Crime Complaint Center (IC3)	58	17.2	31.8
Global Risk Specialists	1	0.3	32.0
Louisiana Technology University	34	10.1	42.1
University in Rock Hill	10	3.0	45.1
University of Plymouth	17	5.0	50.1
Norman Paterson School of International Affairs	25	7.4	57.6
Ponemon Institute	107	31.8	89.3
RAND Corporation	36	10.7	100.0
In total	337	100.0	

Tab. 3: Country institutions which analyse the impact of cyber attacks

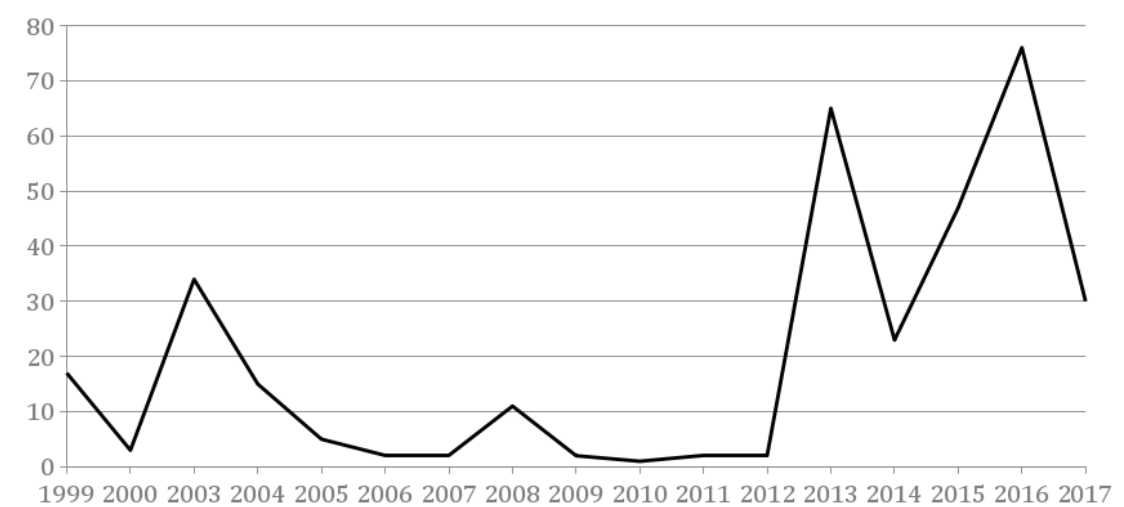| Country	Frequency	Percent	Cumulative percent
The United Kingdom	57	27.9	20.2
World	11	2.3	3.3
The United States of America	269	69.8	100.0
In total	337	100.0	

Fig. 1: The frequency of the selected materials 1999–2017

CNN, eBay, Amazon and Yahoo in 2000. It may have cost around 1.2 billion dollars for industry.

The reason for the increased interest in cyber security might have been due to various cyberattacks in 2012: hacking of the Vatican Websites, the theft of Michael Jackson's catalogue from Sony, and the leak which targeted Vector Inc., a Japanese computer selling firm, potentially affecting more than 260,000 users. Data Breaches (2012) stated that LulzSecReborn hacking group had initiated a massive information leak – of approximately 170,000 records from a military dating site (MilitarySingles.com) which might have cost over $33 Millions in 25 March, 2012. Kovacs (2012) announced that these hackers also had breached the website of CSS Corp, a global ICTs company, leaking the main domain's entire database in 27 March, 2012.

It was also revealed that an unknown group of cybercriminals had infiltrated multiple financial firms after phishing its targets with infected email attachments in 2013. The spread of massive attack was investigated by Kaspersky Lab, which stated that due to this attack at least "100 banks in 30 countries, including Russia, the US, Germany, China, and Ukraine, were affected. In many cases, criminals used their computer exploits to dispense cash from ATMs or transfer cash digitally to accounts they controlled" (Szoldra, 2015).

Following the above considerations, it can be pointed out that interest in ciberattacks has increased among members of the information society. Individuals are getting aware and are searching for more information which could help them to identify the effect of a digital deviance. Google trends reveal that the number of search queries for specific keywords such as "cyberattacks AND cybercrime costs" has been rapidly increasing (Fig. 2). The number of searches for information about the impact of cyberattacks has even doubled since 2016.

Based on the collected data, the sets of predictor variables and the control group were regressed (Tab. 4). The first hypothesis, that the growth of Internet users is significant, was approved, whereas the second hypothesis, that the GDP growth does not have impact on models of cybercrime costs, was rejected. There are no significant associations between the control group and other meta-clusters. What is more, the majority of determinants in meta-clusters of different models are statistically significant.

5   DISCUSSION AND CONCLUSIONS

The paper reveals that most authors and institutions are focused on technical detection and prevention of cyberattacks rather than taking evidence based view from the reports or collaborating with governmental institutions. Following new trends, cybercrimes are described as a destructive phenomenon – the highest threat for public and private institutions. To guide and align stakeholders' behaviour, investigations of cybercrime rely on the regulation and deliberate incentive structure of sponsorships.

Descriptive statistics lead to unique contributions since the analysis of reports of independent IT firms and cyber security institutes as well as scientific publications and working papers broaden our understanding of the analysis of cybercrime and its effect focusing on computer worms, viruses and other malware. It should be noted that this survey is limited to a statistical tool indicating only considerable subjectivity of the effect of cybercrimes. Nevertheless, Cashell et al. (2004) state that survey data is an objective way to measure the impact of cyber incidents on individual firms. Cavusoglu et al. (2004) argue that it is impossible to measure intangible costs and many companies underestimate the costs of security breaches. For this reason, the estimation of incidence reported by the CSI and FBI survey is much lower than the real price after cybercrimes.

The exponential growth in the selected online materials in 2003, 2013 and 2016 was also noticed. This may reflect the increased interest of IT companies and policy makers after the

Tab. 4: The clustered OLS regression

	1	2	3	4	5	6	7	8
GDP growth	−0.164	−0.204	−0.193	−0.178	−0.174	−0.208	−0.172	−0.166
	(−0.244)	(−0.249)	(−0.248)	(−0.246)	(−0.241)	(−0.251)	(−0.247)	(−0.254)
Growth of Internet users	0.001*	0.000	0.001*	0.001*	0.001*	0.001*	0.001*	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Sponsored by CSI	0.054	0.035	0.057	0.054	0.049	0.056	0.056	0.019
	(−0.048)	(−0.051)	(−0.046)	(−0.048)	(−0.052)	(−0.047)	(−0.046)	(−0.058)
Sponsored by IC3	0.476**	0.454**	0.473**	0.476**	0.480**	0.476**	0.474**	0.430**
	(−0.068)	(−0.071)	(−0.068)	(−0.068)	(−0.068)	(−0.068)	(−0.068)	(−0.074)
Sponsored by CISCO	0.507**	0.488**	0.510**	0.507**	0.503**	0.508**	0.510**	0.473**
	(−0.036)	(−0.038)	(−0.034)	(−0.036)	(−0.039)	(−0.035)	(−0.035)	(−0.043)
Sponsored by Global Risk Specialists	1.019**	1.001**	1.023**	1.020**	1.015**	1.021**	1.022**	0.986**
	(−0.037)	(−0.039)	(−0.035)	(−0.037)	(−0.041)	(−0.037)	(−0.036)	(−0.044)
Sponsored by PwC	0.593**	0.638**	0.590**	0.593**	0.597**	0.593**	0.590**	0.674**
	(−0.032)	(−0.037)	(−0.031)	(−0.032)	(−0.033)	(−0.031)	(−0.031)	(−0.047)
Sponsored by IBM	0.202**	0.202**	0.202**	0.211**	0.210**	0.206**	0.213**	0.216**
	(−0.039)	(−0.037)	(−0.039)	(−0.042)	(−0.040)	(−0.039)	(−0.041)	(−0.042)
Sponsored by universities	0.253**	0.244**	0.281**	0.254**	0.279**	0.260**	0.274**	0.339**
	(−0.078)	(−0.076)	(−0.077)	(−0.078)	(−0.089)	(−0.080)	(−0.075)	(−0.086)
Notification costs	0.399**							0.339**
	(−0.040)							(−0.045)
Data Breach Costs		−0.066**						−0.127**
		(−0.030)						(−0.043)
Privacy violations			−0.312**					−0.414**
			(−0.078)					(−0.092)
Stolen Devices				−0.151**				−0.201**
				(−0.030)				(−0.030)
Thefts					−0.334**			−0.413**
					(−0.094)			(−0.090)
Opportunity costs						−0.148*		−0.258**
						(−0.073)		(−0.077)
Phishing							−0.247**	−0.337**
							(−0.057)	(−0.090)
Constant	−0.123**	−0.100**	−0.119**	−0.123**	−0.127**	−0.121**	−0.120**	−0.077*
	(−0.034)	(−0.040)	(−0.033)	(−0.034)	(−0.035)	(−0.034)	(−0.033)	(−0.042)
Observations	326	326	326	326	326	326	326	326
R-squared	0.219	0.219	0.223	0.218	0.223	0.219	0.222	0.242

Note: The numbers in the parentheses indicate standard errors, * indicates a 10% significance level, ** indicates a 5% significance level.
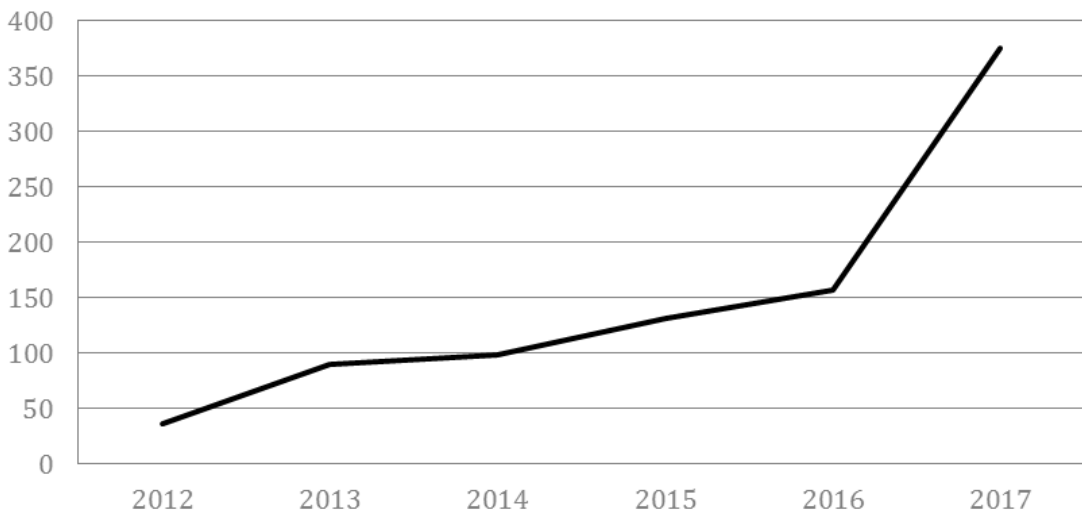

Fig. 2: The frequency of searching for specific keywords in 2012–2017

major cyberattacks in different countries. It is assumed that the sample of online materials can shed light on challenges and vulnerabilities of cyber incidents. This paper contributes to the understanding of the threat of cyberattacks by presenting interests, motivation and implication in different sectors.

Furthermore, the study reveals that the major vulnerability of the research in the field is the lack of information. This is illustrated by a limited number of institutions and scientific publications which analyse the costs of cybercrimes. Along similar lines, Cardenas et al. (2009) agree that researchers tend not to consider how cyberattacks affect the physical world because of limitations of control systems and technical challenges. Gol and Abur (2013) also add that state estimators are vulnerable to any existing critical measurements since their errors cannot be detected. Thus, by manipulating the number of critical measurements, the interested parties can bias results of the state

estimation without being detected due to the lack of scientific publications and continuous research in this field.

The main limitation of the chosen methodology is randomised representativeness, which may cause the selection bias. It can be eliminated by further research, using different methodological techniques and analysing related macroeconomic factors. Moreover, instead of the GDP growth and the growth of Internet users other annual economic indicators can be used.

The empirical contributions provide the analysis of cybercrime costs and reveal the bias in this research field because of a limited number of institutions. Professionals and policy makers can use this information to manage the risk control of cyber security and reduce costs related to cybercrimes. There is a wide range of opportunities for future studies in this field as this issue can be addressed using multidisciplinary approach.

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THE IMPACT OF E-COMMERCE IN VIETNAMESE SMES

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ABSTRACT

Vietnam, is one of the developing countries, which approaches new technology, especially Internet is extremely fast approximately 67.1% in the population in 2017. With the boosting of information technology, it creates a new environment and tool to reach the customers' requirement. The new and effective method of narrowing the gap between the distributors and clients is electronic commerce (e-commerce). E-commerce is one of the most innovative expansions of the technologies that enable small and medium-sized enterprise (SMEs) access to global communication and trade. It can help SMEs expand their businesses to global market and increase sales, reduce costs as well as profits. In order to explore the impact of e-commerce as a novel way to boost the development in Vietnamese SMEs, this paper investigated the benefits and barriers of SMEs in e-commerce. Therefore, a questionnaire survey was conducted to study the impact of e-commerce on SMEs in Vietnam. From the results of this survey, we strongly believed that e-commerce is the main key to bring a lot of benefits to not only SMEs but also big companies in Vietnam.

KEY WORDS

business, electronic commerce, e-commerce, SMEs

JEL CODES

O12, M15, D00

1 INTRODUCTION

Nowadays, Internet of Things (IoT) and Information communication technology (ICT) step by step play an important role in our life. Moreover, IoT can help big and small companies or factories in improving operations and increasing customer satisfaction by selling products online, tracking their goods on shipping, location, control and security (Lopez Research, 2013). With the rapid growing of globalization trend, small businesses need to change the business

environment; therefore, it needs to implement the Internet, especially for SMEs to compete and gain access to the market (Dan, 2014). Due to the development of economic globalization and information technology, e-commerce is a new way in approaching the customers and satisfying our lives. Some researchers analyze that e-commerce has a strong impact towards SMEs on organization, technology and environment characteristics (Kendall et al., 2001). Thus, in this paper, first summarizes key concepts in the field of e-commerce and Vietnamese SMEs, then we focus on exploring the impact of e-commerce on SMEs in Vietnam. Moreover, this research also figures out the current barriers of deploying e-commerce in Vietnamese SMEs in order to help the companies find the solutions for them.

2 BACKGROUND

2.1 E-commerce Definition

There are many definitions about the term "e-commerce" (EC). Firstly, e-commerce expresses the process of buying, selling or exchanging services and information between clients and seller or retailer via computer networks (Turban et al., 2009). Secondly, e-commerce is the information exchange and commercial transaction support between customers and suppliers on telecommunications networks (Raymond, 2001). Thirdly, any economic transaction such as delivery of goods and services, payments, pricing and complete the transaction through the delivery of payments via electronic media of Internet is also considered as e-commerce (Kaynak et al., 2005). In another way, EC is also a platform to connect between clients, business partners, employees, and suppliers through the Internet (Beheshti and Salehi-Sangari, 2007). In short, in this article, we used e-commerce definition as an environment to sell and buy the products activities online between customers and suppliers.

2.2 Small and Medium-Sized Enterprises in Vietnam

Small and medium-sized enterprises (SMEs) play an important role in Vietnam, especially in the Vietnamese economy. In Vietnam, a developing country, the process of globalization brings many chances for business. However, many Vietnamese companies, especially more than 97% of SMEs are facing to some challenges such as the competitiveness of SMEs in the market, the lack of information technology, the challenge of shortage of high-quality human resources, employee management, and sustainable business.

With the dramatic developing of multimedia and networking, it creates a new environment to meet the requirement for human's needs. The new and innovative method of getting goods everywhere and every time is e-commerce. E-commerce can offer potential benefits in making high – quality and cost-effective in society and customers; therefore, it can help SMEs achieve their sustainable business goals. E-commerce is related to the customers or buyers and sellers who use the laptops or computers to surf the websites to make transaction online. The primary advantages of e-commerce consist of buying anytime and anywhere by accessing to the Internet, flexibility and more effectiveness.

2.3 Advantages

E-commerce has a lot of advantages in SMEs such as cost savings, reducing production costs, decreasing lead time and administration costs (Rahayu and Day, 2015). For example, it brings direct links with the customers, sellers and distributors in order to facilitate information transferring (Kaynak et al., 2005). It also offers chances for companies to advertise their products around the world without physically contact customers (Karakaya and Karakaya, 1998). Furthermore, EC can improve the management capabilities or the easy reach to the global market among the other objectives (Ifinedo, 2009). Besides, customers can compare the

product's price; good and bad reviews from other customers between this company and the others (Franco and Bulomine Regi, 2016). E-commerce also helps the SMEs make a good relationship with customers (MacGregor and Vrazalic, 2007). Other study found that SMEs can have ability to reach new customers via e-commerce (Quayle, 2002). In another hand, if the bad weather like snowing and the roads are closed, the online business still opens for the customers 24/7 every day of the year, therefore; the profits of company will keep rising (Franco and Bulomine, 2016). In summary, e-commerce not only enhances SMEs' service quality but also help SMEs make a good connection between the buyers and the sellers.

2.4 Drawbacks

Although e-commerce offers a lot of potential benefits, it also has some disadvantages. First of all, e-commerce based on Internet; therefore, it requires SMEs spend an initial cost to set up a high ICT structure. E-commerce runs on internet environment through website applications; hence, it depends on the speed of internet connection. The employees and customers are required to have good Internet connection which allows order process, payment transaction easily. Moreover, a huge amount of things can be purchased online because it is easy and convenient such as clothes, foods, toys, music and so on. However, the security of e-commerce is also essential concerns (Niranjana-murthy and Chahar, 2013). Moreover, some EC software might not suitable for some hardware or operating system.

3   METHODOLOGY

E-commerce is now being applied in many SMEs in Vietnam; therefore, the authors used the research methodology and statistical de-scriptive methods for this article. Firstly, the authors designed a questionnaire to investigate the application of e-commerce by SMEs in Vietnam. The questionnaire was divided into three parts. The first part included questions about the demographic information of the business such as the number of employees; the location of the suppliers, the customers and the industry. The second part discovered how ecommerce brings benefits to SMEs. It included the use of the Internet, the company's website, as well as the effectiveness and the way of the company doing business by applying e-commerce. The last part, the authors would like to investigate the understanding of SMEs in the use of electricity trade as well as the barriers of applying e-commerce.

Secondly, based on the questionnaire was designed, the authors collected data through the Google form. The online survey was used to study the opinion of managers in SMEs on the benefits and barriers in applying e-commerce. This method will allow the authors to easily collect data and facilitate for the respondents. In this study, the authors sent out 245 ques-tionnaires, including 23 valid questionnaires for the study. At the same time, in this study, the authors used SPSS software to analyze the benefits and barriers in e-commerce application of SMEs in Vietnam.

4   ANALYSIS OF RESULTS

What form did SMEs in Vietnam use to serve the business? Vietnamese SMEs have several ways of information technology which they used for business activities and might use more than one (Tab. 1). The main of respondents indicated that 58.1% SMEs used e-commerce and electronic payment. In addition, 55.6% SMEs used the websites for their business as

the second method. Similarly, 50% company's own network was used as the third way. In particularly, 28.2% SMEs used social network for online business. However, 1.6% SMEs stated that they did not use any method in their company.

Tab. 1: The method to apply information technology to business activities of SMEs

Method	Percent
E-commerce and electronic payment	58.1
Company's website	55.6
Company's own network	50.0
Social network	28.2
Do not use any method	1.6

4.1 Expected Benefits from E-commerce

Vietnamese SMEs were asked to indicate whether they get more benefits from using ecommerce in their business. The top five benefits for all respondents consisted of "cost reducing such as transaction fee and marketing", "increasing the profitability of the business", "enhancing market share of the business", "improving the business processes" and "consolidating customer services". With the adoption of e-commerce, SMEs do not have to spend a lot of money to rent stores, premises, a large number of staffs and storage. Especially for the exporting businesses, they can sit at home and search for customers online without spending a lot of time on "outbound" personal trips. In addition, regarding e-commerce, SMEs can market on a global scale at extremely low costs. With a remarkably small cost, SMEs can bring their advertising information from hundreds to millions of viewers from around the world. It is considered that e-commerce can be more effective for enterprises than the other methods. E-commerce's benefits can be considered as a key factor of increasing the enterprises' profits. With e-commerce, the customers of SMEs are now no longer limited geographically, or working time. SMEs not only sell in the local but also they can sell in Vietnam or other countries. Rather, enterprises do not need to wait the customers to find themselves

but they may actively seek customers through their e-commerce. Therefore, it is certain that the number of SMEs' customers will increase significantly, which leads to enrich the profits of companies. Furthermore, SMEs with lower expectations for other benefits to their business operations comprising "increasing brand name and business profile", "helping businesses reach customers more effectively", "strengthening and maintaining the trust of customers for the business", "improving the efficiency of production and business" and "developing the efficiency of working with suppliers". These were the indirect benefits of e-commerce that affect the SMEs' business results. Hence, SMEs should take full advantages of all e-commerce's benefits to make business operations better and sustainable development.

4.2 Barriers to Apply E-commerce of SMEs

Respondents were asked which factors represent barriers to e-commerce. The key barriers for all Vietnamese SMEs were "technical difficulties when using e-commerce websites", "who is responsible for the service and payment related to issues", "reliability of service use", "poor Internet service" and "barriers to information security and privacy of customers". "Technical difficulties when using e-commerce websites" was the most common barrier for almost all respondents. Although Vietnam has a rich resources of skilled people in this field, SMEs may feel their employees is not suitable for applying e-commerce. Moreover, many SMEs are newcomers so they do not have much technical experiences in implementing and applying e-commerce. Besides, SMEs are also afraid of other barriers when applying e-commerce in their production and business activities such as "who is responsible for the service and payment related to issues", "reliability of service use", "Internet service is not good" and "barriers to information security and privacy of customers". These are the common issues of e-commerce in Vietnam beyond the control of SMEs; therefore, the government needs to have solutions to ensure the safety, security in use and pay-

Tab. 2: Benefits from using e-commerce of SMEs in Vietnam

Benefits from e-commerce	Rank	Mean	Std. deviation
Cost reducing such as transaction fee and marketing	1	3.4700	0.71142
Increasing the profitability of the business	2	3.2160	0.74730
Enhancing market share of the business	3	3.2120	0.79770
Improving your business processes	4	3.1260	0.79207
Consolidating customer services	5	3.1180	0.80584
Increasing brand name and business profile	6	3.0680	0.69595
Helping businesses to reach customers more effectively	7	3.0540	0.85120
Strengthening and maintain the trust of customers for the business	8	3.0480	0.79180
Improving the efficiency of production and business	9	2.9800	0.79301
Developing the efficiency of working with suppliers	10	2.9320	0.79790

Note: The mean is the average on a scale of 1 = strongly disagree, 2 = disagree and 3 = neither agree nor disagree; 4 = agree, 5 = strongly agree; $N = 237$.

Tab. 3: Barriers to apply e-commerce of SMEs

Barriers to apply e-commerce of SMEs	Rank	Mean	Std. deviation
Technical difficulties when using e-commerce websites	1	3.2581	0.75608
Who is responsible for the service and payment related to issues	2	3.2389	0.75874
Reliability of service use	3	3.1996	0.83029
Internet service is not good	4	3.1951	0.75687
Barriers to information security and privacy of customers	5	3.1754	0.78075
Language difficulties	6	3.1179	0.75672
High user support cost	7	3.1120	0.78274
Lack of knowledge about e-commerce	8	3.0660	0.79430
Issues related to registration and certification	9	3.0285	0.75268
The cost of operating and maintaining the e-commerce system is higher than expectation	10	2.9490	0.79585

Note: The mean is the average on a scale of 1 = strongly disagree, 2 = disagree and 3 = neither agree nor disagree; 4 = agree, 5 = strongly agree; $N = 237$.

ment by e-commerce as well as upgrading the quality and service of the whole system. The results also suggested that SMEs faced other difficulties such as "language difficulties", "high user support cost", "lack of knowledge about e-commerce", "issues related to registration and certification" and "the cost of operating and maintaining the e-commerce system is higher than expectation".

5   DISCUSSION AND CONCLUSION

E-commerce can be stated as an effective way which far outweighs the traditional trade. Moreover, this technology can facilitate customers and distributors in business environment. Besides, e-commerce is both essential and useful tool to help sellers or managers to reach the client's requirement. In fact, regarding our research, e-commerce enhances the marketing share for the companies because it makes the clients quickly reach the products via companies' websites. It is more convenient that the clients can order the goods, pay online from anywhere at any time by their smartphone device (mobile phones, tablets, and laptops

or desktops) and reduce the time consuming to go shopping. It may enrich the profits in reducing the cost for marketing products on mass communications. Furthermore, the survey results of the e-commerce's impact towards SMEs showed that e-commerce is significant for Vietnamese employers during their business. Although this research indicated the effectiveness of e-commerce for SMEs, there are some barriers in applying it. Therefore, it is necessary for doing more research into the role of e-commerce which suppliers and customers can rely on. The researchers strongly believe that e- commerce will become more popular in the future in order to make more profit and help not only for SMEs but also for big organizations to access to global market and sustainable development.

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OVERVIEW OF WEB ANONYMIZATION

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ABSTRACT

Web anonymization tools have been used for a long time, primarily by the users afraid of possible undesirable consequences of their on-line activity on the web. The paper analyzes both historically proven anonymization tools like TOR and newer tools, namely JAP/JonDo and CyberGhost VPN that are based on slightly modified technological principles. The primary focus is given to the measurement and evaluation of the latency increase and the transmission speed decrease in comparison to normal (non-anonymized) web browser operation. Results show that all anonymization tools being subject of the analysis provide relatively moderate latency increase. On the opposite, the transmission speed decrease was more significant, especially for JonDo. This confirms the conclusions of previous studies resulting that no anonymization tool is suitable for daily web browsing. On the other hand, in the case when higher anonymity is required, their use can be reasonably comfortable from the point of view of latency increase. However, their usefulness for downloading larger files is always disputable.

KEY WORDS

world wide web, anonymization in communication, onion routing, cascade mix, TOR, JAP, JonDo, I2P, CyberGhost VPN, latency, transmission speed

JEL CODES

L86, A100

1   INTRODUCTION

World-wide web seems to be almost omni-present application service in present networks. Due to the fact that www service is used by a huge number of users – e.g. according to Statista.com (2017), there were almost 3.6 billion of Internet users in 2017 – usually on daily basis, not only the security of the communicated contents and resiliency against

breaches of various types (for details about current threats, see e.g. Zuzčák and Sochor, 2017) is an issue. There are situations when the client identification should not be disclosed to the server, too. This is because the client IP address is often closely related to the place of residence of workplace of the user. In situations when the user's activity does not follow the rules enforced in the specific state, they usually try to conceal their location. Such situations were not anticipated when the Internet (and its key protocol, namely Internet Protocol – IP) was designed. Thus, special tools that are able to "anonymize" the Internet communication are applied in such situations. In most cases, such tools concentrate on www traffic anonymization.

It should be emphasized here that the term "anonymization" means solely the anonymization for the sake of keeping the communication private (including, and primarily, the communication metadata, namely the identification of the parties hereof). This comment seems to be particularly important in the present context of ICT where the same term "anonymization" is more frequently used in the context of removing or hiding a part of data files (or their replacement with e.g. symbolic names – that should be called "pseudonymization"). This different meaning for "anonymization" increases its popularity because of recent increase of attacks against private data in various data stores and new rules aimed to prevent such attacks (e.g. GDPR).

Sometimes, anynomization is confused with encryption. However, encryption, which is widely available for www communication via https protocol (that is, in fact, just ordinary http protocol with encryption using SSL or TLS protocols added), cannot provide anonymity for a user. While the contents of the communication is encrypted and therefore (if implemented properly) unreadable for any third party, the sole fact of communication with a specific www server is not hidden using https. Therefore different tools have been designed to disguise even the IP addresses.

1.1 Anonymization Principles

To avoid the client's IP address disclosure, various tools for web anonymization have been developed. Virtually all of them focus on concealing the client's IP address because concealing the other, server side IP address seems infeasible due to the properties of addressing schemes used in the Internet (primarily DNS service). The basic principle of anonymization tools is illustrated in Fig. 1.

Among anonymization tools, The Onion Routing project (abbreviated as TOR) described in Dingledine et al. (2017) is one of the oldest and best-known ones. While the original idea behind TOR was to help people living in states with authoritative government, its availability also helped criminals to improve their ability to hide their activities from the police (Glenny, 2012). Some other tools have emerged later, namely I2P (see I2P, 2017) and JAP/JonDo (see JAP, 2017). Also, new approaches (namely the application of virtual private networks – or VPN) appear in anonymization tools that is demonstrated by CyberGhost VPN (for details see CyberGhost, 2017).

The anonymization techniques have been studied recently, both from the point of view of general properties of anonymity tools (e.g. in Bagai and Hu, 2016), and more specifically, from the point of view of the onion routing principle (Feigenbaum et al., 2012) and from the point of view of the efficiency of various anonymization tools (e.g. Liška et al., 2010; Sochor, 2012; Sochor, 2013; Kapusta, 2016).

All of the above mentioned anonymization tools are based on a certain type of usage of intermediate nodes where either cascading or encapsulation happen. Completely different approach is implemented in a newer tool called CyberGhost VPN where the anonymity is obtained by replacing a real client with the VPN server address. The latter approach seems to be constrained somehow by the fact that the VPN server (or servers) present a single point of failure and for its applications e.g. in countries where the majority of the Internet traffic is under governmental control it could be easier to block the traffic from the VPN servers'
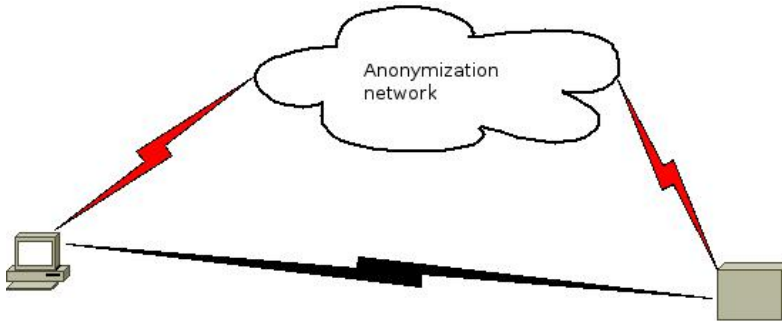
Fig. 1: Comparison of ordinary www traffic (lower part direct from the client to the http server) to the anonymized traffic (upper part when the traffic passes through the network of anonymization nodes)

IP addresses rendering the service useless. On the opposite, distributed tools relying on users' engagement (by providing their own resources to the cascade or onion network, e.g. TOR) is much more resilient in such a situation. CyberGhost VPN was added in the older set of tools to measure in order to investigate its efficiency and to compare with traditional tools. Nevertheless, the above mentioned weakness of this tool is a factor to consider in choosing the appropriate tool in the context of the network where it should be used.

The majority of the studies mentioned above focused on free tools, like TOR and I2P, and a free part of JAP/JonDo services. The prevailing approach was to examine the anonymization tool behavior from the users' perspective. This is the approach applied in this paper, too.

The contribution of the paper is the significant update of the findings obtained in older studies, whose part was initiated by the author hereof, as well as including newly emerged tools into the set of evaluated anonymization tools.

2   ANALYSIS OF ANONYMIZATION TOOLS

During the history of the internet usage, various anonymization techniques emerged. Some of them (e.g. using private GRE tunnels or later private VPNs) has not proven to be secure enough and they are not used any more (at least for anonymization) while others, more successful ones, have been implemented in various anonymization tools, both commercial and freely available. There is a technique used for anonymization for quite a long period that is called *onion routing*. This is implemented in the most traditional anonymization tool called The Onion Routing (abbreviated as TOR).

2.1   The Onion Routing – TOR

As mentioned above, TOR is the oldest and the most frequently used tools among anonymization ones. TOR operation is based on a list of available nodes throughout the world called

onion routers. Most of the onion routers are operated by TOR users. When sending a web request, a client automatically forms a way through 3 onion routers. On each of the onion routers, a cryptographic encapsulation is formed. The third (i.e. last) onion router decapsulates the http request and sends the request in a standard way to the target web server on behalf of the client.

No onion router in the network knows more that its direct predecessor and its direct successor. Moreover, thanks to the encryption, the intermediate onion router even cannot interfere into the payload of the packets being transmitted. This ensures the non-disclosure of the client's IP address. This procedure is called "onion routing" because of the subsequent encapsulation. As a result, every packet is "wrapped" in multiple layers of encapsulation thus resembling the onion bulb.

2.2 Invisible Internet Project – I2P

I2P approach to concealing the source IP address is so-called "garlic routing." This approach has been partly inspired by TOR's onion routing and tries to improve it. Garlic routing's improvement (in comparison with onion routing where the request is encrypted repeatedly layer-by-layer and those layers are removed on the way through onion nodes) consists in optional chaining of multiple requests inside a single encrypted layer. However, because of technical problems in long-term usage of I2P that made obtaining the complete set of measurement using I2P very difficult, I2P was finally not included in the set of anonymization tools to measure for this study.

2.3 JAP/JonDo

JonDo (sometimes called JonDonym, formerly JAP) has started as a free tool at the University of Dresned (Germany). It has been changed into partially paid service later but certain (limited) part of the service remained free of charge. JonDo operation is based on so-called cascade-mix. Cascade-mix is a special routing method differing from onion or garlic routing. In this case, a network of special nodes (called mixes) is formed and used. The JonDo client connects to the selected starting node in the cascade mix. Then, the client sends a packet (e.g. a web request) that is encrypted on the first mix-node and subsequently sent to another mix-node. The set of mix-nodes used for sending a single packet is called a cascade. Individual packets are sent through different cascades up to the target server. During transmission, packets can be intentionally delayed, or re-shuffled, in various cascades. Even the data from various clients using the same cascade could be merged to make the reverse decoding even more complex task this improving the anonymity.

2.4 CyberGhost VPN

CyberGhost VPN is a relatively new tool, it started in 2011. The basic available for free (after a free registration) while so-called premium service (offering higher speed) is commercial. The principle of the client's IP address anonymization is based on connection to the selected VPN server provided by the service (their number is claimed to exceed 1000) and subsequent communication passed by the server on behalf of the client. One of the main advantage CyberGhost VPN is its multiplatformness (the native client is available not only for Windows and MacOS but for mobile OS Android and iOS, too).

2.5 Special Operating Systems for Anonymity

In addition to specific application providing anonymity as described above, there are some specialized operating systems designed so that they support better integration of anonymization tools into the operating system services thus providing even better protection for users' anonymity. Most of such systems are built on various Linux distributions and two of them are briefly introduced in this subsection. Nevertheless, this subsection is included here rather to provide a complex overview. The operating systems described here were not incorporated into the anonymization efficiency measurements. The primary reason for this decision was the fact that both of them employs TOR system for anonymity that is already included in the measurements

2.5.1 Tails

Tails stands for the acronym of The Amnesic Incognito Live System[1]. This is, as indicated in its title, a "live" system whose very first emphasis is the users' privacy and anonymity protection. Tails is a free software based on Debian Linux. The system can be executed from a USB disk (either flash or hard drive), CD, DVD or SD card. The system can be run on virtually any PC. Thanks to the fact that this is a "live" system, there are almost no tracks

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[1]Tails is available at `https://tails.boum.org`.

remained on the PC disk after finishing its operation. Tails redirects all networks requests through TOR service that is described earlier. The operating system includes several applications supporting anonymous traffic, namely web browser, instant messaging client, e-mail client, office suite, sound and graphic editors and others.

2.5.2 Whonix

Whonix is also a GNU Debian/Linux-based operating system[2]. Unlike Tails, this is not a live system and therefore is cannot be executed from a removable medium. Its basic approach to anonymity is splitting the operating system into several (usually two) separate virtual machines (VM). The first VM is working part that is allowed to communicate exclusively through the second VM that is configured so that it communicates via TOR. Like Tails, Whonix includes a bunch of preinstalled applications for anonymous operations in the Internet.

3 WEB ANONYMIZATION EFFICIENCY EVALUATION

The main goal of the presented study was to verify and/or update older results that evaluated the efficiency of web anonymization tools as the latency increase and transmission speed decrease resulting from anonymization. As shown by previous measurements (Liška et al., 2010; Sochor, 2012; Sochor, 2013), the latency increase as well as transmission speed decrease were significant, sometimes much worse that by the factor of 10.

However, due to the fact that anonymity services develop and the bandwidth capacities of ordinary residential and SMB Internet connections increase (supposing that free anonymization services are primarily used by residential users while corporations tend to look for commercial solutions) as well, it is expected that the situation can change rapidly from the point of view of anonymization tools, too.

The proven approach applied in earlier papers consisting in repeated measurements of the anonymized web traffic using different tools and their comparison with the traffic to the same websites without anonymization is applied here, too. Nevertheless, a wider variety of web pages and files and higher number of measurements was used. Moreover, more detailed statistical assessment of measured data was performed here.

4 MEASUREMENT SETUP

The measurement setup design bore in mind the results of earlier measurements (mainly Sochor, 2013) that have demonstrated that the the anonymization requirements to local computing resources are low. Therefore, the decision was made to perform all measurements on an ordinary laptop (namely a PC laptop with Intel Pentium running at 1.5 GHz, 4 GB RAM running 64-bit Windows 10 Home operating system). The Internet connection has been facilitated using a Qualcomm Atheros WiFi interface supporting IEEE 802.11b/g/n communication modes.

4.1 Specification of the Internet Connection used for Measurements

All the measurements analyzed here have been performed in the end of 2016 on a small residential local network connected to the Internet via an Internet Service Provider using 2.4 GHz WiFi connection. There were no explicit limitations applied to the connection to the Internet, and a fixed public IP address was assigned to the client's router (NAT was used here, supposed having no influence to

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[2]Whonix is freely downloadable at `https://www.whonix.org`

Tab. 1: List of www pages for measurement

ID	Title (abbr.)	Size (kB)	IP address	Country	Pict.	CSS	Scr.
1	Stormware contacts	2946.1	217.198.115.210	CZ	18/1	3	7
2	Think Ostrava	1066.5	81.91.222.110	CZ	13/3	5	5
3	Fares – City transport Praha	511.84	194.228.3.208	CZ	35/13	4	8
4	Brno airport	3054.7	62.168.14.114	CZ	19/7	4	10
5	Facebook Log In	479.4	31.13.84.36	IRL	4/84	8	2
6	Who we are	UNICEF	412.76	23.64.15.26	NL	24/10	12	15
7	BBC – Local – BBC Local	1119.6	212.58.246.80	UK	6/172	10	18
8	About Us – LEGO.com	2421.0	171.20.53.203	DK	13/0	0	5
9	Google	344.51	216.58.201.227	USA	3/0	0	0
10	NHL Hockey Tickets	329.12	104.90.155.82	USA	76/0	3	1
11	Ebay Online Customer Service	219.05	66.135.223.16	USA	2/26	5	5
12	Official Apple Support	2983.9	104.90.164.244	USA	10/25	4	17
13	AirAsia	Check-In	618.1	54.169.4.245	SGP	5/0	4	4
14	Univ. of Tokyo	2180.2	210.152.135.178	JP	15/95	7	3
15	TOYOTA EAST JAPAN	449.83	203.211.201.139	JP	13/0	0	3
16	A.I.Corp.	Embed. Software	436.35	153.122.124.217	JP	77/26	2	5
17	Africa Universities	2079.1	41.203.16.58	SA	9/41	1	12
18	Lagos University	129.43	195.45.48.50	NGA	40/2	2	1
19	About Us	106.44	164.97.249.110	AUS	3/31	1	2
20	Austral. animals	Perth Zoo	3303.5	119.252.89.140	AUS	30/9	12	36

Tab. 2: URL of www pages for measurement

ID	URL
1	http://www.stormware.cz/kontakty/
2	http://thinkostrava.cz/cs/
3	http://www.dpp.cz/jizdne-na-uzemi-prahy/
4	http://www.brno-airport.cz/sluzby-na-letisti/mapa-terminalu/
5	ttps://www.facebook.com/
6	http://www.unicef.org/about/
7	http://news.bbc.co.uk/local/hi/default.stm
8	http://www.lego.com/en-us/aboutus
9	https://www.google.cz/
10	https://www.nhl.com/tickets
11	http://ocsnext.ebay.com/ocs/home?
12	http://www.apple.com/support/
13	https://checkin.airasia.com/
14	http://www.u-tokyo.ac.jp/en/about/history.html
15	http://www.toyota-ej.co.jp/index_top.html
16	http://www.aicp.co.jp/
17	http://africauniversities.org/
18	http://www.unilag.edu.ng/pages.php?page=contact-details
19	https://www.border.gov.au/about
20	http://perthzoo.wa.gov.au/animals-plants/australia

the connection performance). The averaged measured downstream speed was 42 Mbps and 9 Mbps for upstream while ISP's declared parameters were 100/10 Mbps.

4.2 Objects Selected for Measurements

The measurements were performed using two custom-made sets, the first one composed of 20 www pages, and the other set was composed of 8 Windows executable files accessible via http protocol.

4.2.1 WWW pages

Web pages for testing have been selected so that only pages with fixed file size (i.e. pages with unfrequent changes). The exact page size was measured using the Web Page Analyzer tool (version 0.98)[3] providing detailed statistics about the web page components (number, type, size, download time etc.).

Among a broader set of such www pages, a subset was selected so that a wide geographical spread (from the point of view of server location) is obtained. As one can see in the Tab. 1, server from all five continents were incorporated in the selection. The geographic location of servers was determined using Flagfox plug-in to Mozilla Firefox (version 5.1.8). The final set of 20 web pages is listed in Tab. 1. As one can see,

four servers were located in the US, another four together in Africa and Australia, four in Asia, four in Europe excluding the Czech Republic and the remaining four in the Czech Republic. Also the number of pictures (headed by "Pict."), style files (CSS) and scripts ("Scr." heading) are displayed. URL information about all www pages is listed in the following Tab. 2.

Before the measurements has started, all pages were tested for correct download and displaying. The results of testing was almost faultless. More specifically, both JAP and CyberGhost displayed all pages correctly, while TOR did not display the single page from Australia (`http://www.seek.com.au/`) that was subsequently replaced and it is not listed in the Tab. 1 and 2.

4.2.2 WWW Files

Files used for testing the download speed were chosen almost randomly but files available from web (http) distributing servers with throttling the download speed for intentional transmissions were excluded. All selected files are freely available Windows executables (*.EXE) without any explicit download speed limit. Downloading was tested in all anonymization tools before commencing the measurements, and the test result was 100% positive. The final selection of 8 files is listed in the Tab. 3.

5   MEASUREMENT METHODOLOGY

Before every measurement start, all other applications communicating with the Internet (which could potentially distort the measurement results) were stopped. In addition, common applications running on ordinary computers, which could affect the computer performance (e.g. checking for updates), were stopped. All measurements were done using web browser Mozilla Firefox 44.0.2. The web browser cache was emptied before measurements and their use during measurement was disabled in order to avoid measurement distortion.

5.1 Measurement of Web Page Latency and Download Speed

The latency of web page download (here, the round-trip time – or both-sided latency) is defined as the time difference between sending the first byte of the web request, and the reception of the first byte of the response. The latency was measured using the Performance-Analyzer 1.1.6.1 plugin. This plugin measures both the www page total loading time and the loading times of individual www page items.

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[3]Available at `http://www.websiteoptimization.com/services/analyze/` for free.

Tab. 3: List of files for measurement

ID	File name	Size [MB]	IP address	Country
1	NetBeans IDE 8.1	214.02	137.254.56.26	USA
2	WireShark 2.0.2	45.33	104.25.10.6	USA
3	PSPad 4.6.0	3.98	81.0.235.28	Czech Rep.
4	ThunderBird 38.6.0	32.4	104.16.40.2	USA
5	Avast 11.1.2253	4.97	104.90.180.145	USA
6	Zoner Photostudio 18	66.1	217.198.122.22	Czech Rep.
7	BS.Player 2.70	10.06	212.18.44.40	Slovenia
8	Gimp 2.8.2	24.3	209.132.180.179	USA

Tab. 4: Files for measurement – URLs

ID	URL
1	`http://download.netbeans.org/netbeans/8.1/final/bundles/netbeans-8.1-windows.exe`
2	`https://1.eu.dl.wireshark.org/win64/Wireshark-win64-2.0.2.exe`
3	`http://pspad.poradna.net/release/pspad460inst_cz.exe`
4	`http://download.cdn.mozilla.net/pub/thunderbird/releases/38.6.0/win32/cs/Thunderbird\%20Setup%2038.6.0.exe`
5	`http://files.avast.com/iavs9x/avast_free_antivirus_setup_online.exe`
6	`https://www.zoner.cz/download/stazeni-souboru.aspx`
7	`http://download3.bsplayer.com/download/file/mirror1/bsplayer270.setup.exe`
8	`http://saimei.acc.umu.se/pub/gimp/gimp/help/windows/2.8/2.8.2/gimp-help-2-2.8.2-en-setup.exe`

In addition, the plugin produced graphical processing of results as well.

The two-sided latency (RTT) was expressed as Time To First Byte (TTFB) value measured in the plugin, i.e. time from sending the request till the first byte of response arrival to the web browser. The transmission speed was calculated as a ratio of the total size of the web page divided by the cumulative time of the web page download.

5.2 Measuring File Download

Measurements of file download times were performed using Download Status Bar 13.4.4.2 plugin into Firefox. This plugin can measure both current and average transmission speed, download total time, file size, etc.

6 MEASUREMENT RESULTS

Both for web pages and files, the four anonymization modes were measured.

- No anonymization,

- Anonymization using TOR
  (in default configuration),

- Anonymization using CyberGhost VPN,

- Anonymization using Jap/Jondo.

6.1 Results of Web Page Anonymization

Measurements of anonymization of web pages were performed in 10 measurement for every web page in the web page set as listed above. Each measurement was performed in every of four anynomization modes listed below (in fact, three modes using different anonymization tool, and one mode without anonymization). This totals in 40 (4 modes, 10 measurements)

Tab. 5: Latency and transmission speed averaged values and standard deviations for web page download

Anonymiz. mode	Lat. [ms]	Incr. [%]	Std. dev.	Speed [kbps]	Drop [%]	Std. dev.
No anonymization	488		128	5,471		783
CyberGhost VPN	777	59%	208	2,536	54%	285
TOR	788	61%	256	2,888	47%	421
JonDo	702	44%	141	2,793	49%	221

values of both latency and download time (later converted to download speed) were measured for every single web page in the set. Each single measurement started from the same web page displayed in the web browser.

The results were averaged (10 measurements) and the standard deviation was calculated as well. The summary results for web pages download (for both latency and transmission speed) are listed in Tab. 5. In addition to the measured results, the ratios of latency increase and transmission speed are displayed in order to get a better overview of how anonymization worsens the parameters of www communication. The results are used for the overall comparison of the measured results to older measurements as described in Section 6.3.

6.2   Results of File Download Anonymization

The file download was measured in 5 sets, i.e 20 values was measure for every single file in the set described above in Tab. 3. Again, the download always started from the www browser home page. The summarized results (averages and standard deviations) for file download are listed in Tab. 6.

Tab. 6: Transmission speed averaged values for file download

Anonymization mode	Speed [kbps]	Speed drop [%]	Std. dev.
No anonymization	40.29		2.54
CyberGhost VPN	13.14	67%	1.46
TOR	15.15	62%	1.27
JonDo	2.843	93%	1.26

Like in the case of www pages, the file download speeds are listed together with speed drop percentages and standard deviations.

6.3   Comparison with Previous Results

The measured results roughly conform to the previous results cited above. According to Sochor (2012), the latency increase factor for TOR was 3.1 while 2.2 for JAP. The present measurements demonstrated that the latency increase is still significant but the increase ratii are significantly lower, just around 1.5 as shown by the "Incr." column in the Tab. 5. This difference was partly caused by the use of a broader range of ages for measurement (among the measured pages, there are specific cases where the latency increase factor is significantly bigger than 2, still), and partly because of the overall decresase of latency in www service due to the increased bandwidth.

Regarding the transmission speed decrease, it was almost 40% for TOR and 2% for JAP for web pages while 5% for TOR and 20% for JAP for file download according to the previous study. As one can see from the current results in Tab. 5 and 6 above, the present results in transmission speed decrease seem to be much worse that they used to be in the past. However, when looking to results closely, it is obvious that the greater differences are observed for newer anonymization tools like JonDo and CyberGhost. On the other hand, the measured results for TOR remained rather similar (37% decrease in 2012 and 47% in 2016). More significant differences for JonDo could be cause by the fact that the "free" part of JonDo service was tested and it is not documented whether the parameters of this free services have remained the same since 2012. The significant worsening seem to indicate that the transmission speed could be intentionally throttled by the JonDo network operators in order to maximize the difference between the free and commercial service.

7   DISCUSSION AND CONCLUSIONS

The results of measurements shown above confirm the main conclusions of previous works as declared in the introduction, i.e. all the anonymization tools subject to the measurement caused a significant latency decrease and transmission speed increase. Therefore, it cannot be recommended to use anonymous web browsers for a daily use unless special circumstances justify doing so, especially for downloading bigger amounts of data (that is almost inevitable in the present web where the average sizes of ordinary pages increase quite rapidly).

On the other hand, the latency increase is relatively favorable for using the anonymous web browsing, especially to smaller web pages. Downloading bigger files using anonymous web browsing can be quite lengthy, nevertheless.

Bearing in mind the fact that situation among anonymization tools changes quite rapidly, it seems reasonable to perform more detailed investigation in this field. There are some other reasons for that, primarily the fact that the transmission speed decrease measured here is bigger that it used to be earlier.

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SOURCE CODE PLAGIARISM DETECTION FOR PHP LANGUAGE

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ABSTRACT

This paper introduces a system for detection of plagiarism in source codes written in the PHP computer language, part of the plagiarism detection tool Anton. We used the greedy string tiling algorithm together with tokenization and hash calculation. The efficiency of the system was tested on both an artificial dataset and on real data coming from a course taught at our university. Our results are compared with other similar systems and solutions, concluding that Anton can detect all examined types of plagiarism with higher accuracy than other systems.

KEY WORDS

source-code plagiarism, anti-plagiarism system, PHP, Anton

JEL CODES

C88, I23

1   INTRODUCTION

Since 1990s, academic integrity has become a central preoccupation for all stakeholders in higher education (Bretag, 2015). In earlier stages of this period, universities focused mainly on plagiarism. Even as the scope has become broader, plagiarism remains one of the most important academic integrity issues appearing in student assignments undertaken individually or in groups, without direct supervision. In the digital era, massive amounts of information are available to reuse for anyone struggling with an assignment who is tempted to plagiarise (Flores et al., 2011).

Student writers are typically advised to build on the ideas of the authors they have read and to incorporate the material in one of three ways: paraphrase, summary or quotation (Jamieson, 2015). In programming assignments, of course students should make use of the work of the others as well. However, the methods for doing so are completely different. Students are advised to use standard libraries and standard

algorithms. On the other hand, these algorithms are often required to be coded by students and not simply downloaded from the internet.

Parker and Hamblen (1989, p. 94) define plagiarism in source code, namely a plagiarised program, as: "a program which has been produced from another program with a small number of routine transformations". The definition differs from "standard" definition of plagiarism, where the fact that someone else's work is presented as author's own is substantial. Unlike natural text, source code has its given precise structure with many possibilities of small changes (the above mentioned routine transformations) which may – without actual knowledge of what the source code is about – change the text completely and hide any plagiarism.

There are several common ways of changing source code in order to hide plagiarism (Clough, 2000). Joy and Luck (1999) distinguish two basic types: lexical changes and structural changes. Mirza and Joy (2015) enumerate following categories of changes: in comments, in identifiers, in declarations, added (extra) content of different kind, changes in the structure of selection statements, and in decision logic.

Joy et al. (2011) investigated students' plagiarism in source codes, focusing on understanding and reasons through a survey performed on 18 universities in United Kingdom. Their findings suggest that even if 94% of the students participating in the survey understand that copying the source code from somewhere else is plagiarism, they fail to understand other types of plagiarism such as self-plagiarism, collusion with peers or conversion of the code from different programming language.

In natural text, not every similarity can be considered plagiarism and not every plagiarism can be considered as an academic integrity breach (Bretag, 2015). Analogically, not every similarity in source code constitutes plagia-rism. Krpec (2015) enumerates some legitimate causes of similarities: properly referenced third-party source code, automatically generated code, commonly used identifiers, commonly known algorithms. For these reasons, simple text based comparison tools that do not consider the special features of source code are likely to produce many false positives while failing to detect plagiarism that has been intentionally obfuscated.

The system discussed in this paper is called Anton, which is an abbreviation of "anti-plagiarism online", and was originally developed at Faculty of Business and Economics, Mendel University in Brno (MENDELU), Czech Republic as a university's own solution for detecting similarities in natural text documents, namely final theses (Foltýnek et al., 2009). It was used as an integral part of University Information System (UIS, `https://is.mendelu.cz`) for checking final theses from 2009 to 2014. In 2014 it was replaced by the Czech national system "Theses" (`www.theses.cz`). In 2015 Anton was re-launched as a standalone online tool (at `https://anton.mendelu.cz`) mainly for experimental purpose including its further development and growth (Všianský and Dlabolová, 2016). In 2017 new functionality for detection similarities in PHP source codes was added to the system (Všianský, 2017). The examination of this functionality and its efficiency will be discussed in this paper.

The PHP language was chosen as the one that would be implemented in Anton as the language that is used in teaching of different computer science courses at MENDELU – primarily in the course 'Application Software Programes' (ASP). In this course students write their projects in this language, so there was a need for teachers to be able to check the projects and find possible instances of plagiarism or copying from colleagues (Všianský, 2017).

2   THEORETICAL FRAMEWORK

Literature and researchers describe multiple approaches for detecting similarities or plagiarism in source codes. The approaches can be divided in two main groups – feature comparison and structure comparison (Prechelt et al., 2000; Arwin and Tahaghoghi, 2006). Feature comparison is based on a certain software metric (e.g. number of comment lines or number of some particular kind of tokens), structure comparison is based on the similarity of the structure of the investigated source codes – source codes are parsed to tokens and the tokens are compared (Arwin and Tahaghoghi, 2006). Another approach which can help to recognize plagiarism in source codes and also to identify the author of the source code is analysis of the coding style (Mirza and Joy, 2015).

Detailed comparison of systems for the detection of plagiarism in source codes can be found e.g. in (Lancaster and Culwin, 2004). In the following paragraphs, selected systems which enable users to compare (at least partly or roughly) source codes written in the PHP language are briefly described.

The MOSS system (Measure of Software Similarity) supports several programming languages, some of which are related to PHP, but does not support PHP. It uses structural comparisons, namely the so-called winnowing method described in the paper "Winnowing" (Schleimer et al., 2003). It is free for non-commercial use as a web service (MOSS, 2017) and it belongs among popular tools (Lancaster and Culwin, 2004).

JPlag is another program that supports several programming languages and text in natural language, but also excludes PHP. It uses structure comparison, it is offered for free (until recent time as a free web service), and is licensed under GNU General Public License (jPlag, 2017; Prechelt et al., 2000). Its main advantages are reliability and support of the main programming languages, which make it one of the most popular tools both among teachers of programming at MENDELU and among experts (Lancaster and Culwin, 2004).

Sherlock is an open source system developed at University of Warwick that checks similarities in source-codes (procedural and object-oriented languages with optimizations for Java) and in text in natural language (Joy, 2014). The system itself does not have a graphical user interface (GUI, see Sherlock, 2017), but it is incorporated in the University of Warwick's online submission system BOSS, which provides it the GUI (Joy, 2014). It uses its own algorithm for structure comparison. According to the authors, the accuracy of the results is comparable with other systems, but Sherlock provides the results in significantly shorter time (Joy and Luck, 1999; Mozgovoy et al., 2005).

Checksims is an open source system developed at Worcester Polytechnic Institute. According to Lauer (2015) and Checksims (2015) it was under active development until 2015. It is not constrained for use over a specific language or group of languages. It works with any programming language, the primary algorithm used for the detection of similarities is Smith-Waterman algorithm. The authors compared Checksims with MOSS and claim that the system has the same success as MOSS within large collections of source codes and that it was even more successful with small collections (Heon and Murvihill, 2015).

The PHP plagiarism recognizer implemented at the Faculty of Information technologies, Brno University of Technology uses Halstead metrics and the Levenshtein algorithm applied to JSON object for first check. Suspicious pairs are then examined more carefully by document fingerprint using the winnowing algorithm and an abstract syntax tree comparison using Sasha's algorithm. Details about the results are not provided, authors just admit that their "results are not totally accurate every time yet" and rely on users' judgement (Krpec, 2015).

Moussiades and Vakali (2005) describe their solution named PDetect which is mainly intended for bulk processing of source codes and searches groups (clusters) of similar parts of source code. The system was tested on C++, but its authors claim that keywords for

any programming language can be added for adaptation to any programming language.

Cross-language plagiarism detection is discussed in paper "Towards the detection of cross-language source code reuse" (Flores et al., 2011) whose authors found that methods applied for natural text (specifically n-gram comparison) work for Java, C and Python too. The other method might be comparison of an intermediate code produced by a special compiler suite. This method is in fact a monolingual comparison, but depends on existence of compilers for different languages producing comparable intermediate code (Arwin and Tahaghoghi, 2006).

3 METHODOLOGY AND DATA

Before the implementation of the new module, an analysis of the current university solution and requirements for a new solution was performed. Lecturers in the course ASP used only a text-based recognition in jPlag. This solution does not support PHP language natively, hence it is inappropriate to be used for recognition of similarities in PHP source codes.

In its initial phase the Anton system used only text-based methods to detect similarities in documents of different text formats. Using this method, documents are processed through four phases. First, the documents are converted to plain text. This means that all information which does not constitute the content itself is deleted. The second phase reduces the text further, e.g. deleting all words shorter than three characters, stop words, numbers, etc. The third phase makes hashes from the remaining words and lastly, in the fourth phase the system compares all hashes and calculates the final results (Floryček, 2015).

For comparison of PHP source codes and source codes in general, text-based methods are unsuitable. As it was mentioned earlier, there are many transformations of a source code which could lead to a different text form. These transformations can be made easily (e.g. to change names of variables, add comments, swap cycles, etc). Text based methods cannot detect these transformations. Therefore, methods developed specifically for source code plagiarism detection need to be used.

The *Greedy string tiling* algorithm (Prechelt et al., 2000) with tokenization (Murao and Ohno, 2010) can be used to compare PHP source codes in the system Anton (Všianský, 2017), which is briefly described below. Firstly,

the source code is transformed to a sequence of tokens with tokens being the smallest semantic element of a source code (Shao, 2015). These tokens, then, represent a structure of the document. PHP includes its own tokenizer, which can be used via function *token_get_all* (The PHP Group, 2017) which transforms the code to a sequence of numbers. In addition, the function can record also content of the tokens and their position in the document (Všianský, 2017).

The sequences of tokens are compared by *Greedy string tiling* in the next step. This algorithm, which is also used in jPlag, firstly takes the sequences from a document containing source code (document A) and compares them to sequences from the second document (document B). If they match, the another pair is compared. All results are recorded and all matched tokens are marked, which means they don't have to be compared anymore.

If the pair does not match, the system continues and compares all other possible combinations of both documents. All matches must meet the minimum threshold and specified length, otherwise the match is not recorded. A longer length provides more accurate results, but it can neglect smaller changes in documents. The length also depends on the structure of the programming language and purpose of the document. With more complex projects and documents, the length can be increased. For purpose of this study the length of seven tokens has been chosen as most appropriate to students in beginner 'Application Software Programes' classes, because students in beginner classes tend to use less complicated codes.
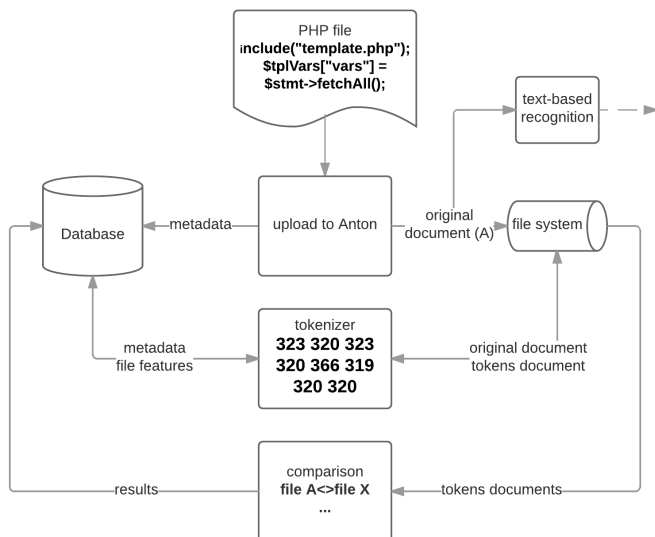
Fig. 1: Processing of a file with source in Anton

GREEDY STRING TILING IN ANTON

Takes the first unmarked token from the shorter document

Compares it with the first unmarked token from the other document

If they matches, it compares the next pair
Otherwise if the match is longer than a minimum length, it marks matched tokens

the match is marked/not marked (because of rules)

Takes next unmarked token from the first document and another unmarked token from the second document

all unmarked tokens combination are compared

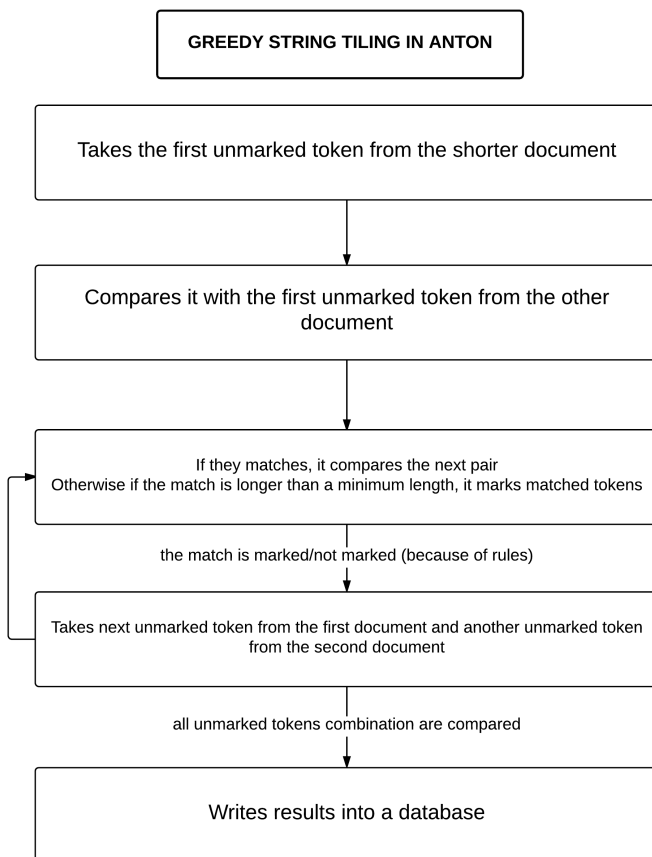Writes results into a database

Fig. 2: Greedy String Algorithm in Anton

For comparison of source code, the text-based method is also used. However, it only compares all strings from the document (Všianský, 2017). In this manner, a user can recognize similarities among names of functions, etc. E.g. if a student just translates the names to a different natural language, like translated Czech names of functions to English, it is recognizable, as the structure and meaning are visibly the same. Some basic features of the document are recorded too. In the current iteration, the system saves counts of lines, strings, tokens, comments and whitespaces but this list can be adjusted in the future to include many different characteristics that can point to a specific writing style of particular student.

For implementation of the system, PHP language was used. The main reason was the availability of the above-mentioned native PHP tokenizer and the fact that the rest of the system Anton is written in PHP as well.

The module for detection of similarities in PHP source codes was implemented as a part of the current Anton system available online. Before uploading a file, users select whether they intend to work with natural language texts or with the source codes.

The implementation is divided into several parts. The first part is a decoder. In this part, all new uploaded documents are inserted into a function, which creates tokens from the documents and inserts them into a new file on the file system. This function called getTokensPHP uses a parser file. This file is another part of the implementation, it contains the tokenizer of PHP and it produces results in a correct format. The format is designed specifically to contain all tokens information in one array in a given order. A developer can add a new parser of a different language using a new function containing a tokenizer of the language with the appropriate output.

The last part is the comparison. The system compares all not-compared documents from one course directory (defined before uploading documents) with each other. The function 'stringTiling' is used, unmarking all tokens in both documents, i.e. leaving all tokens are marked with a number zero. Then, according to the algorithm, all unmarked tokens are tested and if they match, they are marked (with number one). This function is using the minimal length of non-overlapping matches (the threshold) which was set previously. The results are saved in the database.

The current MySQL database was used to record the results. One of the most important tables is *tokens_pos*, which records a position of a token sequence across two documents with lengths and line position specifically according to each document. Data stored in this table then allows Anton to show similarities in graphical form. Percentages of similarities are stored in two separate tables. One of them contains a similarity ratio from the point of view of one particular document; the second one contains similarity of two documents. The second index shows similarity emphasizing common length, whereas the first result could be distorted by different lengths.

Our test data were acquired in two different ways. The first dataset consists of a set of real students' works in a course "Application Software Programmes" (ASP), where students learn basics of PHP language taught by members of the Faculty of Business and Economics, MENDELU. Overall, 66 files of student projects were collected. From all these files, the segments written in other languages such as CSS and HTML were removed. These data were chosen because the projects have been written in clear form of PHP without use of any frameworks or libraries.

The second dataset consisted of 7 files was created specifically for testing the system. Each of the created files represented a different method of source code plagiarism:

- The first file was a basic file with a solution for the task of creating a profile page of a user obtained from the author's university project which was elaborated in ASP, (the same project as in the first dataset).
- The second file was a modified version of the first one with changed identifiers and added comments.
- The third file was made of 50% of the first file with the second half composed of a file originating from a completely different

project. This procedure was chosen because the file should be structured as a normal PHP file code. Only the first half should be matched with other files in comparison.

- The fourth file was a new file with no connection to the previous files.

- The fifth was a combination of the third and the fourth file.

- The sixth file was the same as the first one with swapped halves.

- The last file was a file containing solution of the same task but had been created by another student.

By using these different types of files, files it was possible to determine how well the system was able to handle different phenomena including changing identifiers, packaging functions, replacing parts of a code, adding and deleting comments. It was also possible to observe the results of situations in which two projects from different students working on the same task are combined.

4   RESULTS

The similarity detection module in Anton is in the first place intended for teachers of basics of programming in the PHP language, who expect their students to submit individual assignments. Having tens of the source code documents with the solutions from the students, the user (teacher) wants to be sure that the students did not copy from each other. After uploading all the assignments, Anton reports the similarities among the documents. Since the PHP language has quite limited vocabulary, the teacher with regards to complexity of the assignments expects some natural matches among the documents, nevertheless the matches which are above the expected threshold (e.g. above 25%) are suspicious. Anton enables visualisation of the matches in the suspicious documents (example can be seen at the Figure 3) to help the teacher to decide whether the match is plagiarism or not. The final decision about plagiarism is up to the teacher; anyway the aim of Anton is to provide the teacher the best possible support.

The first round of testing of problem solutions was performed on the artificial data prepared specially for this purpose which are described above. The results are displayed in Tab. 1. This table shows the expected results based on the previous knowledge of the particular data and the results provided by Anton.

The results showed promise for the utility of the system. They did not contain any false-negative results (i.e. all similarities were revealed).

The test case A shows that the system is resistant to one of the most prevalent form of plagiarism – renaming variables and identifiers, or adding comments. The system also identified the identical parts of the code as it is visible from the test results B–E. From the graphical representation of the matches, it can be seen that the system correctly identified the same parts. This proves that the system is resistant to swapping larger parts of codes. The resistance to swapping smaller pieces of code depends on the settings of the minimal length of match (i.e. number of tokens), which needs to be set carefully because low threshold would cause reporting of coincidental matches. The coincidental matches – i.e. false-positive results are visible in the cases F and G. There were similarities discovered even in source codes which were not supposed to be similar at all. The reason for this is the simplicity of the PHP dictionary and the tokenizer which incorporates only limited amount of types of tokens. Dictionaries of all programming languages are less complex than those of natural languages: programmers use only a few keywords whereas natural languages have thousands of words). Source codes can contain different functions and variables with the same structure. While PHP source codes can contain different functions and variables within the same structure, the functions appear identical to the tokenizer, which does not take
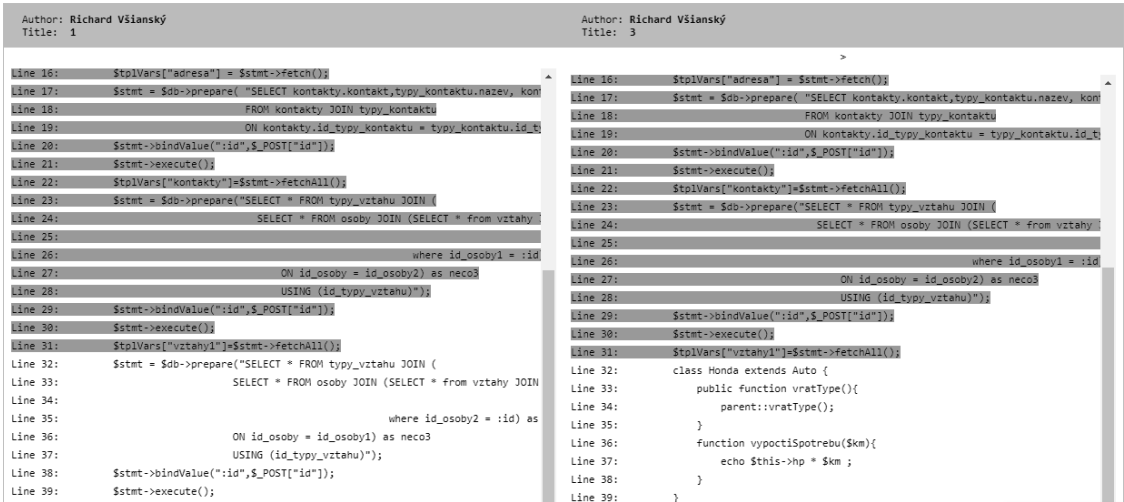
Fig. 3: Example of a screen with a result of comparison of two documents

Tab. 1: Test results over artificial test data

Test case	The compared file	Same data	Expected match	Real match	Modification
A	1	2	100%	100.00%	Identifiers, functions and variables were changed, extra comments
B	1	3	50%	59.40%	Identical half
C	5	3	50%	49.20%	Identical half
D	5	4	50%	69.80%	Identical half
E	1	6	100%	100.00%	Switched halves of the code
F	7	1, 2	Two different files	55.24%	Coincidental similarity in two works on the same assignment
G	4	1, 2, 7	0%	20.62% 20.62% 17.01%	Two different files

into account the effect of context. In this case, the user must take care to define a minimum match length that will exclude most false positive results, while retaining sufficient accuracy to find significant similarities. In the future, Anton could be used with more complicated languages where it would have greater accuracy. Better functionality could also be achieved by developing a tokenizer with the ability to recognize context (e.g. it could divide functions according their return types, position etc.). These are issues for further development.

In terms of the dataset of the 'Application Software Programmes' course, the results are less meaningful, because they cannot be compared to expected outcomes. However, a few observations can be noted. The module can find and identify 100% plagiarism, whereas currently used jPlag finds only 96% similarity across same files. This difference is caused by configuration of jPlag, which examines words only with some minimal length, to allow for the fact that many files have a high degree of similarity because students are using same learned functions, algorithms and techniques. This allowance is also made because in this course, the codes are not very complex, as students have just started to learn how to write a PHP code. Users should take care to set appropriate thresholds for recognition and observe all similarities personally to decide what size words may, when duplicated, constitute plagiarism. The graphical overview of similarities should make this decision easier.

Users can see which parts of the code match with which part from the other document, they can also see the results of comparison (percentage of similarity). The system also shows the text-based similarities between files' strings for better understanding of the code contents (see Fig. 3).

5 DISCUSSION

The issue of searching for plagiarism in source code is often discussed in the academic environment, where educators must address possible academic integrity breaches of their students. A variety of systems are available for revealing similarities in source codes with MOSS and jPlag among the most popular among specialists over the world (MOSS, 2017; jPlag, 2017; Lancaster and Culwin, 2004), but they do not support all programming languages (e.g. the PHP, which is needed in the programming courses at Mendel University in Brno) and do not meet the needs of all teacher. For this reason, many educational institutions develop their own solutions – University of Warwick's system, Sherlock (Joy, 2014); Worcester Polytechnic Institute's system, Checksims (Heon and Murvihill, 2015); Brno University of Technology's system, (Krpec, 2015); and MENDELU's system Anton which is discussed in this paper.

Anton was tested on two sets of test data. One set consists of artificial data made directly for the testing purpose. Results were satisfactory – the system detected all similarities, however there were a significant number of false-positive matches caused mainly by the nature of the testing data and of the PHP language itself. The high match in the case F depicted in the Tab. 1 was also caused by the fact that the tested source codes were school assignments – the assignment was the same for both source code, it was rather uncomplicated and both authors used similar approach that they learned at school.

This is certainly an issue for further development as 20% rate of false positives would discourage teachers from using the system. Because the system was designed primarily to detect deliberately obfuscated plagiarism a high false positive ratio is predictable. Moreover,

false positives are more likely in programming language than in a natural language due to limited vocabulary and due to general recommendation to reuse source code. For example, in PHP, there are only 135 possible tokens which naturally lead to false positives. This can be addressed by using a filter set to hide matches below 20, 25 or even 30 per cent so user is not confused. On the other hand, small changes remain undetected, which should not be critical problem. Setting the correct threshold will be considered as soon as the system is used more widely.

The other set of data tested here are 'real' data from students – a set of 66 assignments from a course taught at MENDELU. Anton provided better results using these data than jPlag which had been used for the examination of the assignments. Since the jPlag is not appropriate for the PHP language, it did not reveal all matches.

In our opinion Anton's user interface is also more user-friendly than jPlag, also Anton's visualisation of the resulting matches provides more information. JPlag highlights the matches in the source codes, Anton also depicts text similarities in the names of the functions and a table of properties, which serve as additional information for the user to support him in the decision whether the matches are plagiarism or not.

As for the comparison with other systems mentioned earlier in this work – the widely popular system MOSS is available only as an online service and a Linux script needs to be used for the submission (MOSS, 2017). The Sherlock system provides the results of the matches only in plain text form. The system's output is a list of pairs of filenames and the percentage value of their match. There is no information about which particular part of the source code

caused the match (Sherlock, 2017). Also, the system Checksims operates only in a command line and does not have any graphical user interface. According to available information the system PDetect seems not being developed after year 2005 (Moussiades and Vakali, 2005). According to Krpec (2015) their solution from Brno University of Technology does not always provide accurate results. Hence none of these systems fully meets the requirements and needs of the educators at MENDELU.

In the current state Anton enables to work with the files only separately, it does not support any bulk operation, which might be considered as a drawback for its use as a tool for examination of school assignments. Hence for now, the system has been tested by several individual teachers. All teachers at the department will be encouraged to use it as soon as the batch upload of files is available. The implementation of the batch operations is currently under development and it should be ready for usage during the spring semester of the academic year 2017/2018 when the course ASP is being taught and when the anti-plagiarism system in this course will be needed. Hence the teachers will be able use the system comfortably for examination of the projects without any limitations.

6   CONCLUSIONS

This paper deals with the system Anton and its extension for detection of similarities in PHP source codes. The principle of searching for similarities in source codes in Anton is based on tokenisation (using a PHP native tokenizer) and the tokens are compared, using the Greedy string tiling algorithm. The reported matches are reported according to the setting of minimal threshold (i.e. the minimum number of matching tokens). For the purpose of this study, the threshold was set to seven.

When used to evaluate samples in the PHP language, Anton provides more accurate results then jPlag. The results are depicted in the graphical form where matches are highlighted and also further information on the source code's similarities are provided to the user.

The topics for future development include enabling bulk operations and accuracy improvement of the thresholds so the system so as to reduce false-positive results.

Anton's specialization on PHP language can be seen as a limitation, but other languages can be added easily by addition of the appropriate tokenizers. One main goal of future development is to recognize similarities across programming languages. When it becomes possible to convert tokens from different programming languages into comparable tokens, we will then gain the significant advantage of being able to discover source codes which were rewritten from one programming language to another.

7   ACKNOWLEDGEMENTS

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SYSTEM MODELLING AND DECISION MAKING SYSTEM BASED ON FUZZY EXPERT SYSTEM

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ABSTRACT

They are available many modeling and decision making systems. Some of them are based on statistical methods like time series analysis. The general problem of these systems is that they cannot correctly react to the changes of modeled systems and their environment. This paper presents an approach based on the fuzzy expert system application, which is able to represent the expert knowledge about the modeled system behavior. This approach combines the statistical methods with expert knowledge and is able to give appropriate information about the system behavior and help with the decision making process. The presented paper describes general principles of this system and its application for waste production modeling as a part of the decision making of the company for waste treatment. This company is able to optimize its resources and warehouse stock management to minimize the production costs.

KEY WORDS

modeling, decision making, time series, expert system, fuzzy logic, analysis, optimization, prediction

JEL CODES

C53, C63, Q53

1 INTRODUCTION

Actually, a lot of companies have tried to optimize their systems of warehouse stock management to minimize their production costs. The optimization means mainly optimization of processes like resources adjustment, resources planning, purchasing, deliveries, sales etc. The main goal is clear – not to spend too much money for stock and optimally use their resources. There are various information systems more or less successfully anticipating and predicting the quantity of resources that should be ordered.

There are generally used different approaches to the sales prediction and thereby the production planning (Brown, 2000; Swift, 2001). These can be equalized on statistical methods, especially the analysis of time series, but in practice we often come across with very simple approaches that are very robust at the same time, such as the method of moving average. Our approach is based on the use of fuzzy logic expert systems (Novák, 1995; Pokorný, 1996). Experts systems, in particular using fuzzy logic are in this area used by a number of authors for different applications (Xu et al., 2010; Zhang et al., 2004; Zhang and Liu, 2005). The applications of artificial neural networks (Vaisla et al., 2010; Vaisla and Bhatt, 2010) or

tools of soft computing are also very interesting. As advantage of Rule-Based Expert Systems is a particular opportunity to use the knowledge of experts and their simple expressions by rules. Fuzzy logic then helps us especially with easy expression of dependences among the values which is poorly expressed using crisp values. Practical use of the expert system is the general trend of the observed value (Baker and Canessa, 2015). It shows that in such cases it is appropriate to analyze the general trend using methods based on time series analysis (Jemelka et al., 2015). An expert system will be used to identify the additional value and description of the dynamic system behavior. This approach is described in this paper.

2 TIME SERIES ANALYSIS

An example of the application of an expert system for prediction of waste production in local area (CSU Prague, 2014) of the city of Ostrava is shown. We have waste production data for each of the weeks in the year 2016 (OZO Ostrava, 2016), split into two parts. We have used the data for odd pairs of weeks to determine the knowledge base. The remaining data, then we have used to verify the behavior of the expert system compared to the prediction based on the moving average method.

The first step is to find out the general trends for all waste groups (paper, plastic, and mixed waste). The standard optimization method of least squares will be used to identify the major trends. We will use discrete time kT, where the time period is $T = $ pair of weeks, $k = 0, 1, 2, \ldots$ for the independent axis. After deduction of major trends we obtain data for the expert system.

3 FUZZY EXPERT SYSTEM DESIGN

The first task is to determine the parameters of the rule-based fuzzy expert system. From previous works, we have already known that the more parameters affecting the waste production we can describe, the more accurate the prediction is, see for example Farana et al. (2017). Thus, as the parameters we set the waste production of individual waste types in the previous two weeks and some known parameters influencing the waste production positively (special event) or negatively (holidays). For the realization of the expert system, we will use the Linguistic Fuzzy Logic Controller (LFLC; see Novák,

1995), which is very convenient for practical applications.

LFLC is the result of the formal theory application of the fuzzy logic in broader sense (FLb). The fundamental concepts of FLb are evaluative linguistic expressions and linguistic description. Evaluative (linguistic) expressions are natural language expressions such as high, medium, deep, about thirty-one, roughly one thousand, very long, more or less deep, not very tall, roughly cold or medium warm, roughly strong, roughly medium important, and many others. They form a small – but very important

– constituent of the natural language since we use them in common sense speech to be able to evaluate phenomena around. Evaluative expressions have an important role in our life because they help us determine our decisions; help us in learning and understanding, and in many other activities. Simple evaluative linguistic expressions (possibly with signs) have a general form:

$$\langle \text{linguistic modifier} \rangle \; \langle \text{TE-adjective} \rangle, \quad (1)$$

where ⟨TE-adjective⟩ is one of the adjectives (also called gradable) small (sm), medium (me), big (bi) or zero (ze), the ⟨linguistic modifier⟩ is an intensifying adverb such as extremely (ex), significantly (si), very (ve), rather (ra), more or less (ml), roughly (ro), quite roughly (qr), very roughly (vr).

A very important feature is the possibility of setting the context of individual variables and use the assembled knowledge base for a different range of values, see Fig. 1.

This set of linguistic expressions has been drawn up on the basis of the experience of the experts, but it does not always suit the particular situation. The frequency of each value shows that most of the values are concentrated in the middle of the interval, which covers little linguistic expressions, so when compiling a system of rules for the expert system, there have often appeared the same values (ze). LFLC tool offers the possibility of user-set assembly of evaluative linguistic expressions that will better respond to the current situation.

Now we are able to set-up knowledge base describing the standardized system behavior based on previous values and identified parameters. For technical reasons, input and output values must be shifted so that we work with positive numbers only. Thus we have the system ready for subsequent modification of contexts according to the major trend.

Below, examples of the IF-THEN rules of the expert system are presented:

```
IF(SEASON IS SUMMER) AND
(PAPER_PREV IS HIGH) AND
(HOLIDAY IS SMALL) AND
(EVENT IS VERY HIGH) THEN
(PAPER IS MEDIUM)

IF(SEASON IS SUMMER) AND
(PLASTIC_PREV IS HIGH) AND
(HOLIDAY IS SMALL) AND
(EVENT IS VERY HIGH) THEN
(PLASTIC IS VERY HIGH)
```

4   EXPERT SYSTEM VERIFICATION

As already stated, the set of rules has been drawn up on the basis of waste production data from the year 2016. Data for odd pairs of weeks has been used for expert system learning, data for even pair of weeks was used for expert system verification. We can see that compared to the moving average (of the four previous values), the expert system reaches an average quarter a deviation from the true value. There is mainly involved in knowledge about the influence of different parameters on the system behavior, which were stored in the knowledge base.

5   CONCLUSION

The paper has introduced a very advantageous combination of conventional methods known from the data series analysis, which enabled to identify the main development trend of the system. The follow-up expert system made it possible to describe the influence of various parameters on the final output value of the system and therefore achieved very good estimates of the system further development. This approach was validated with real data from the local territory waste production and showed the correctness of the presented methodology.
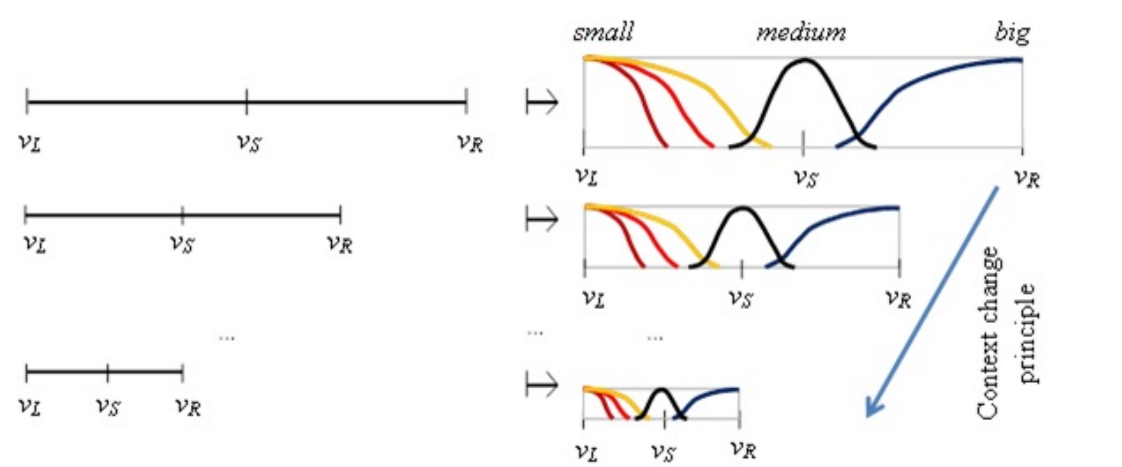
Fig. 1: A general scheme of intension of evaluative expressions (extremely small, very small, small, medium, big) as a function assigning to each context a specific fuzzy set (Novak, 1995) and the automatic context change principle

Tab. 1: Comparison of prediction results – moving averages

Week	Real data				Moving average			Moving average		
	Total	Paper	Plastic	Mixed	Paper	Plastic	Mixed	Paper	Plastic	Mixed
6	3769.6	140.7	269.9	3359.0	170.9	305.2	4291.4	17.7%	11.6%	21.7%
8	3805.4	145.2	286.4	3373.8	178.6	326.9	4339.6	18.7%	12.4%	22.3%
10	3605.3	140.6	277.2	3187.5	183.99	356.8	4428.0	23.6%	22.3%	28.0%
12	3541.3	134.86	258.3	3148.1	189.53	375.1	4341.6	28.8%	31.1%	27.5%
14	3406.3	145.11	267.68	2993.54	189.18	369.3	4220.6	23.3%	27.5%	29.1%
16	3635.06	144.32	280.36	3210.38	189.76	364.3	4131.9	23.9%	23.0%	22.3%
18	3711.76	160.77	283.3	3267.66	193.75	365.5	4174.8	17.0%	22.5%	21.7%
20	3655.59	158.51	275.5	3221.6	201.04	372.9	4300.4	21.2%	26.1%	25.1%
22	3780.5	155.81	273.5	3351.23	208.4	375.66	4335.4	25.2%	27.2%	22.7%
24	3807.26	166.75	286.5	3353.98	205.99	371.6	4416.3	19.0%	22.9%	24.1%
26	3798.4	216.6	249.7	3332.0	211.6	373.2	4445.4	-2.4%	33.1%	25.0%

Tab. 2: Comparison of prediction results – LFLC expert system

Week	Real data				Fuzzy-expert system			Fuzzy-expert system		
	Total	Paper	Plastic	Mixed	Paper	Plastic	Mixed	Paper	Plastic	Mixed
6	3769.6	140.7	269.9	3359.0	145	270	3400	3.0%	0.1%	1.2%
8	3805.4	145.2	286.4	3373.8	150	290	3400	3.2%	1.2%	0.8%
10	3605.3	140.6	277.2	3187.5	145	280	3200	3.1%	1.0%	0.4%
12	3541.3	134.86	258.3	3148.1	130	260	3200	-3.7%	0.6%	1.6%
14	3406.3	145.11	267.68	2993.54	145	260	3000	-0.1%	-3.0%	0.2%
16	3635.06	144.32	280.36	3210.38	145	280	3200	0.5%	-0.1%	-0.3%
18	3711.76	160.77	283.3	3267.66	160	280	3300	-0.5%	-1.2%	1.0%
20	3655.59	158.51	275.5	3221.6	160	270	3200	0.9%	-2.0%	-0.7%
22	3780.5	155.81	273.5	3351.23	155	270	3400	-0.5%	-1.3%	1.4%
24	3807.26	166.75	286.5	3353.98	170	280	3400	1.9%	-2.3%	1.4%
26	3798.4	216.6	249.7	3332.0	230	260	3400	5.8%	4.0%	2.0%

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DECISION MAKING
ON VARIOUS APPROACHES
TO IMPORTANCE-PERFORMANCE
ANALYSIS (IPA)

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ABSTRACT

The purpose of this paper is to compare several approaches to Importance-Performance Analysis (IPA) and show how different criteria can be used for dividing the IPA matrix to decision-making fields. The authors performed the IPA analysis basing on the data collected in customer satisfaction survey in health care sector. The survey was conducted from January to April 2016 in selected dentist's surgeries in cities Żywiec and Bielsko-Biała (southern Poland). Over 200 questionnaires were distributed, 100 of them returned. The study may facilitate the selection of appropriate form of matrix used in customer satisfaction surveys. It may be useful in future studies on adequate approach to IPA analysis. The paper is based on unpublished, own study.

KEY WORDS

customer research, customer satisfaction, customer satisfaction survey, Importance-Performance Analysis, IPA

JEL CODES

M300, I110

1   INTRODUCTION

1.1 Importance-Performance Analysis (IPA)

IPA is a tool that is easily applicable in marketing research. It helps to indicate main factors, attributes of product or service which require an immediate response (improvement). Furthermore the visualization of data can clearly show areas of concern and facilitate changes.

The IPA analysis was introduced by Martilla and James (1977). Since then IPA has been applied to a diverse range of context including various branches, among them: automotive (Meng and Yun, 2016), food (Tzeng and Chang, 2011), health care (Yavas and Shemwell,

2001; Olbrych and Łopyta, 2011; Gajewska and Piskrzyńska, 2016), tourism (Guadagnolo, 1985; Haahti and Yavas, 2004), educations (Biesok and Wyród-Wróbel, 2015; Kitcharoen, 2004), banking (Joseph et al., 2005).

The classic form of IPA, proposed by Martilla and James (1977), recognizes satisfaction as the function of two components: the importance of the product or service to the client and the performance of business in providing that service or product.

The means of importance and performance rating are placed on the Cartesian diagram in which one axis represents importance of selected attributes and the other one shows the product's/service's performance in relation to these attributes. This graphic interpretation of the IPA is called an Importance-Performance matrix or grid. The matrix is divided into four quadrants (2×2). Each quadrant suggests a different marketing strategy, recommendation for the attribute. Fig. 1 illustrates the classic IPA matrix.

The four quadrants in IPA are characterized as (Martilla and James, 1977; Silva and Fernandes, 2011):

A. Keep up with the good work – high importance, high performance: attributes placed here indicate opportunities for achieving or maintaining competitive advantage and are major strengths.
B. Concentrate here – high importance, low performance: these attributes require immediate attention for improvement and are major weaknesses.
C. Low priority – low importance, low performance: these attributes are minor weaknesses and do not require additional effort.
D. Possible overkill – low importance, high performance: these attributes indicate that business resources committed to them would be overkill and should be deployed elsewhere.

The organization should focus their attention on those attributes for which importance is high and performance is low. If the organization is able to improve on these attributes they represent the largest potential gains (Eskildsen and Kristensen, 2006).

1.2 Alternative Approaches to the Analysis

Despite of simplicity IPA analysis several different approaches to inferring priorities and measuring importance have emerged in the literature (e.g. Oh, 2001; Bacon, 2003; Fuchs and Weiermair, 2003; Abalo et al., 2007; Biesok and Wyród-Wróbel, 2015). Usually modifications rest on different division of the matrix. For example Abalo et al. (2007) proposed such solution: the main matrix was divided by diagonal line (45-degree line, also called iso-line) into two equal parts (the new area occupies the whole of the zone below the priority line). The quarter below the diagonal line is an area that requires special attention. In relation to the criteria contained in this part of the graph improvement actions should be introduced (Fig. 2a). The interpretation of the areas above the diagonal line is the same as in the original Martilla and James (1977) diagram.

For comparison, Biesok and Wyród-Wróbel (2015) used other convention. The data for the analyses were gathered in survey on satisfaction of students of management at the University of Bielsko-Biala. In conclusion of the study, the authors proposed applying 6 decision fields (Fig. 2b):

- Field A1 – keep up the good work.
- Field A2 – warning: good work, but worsening of these factors implicates immediate improvement because it can affect on customer satisfaction in a large extent.
- Field C1 – factors of low priority with which you do not have to deal.
- Field C2 – factors that can be improved in some time horizon.
- Fields B and D have the same meaning as in classical IPA matrix.
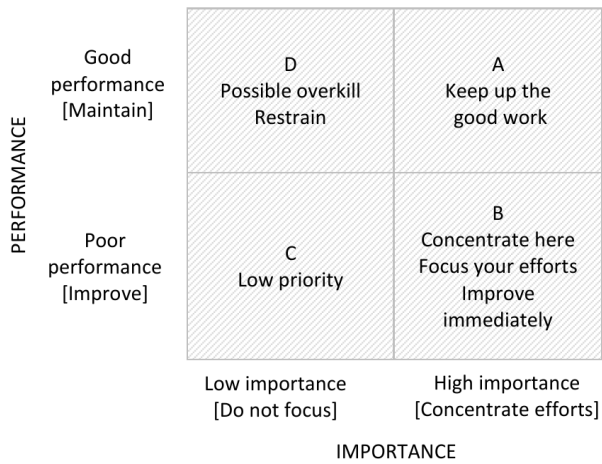
Fig. 1: The IPA matrix – adapted from Martilla and James (1977).
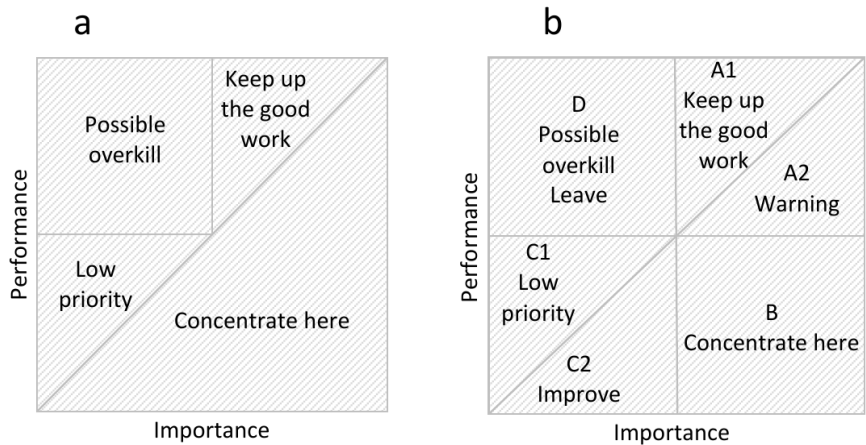
Fig. 2: Modifications of the IPA matrix – (a) Abalo et al. (2007); (b) Biesok and Wyród-Wróbel (2015), adapted from Martilla and James (1977), Bacon (2003).

2   METHODOLOGY AND DATA

2.1   Research Instrument

Various approaches to IPA analysis was tested using data gathered in the survey on customer satisfaction of dental surgeries in Żywiec and Bielsko-Biała (Silesian Voivodship, Poland). The survey was performed from January to April 2016.

The questionnaire for this study included four main sections. The first section included questions connected with dental service and among them the question about overall satisfaction

of the dental service. The second section of the questionnaire contained 15 dental service attributes which were identified basing on a focus group discussions.

In the survey, the respondent was asked to evaluate importance and the performance of these attributes. For evaluating the attributes 5-point scale was used, ranging from 1 – not important at all, very bad (performance) to 5 – very important, very good performance.

The other sections of the questionnaire included questions about loyalty, expectations and recommendations.

2.2   The Sampling Method

Data was collected using a paper questionnaire that was available in selected dental surgeries. Patients could take a part in the survey voluntarily, filling the questionnaire. There were no age or other limitations for participation in the study. Over 200 questionnaires were distributed and 100 valid questionnaires were received, so the response rate reached nearly 50%.

2.3   Data Analysis

The data was analysed in two variants:

- classical – the IPA matrix was constructed using mean performance and importance rating taken from the survey,
- in the second variant the importance measures was estimated using linear regression.

The second variant is part of a broader problem: how to perform the analysis without data about the importance of the attributes, for example in case of using survey data in which respondents were not asked about the importance of quality attributes. In the literature you can find various proposals of the solution of the problem: with using multiple regression coefficients (e.g. Matzler and Sauerwein, 2002) or linear correlation coefficients (e.g. Biesok and Wyród-Wróbel, 2015).

In this case we used another approach. The measures of the attributes importance was estimated using single linear regression. We assumed that overall satisfaction rating (SAT) expressed by respondents in the survey is linear and related to every studied attribute. The relation among them can be shown as a such linear equation:

$$\text{SAT} = I_i P_i + b_i, \tag{1}$$

where: SAT – overall satisfaction rating expressed by respondents, P_i – performance rating of $i = 1 - 15$ attributes expressed by respondents, I_i – linear regression coefficient, b_i – linear regression intercept.

Then we calculated linear regression coefficients $I_1 - I_{15}$ between overall satisfaction rating (SAT) and ratings of every attribute performance. These coefficients were used for analysis as measures of importance of the attributes.

In both variants the matrix was divided into four decision fields in the "centre of gravity" of the importance and performance rating and cut in half with priority-line (iso-line). Then the attributes were classified into decision fields, using following approaches:

- simple – based only on priority line (iso-line),
- classical 4-field,
- 6-field, proposed by Biesok and Wyród-Wróbel (2015).

At the end we compared the results of the analysis and showed both the similarities and differences and different approaches witch influenced conditions for decision making, based on the IPA analysis.

3   RESULTS

In the first variant of the study, we performed IPA analysis in a classical way. Lines dividing the matrix were lead in the relative middle ("centre of gravity" of the attributes) with additional 45-degree iso-line. The classical IPA matrix is shown on the Fig. 3.

Tab. 1 shows the results of IPA analysis in the first variant. All three decision criteria are consistent only in one case: attribute A5 and

suggest focusing attention on the prices in the office.

The approach based on priority line (iso-line) causes the biggest differences in the assessment of attributes. It gives only dichotomous response (concentrate or leave) and its recommendations stand out from other approaches.

In the case of analysed survey, the classical division of the IPA matrix gives to

Fig. 3: Classical IPA matrix. Attribute A6 (Acceptability of credit cards) is over the range because of its low importance.

Tab. 1: Classical IPA analysis results and decisions about attributes

Attribute		I	P	Priority line criterion	4-field criterion	6-field criterion
A1	Time you wait for appointment	4.25	3.98	Concentrate	Low prio.	Improve
A2	Interior decoration of the waiting room	3.75	4.21	Leave	Low prio.	Low prio.
A3	Waiting room equipment	3.75	4.20	Leave	Low prio.	Low prio.
A4	Contact with a patient	4.48	4.57	Leave	Keep up	Keep up
A5	Prices of treatments	4.67	4.39	Concentrate	Concentrate	Concentrate
A6	Acceptability of credit cards	3.23	3.39	Leave	Low prio.	Low prio.
A7	Doctor's surgery equipment	4.38	4.42	Leave	Leave	Leave
A8	Interior decoration of the doctor's surgery	4.07	4.39	Leave	Low prio.	Low prio.
A9	Quality of treatments	4.78	4.50	Concentrate	Keep up	Warning
A10	Modernity of tools and treatments	4.73	4.55	Concentrate	Keep up	Warning
A11	Tidiness	4.85	4.70	Concentrate	Keep up	Warning
A12	The attitude to the patient	4.83	4.77	Concentrate	Keep up	Warning
A13	The reputation of the office	4.50	4.53	Leave	Keep up	Keep up
A14	Customer service quality	4.83	4.68	Concentrate	Keep up	Warning
A15	The competence of the staff	4.84	4.74	Concentrate	Keep up	Warning

many attributes recommendation "keep up", so therefore it may seem that respondents are satisfied with them. Here 6-field approach is more accurate because most of these attributes have the recommendation "warning", which means that despite the good reception by the respondents, we should pay attention to them, because their worsening can have a significant impact on the perception of the service and customer satisfaction.

In the second variant of the study, IPA analysis was performed with a regression-derived importance values. Fig. 4 and Tab. 2 show the results of IPA analysis with obtained regression coefficients (I-r) in function of importance measure. Additionally their statistical significance at level 0.05 is marked with an asterisk (*). The lines dividing the matrix were lead in the same way, as in the preceding variant.

This variant used different importance values, so the matrix structure was rebuilt. Although it does not differ considerably from the classic IPA matrix. We can notice a greater compatibility between 4-field and 6-field approaches. The attributes A2, A7, A10, A8, A13 have the same recommendations, regardless of the used criterion. The disadvantage of this result, limiting the possibility of proper conclusions, is that not all that received the regression coefficients are statistically significant (statistically different from zero).

As already stated, in presented case, the matrix obtained by estimating the importance measures does not differ much from the classical matrix IPA. Tab. 3 shows the results of these analyses and recommendations obtained in both variants with 6-field criterion used.

4   DISCUSSION AND CONCLUSIONS

In classic way, importance of attributes in the IPA analysis is rated consciously by the respondents. In contrast, importance measures estimated with the statistical methods can be considered as an importance expressed indirectly. Matzler and Sauerwein (2002) call those two importance measures as the explicit and implicit importance.

The importance of the attributes rated by the respondents is different from the statistically derived ones. It can be assumed that the importance of attributes will correlate with overall assessment of satisfaction (very important attributes should have a strong impact on overall satisfaction score). However, it is not like this attribute having significant statistical influence on overall satisfaction may not always be rated by the respondent as the most important.

Our short study also showed, that a change in approach to IPA analysis, implies taking various decisions. All of these approaches are equal and literature or studies do not indicate any of them as a model. Oh (2001) says explicitly that one of the IPA limitations is the lack of framework

for this method. Therefore various approaches to IPA may provide contradictory results.

The main limitation of our study is the selection of the sample. The sample was rather small and its random nature may cause that the sample is unrepresentative. The second limitation of the study may also be a branch where we performed our survey. Dental surgeries are expected to be a specific type of services and our results cannot be directly generalized to other commercial services. The third limitation is that not all received regression coefficients are statistically significant, which limits the possibility of proper conclusion in the second variant of our study.

Future research should test and compare various variants of the analysis, especially in other branches. Researchers should also look for other, more effective methods of importance measurement. This will facilitate future research (the respondent would not have to asses twice the same list of attributes) and will give an opportunity to provide the IPA analyses using data, where respondents did not rated the importance of attributes.

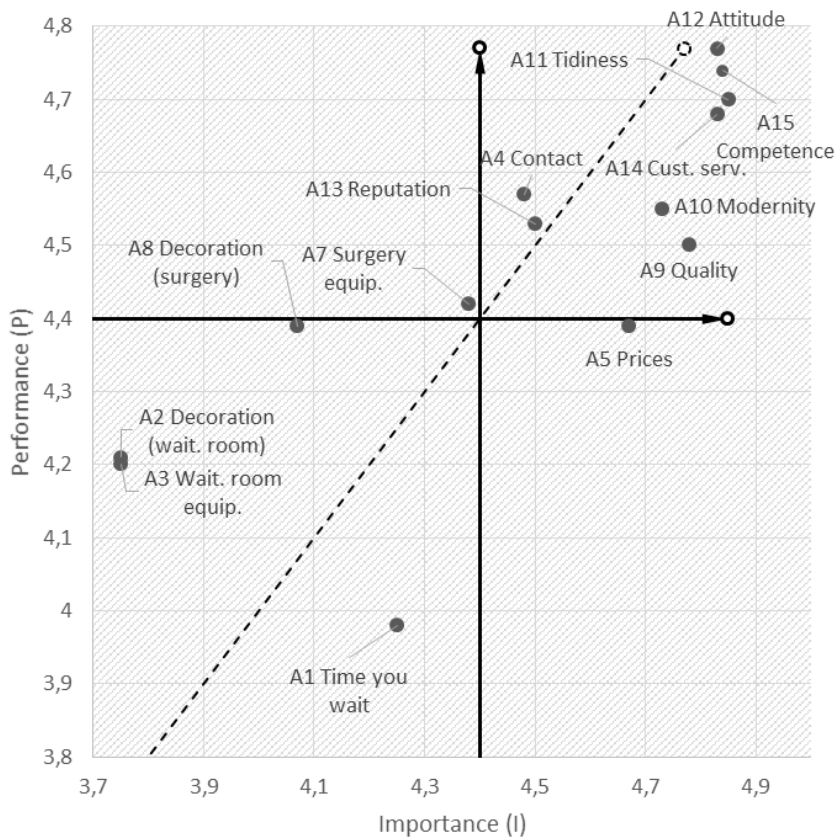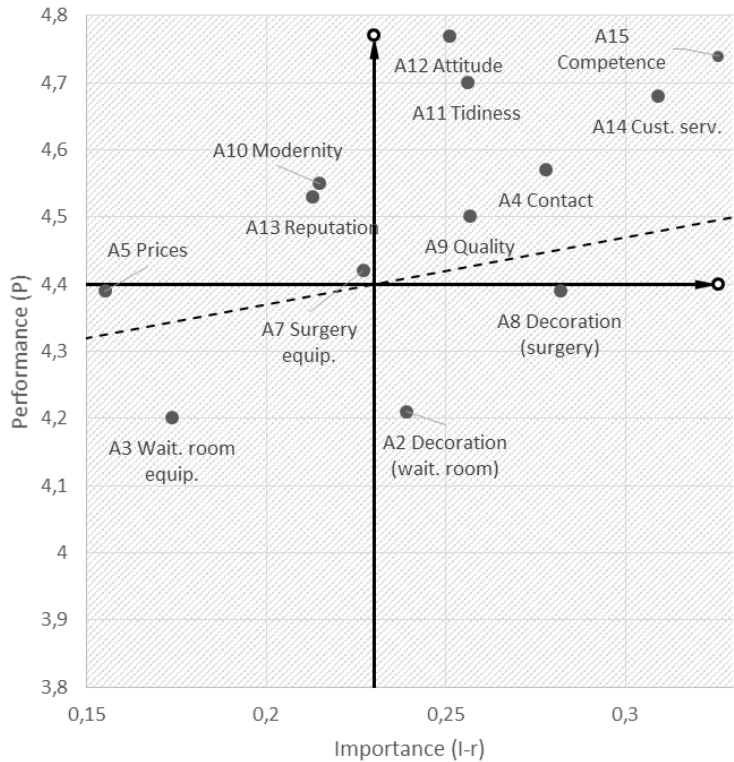Fig. 4: IPA matrix with a regression-derived importance values. Attribute A6 (Acceptability of credit cards) is over the range because of its low importance.

Tab. 2: IPA analysis with a regression-derived importance measure and decisions about attributes

Attribute		I-r	P	Priority line criterion	4-field criterion	6-field criterion
A1	Time you wait for appointment	0.140	3.98	Concentrate	Low prio.	Improve
A2	Interior decoration of the waiting room	0.239*	4.21	Concentrate	Concentrate	Concentrate
A3	Waiting room equipment	0.174*	4.20	Concentrate	Low prio.	Improve
A4	Contact with a patient	0.278*	4.57	Leave	Keep up	Keep up
A5	Prices of treatments	0.155	4.39	Leave	Low prio.	Low prio.
A6	Acceptability of credit cards	0.055	3.39	Concentrate	Low prio.	Improve
A7	Doctor's surgery equipment	0.227*	4.42	Leave	Leave	Leave
A8	Interior decoration of the doctor's surgery	0.282	4.39	Concentrate	Concentrate	Concentrate
A9	Quality of treatments	0.257*	4.50	Leave	Keep up	Keep up
A10	Modernity of tools and treatments	0.215*	4.55	Leave	Leave	Leave
A11	Tidiness	0.256*	4.70	Leave	Keep up	Keep up
A12	The attitude to the patient	0.251	4.77	Leave	Keep up	Keep up
A13	The reputation of the office	0.213*	4.53	Leave	Leave	Leave
A14	Customer service quality	0.309*	4.68	Leave	Keep up	Keep up
A15	The competence of the staff	0.326*	4.74	Leave	Keep up	Keep up

Note: Statistically significant at level 0.05 (*) or non-significant.

Tab. 3: Results and recommendations of IPA analysis in classic variant (I) and with importance measures estimated using linear regression (I-r)

Attribute		I	I-r	Recommendation
A1	Time you wait for appointment	Improve	Improve	The same
A2	Interior decoration of the waiting room	Low prio.	Concentrate	Different
A3	Waiting room equipment	Low prio.	Improve	Similar
A4	Contact with a patient	Keep up	Keep up	Similar
A5	Prices of treatments	Concentrate	Low prio.	Similar
A6	Acceptability of credit cards	Low prio	Improve	Similar
A7	Doctor's surgery equipment	Leave	Leave	The same
A8	Interior decoration of the doctor's surgery	Low prio.	Concentrate	Similar
A9	Quality of treatments	Warning	Keep up	Similar
A10	Modernity of tools and treatments	Warning	Leave	Different
A11	Tidiness	Warning	Keep up	Similar
A12	The attitude to the patient	Warning	Keep up	Similar
A13	The reputation of the office	Keep up	Leave	Different
A14	Customer service quality	Warning	Keep up	Similar
A15	The competence of the staff	Warning	Keep up	Similar

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AFFECTS CORPORATE TAXATION ECONOMIC GROWTH? – DYNAMIC APPROACH FOR OECD COUNTRIES

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ABSTRACT

This contribution deals with issues of corporate taxation in relation with economic growth. Its main objective is to quantify and analyse the relation of corporate taxation and economic growth using of OECD countries. The corporate tax rate is approximated by effective corporate tax rates such as corporate tax quota, marginal effective and average tax rates as determined by micro-forward looking approach and the alternative approach World Tax Index. The relation of taxation and economic growth is verified using an econometric model based on panel regression methods and tests using a dynamic panel. The model has shown a negative impact on economic growth for all six of the selected corporate tax approximators under the assumed significant level. A quantitatively higher negative impact has been verified in the case of labour taxation.

KEY WORDS

corporate taxation, economic growth, growth models, dynamic panel, effective tax rate, OECD

JEL CODES

C50, H20, H25, O47

1   INTRODUCTION

The global economy experienced sharp growth followed by a decrease caused by the economic (financial) crisis in the last decade. The national economic policy-makers try to handle its consequences until now. Currently, individual countries face mainly debt issues, which were especially caused by fiscal policy, over indebtedness of the private sector and a decrease in economic activity. The crucial question is – how to set up fiscal systems in a way that would support economic growth and simultaneously follow the budget discipline with focus on decreasing current budget deficits?

The existence of the public sector requires the immediate need for tax collection, but until now the issue of optimal taxation and composition

of tax mix remains in the hands of individual countries. The consolidation of public budgets is realized mainly on the income side (tax policy). The main reason is the high portion of mandatory expenditures on all government expenditure. This leads to the limitation of active expenditure economic policy. The effort to find the optimal level of taxation appears to be inevitable. The above mentioned must also be realized with respect to the dynamic side of economy. Taxation needs to be set up in a way that governments are able to fulfil their targets without any deformation of the economy. Systems, which are correctly set up, can lead to the optimal source of allocation and to higher economic growth.

From a global point of view the possibility of adequate tax system approximation sources for following economic analysis and the conclusion about usage of convenient tax rates can provide a basis for the next studies. The possibility to compare tax systems and their implementation provides, clearly, a new view on the tax system as a whole. The tax system, which also includes taxation of corporations, also presents part of economic policy of the country and the choice of correct indicator of tax burden enables a suitable evaluation of economic environment of the country. Corporate tax is mainly related to capital.

Capital is considered to be a highly mobile factor of productivity. It is necessary to carefully consider individual taxation systems as those are usually very complex and to allocate the capital to the country with the most convenient tax system. The taxation of the corporations influences not only revenues, but also the distribution of the profit. At the same time, capital (physical capital) is the elementary source of economic growth; hence taxation of corporations has an intermediate impact both on capital accumulation and economic growth. The remaining question is how to correctly approximate taxation so that the final

indicator would reflect the economic reality in the best possible way.

The studies which focus on the taxation and economic growth usually use different variables approximating tax burden (tax quota, implicit tax rate). This approach reflects the elementary tax burden but it basically represents the share of the tax revenues to the basic value. It also omits the dynamics of the economic process as it uses only cross sectional data and therefore can lead to a biased conclusion. The presented paper utilizes not only the above mentioned variables (tax quota, implicit tax rate) but also effective marginal and average tax rates. The paper also uses the World Tax Index. All variables are incorporated by dynamic panel regression.

Taxation, on the one hand, presents a burden on economic subjects, on the other hand it also represents significant income for government expenditures.

Studies focusing on taxation and economic growth very often neglect the complexity of the tax systems. Denaux (2007) or Izák (2011) note that it is very important to include government expenditures to the models analysing impact of taxation to the economic growth as they represent one of the aspects of the taxation. With regard to the modern approach to taxation and economic growth (e.g. Kotlán and Machová, 2014a) it is suitable to also include other fiscal variables – other kinds of taxation. Then the evaluation of the tax to the economic growth can be considered as complex.

The aim of the paper is to evaluate the relation between corporate taxation and economic growth. We expect to confirm the negative impact of corporate taxation on economic growth on the sample of OECD member countries. The analysis is based on the neoclassical growth model extended by the human capital. The model also takes into consideration all the main types of taxation and government expenditures.

2   THE IMPACT OF TAXATION ON ECONOMIC GROWTH – CURRENT STATE OF KNOWLEDGE

There are many factors which impact the speed and size of economic growth. These can include climate, education, property rights, savings, access to ports etc. Generally the sources of economic growth can be divided into human and capital. As Frait and Červenka (2002) state, human sources are characterised by the growth of labour productivity and an increase in work effort. Similarly, this situation is valid for the capital which is influenced by the stock of real capital and the technical level of capital goods. Accumulation of those determinants is derived from the motivation of individuals to save and invest which then leads to the changes of economic growth.

The relation of taxes to economic growth can be considered from many aspects. It can be perceived as a feature which burdens economic subjects and their behaviour and therefore influences their willingness to save or invest; or their work efforts. It can be also viewed as an instrument which ensures sources for government expenditures which can lead to the areas supporting economic growth (productive government expenditures, see below). With the respect to the afore-mentioned it is necessary to see taxation in its wider context.

One of the first studies which noted the possible relation between taxation and long-term economic growth was e.g. Barro (1999) or King and Rebelo (1990). The impact of taxation on the total economic growth was studied by Judd (1985), Chamley (1986), Rebelo (1991), Devereux and Love (1994); their papers are based either on the neoclassical growth model with physical capital or the two sector growth model with human and physical capital. Their common conclusion supports the idea that the three most commonly used taxes (consumption, corporate, taxation of labour) have a negative impact on the economic growth within the OECD member countries. They consider corporate taxation followed by income taxes and consumer taxes as the most damaging for economic growth. Similar results for corporation taxation

were also received from Lee and Gordon (2005). On the other side there is also analysis that did not confirm this conclusion; these are more of an exception than the rule. For example

Forbin (2011) analysed the Swedish economy for 1951–2010 period and didn't confirm any significant relation between tax corporation and long-term economic growth. He also admits that if he used marginal effective tax rates the conclusions could be different.

In the case of property and consumer taxes there are countless numbers of studies showing their low distortion effect and nearly no impact on the economic growth (e.g. Arnold, 2010; Johansson et al., 2008 or Widmalm, 2001). To support economic growth, Myles (2009) supports a transition of taxation of income to the consumer. He also adds that taxation of capital is ineffective in the long-term. The new study of Gemmell et al. (2014) explores the merits of macro- and micro-based tax rate measures within an open economy. Their conclusion is that in general, tax effects on GDP operate largely via factor productivity rather than factor accumulation.

Engen and Skinner (1996) define five main channels on how corporate taxation influences economic growth. They are represented by (i) investment discouragement, (ii) impact on the labour offer, (iii) decrease of the productivity growth of corporates, (iv) decreasing marginal productivity of capital, and (v) increase of effective utilization of labour capital. All above mentioned channels are usually connected to corporate and labour taxation. This fact is also confirmed by the knowledge of the distortion effect of taxation which influences behaviour of economic subjects. Cullen and Gordon (2002) conclude that tax policy is the key factor influencing business activity in the sense of its movement between employees and self-employment. Kotlikoff and Summers (1987) support the opinion that the taxation of corporations leads to a lower return on capital which as a result tends to move out of the country.

Kotlán et al. (2011) state that integration of taxation to growth theories can be divided into two main streams. The first one is focusing on the impact on the level of the savings, investments and capital accumulation. The pro-growth effect is notable mainly in the case where countries which haven't reached a steady state. The second stream analysis integration via economic progress and accumulation of human capital; the final effect should be on countries which have already reached the steady state.

The relationship between economic growth, corporate taxation and economic activity of corporations is probably the most important and also commonly discussed in the empirical studies. Many published papers also study the impact of taxation on corporate decision making and their influence not only on the investment decision making but also on dividend policy, organizational structure etc. (e.g. Scholes and Wolfson, 1992; Auerbach and Slemrod, 1997; Shackelford and Shevlin, 2001). The results unambiguously confirmed the impact of corporate taxation on corporate policy. Tax policy has a significant impact on how corporations finance themselves. The capital for new investments can be obtained through their own capital, debt or undivided profit. High tax rates lower the income of the corporations and therefore possibility of the following reinvestment. Simultaneously the international movement of capital allows an easy choice for the investment allocation. For small open economies, which are usually recipients of the investments, the high taxation represents a competitiveness problem. The inflow of foreign investments has its positives, e.g. on the employment level. Harberger (1962) believes that high corporate tax rates discourage investment activity. The inflow of foreign investments has its positive relations also in the case of higher employment. The relation between foreign direct investments and corporate taxation confirmed e.g. Simmons (2003). In his study the index evaluating the attraction of the country based on the corporate taxation was presented. The impact of the tax rates changes on the intensive investments studies also Devereux (2007) or De Mooij and

Ederveen (2003). They conclude that this kind of investment is more sensitive on the tax related law changes and on the average tax rate compared to the standard investments. Analysis of Buettner and Ruf (2007) or Buettner and Wamser (2009) point out that corporate taxation influences both the extent and allocation of the investments. Keuschingg (2008) created a model of monopoly competitive industry with extensive and intensive investments and showed how margin changes of those investments react on the changes of average and marginal rates of corporate taxes. Lanaspa et al. (2008) note that government has the ability to influence localised decisions (in the case of FDI) of the corporates due to the tax rate of capital incomes. They confirm the general conclusion that countries with a lower tax burden are net receivers of FDI. Mutti and Grubert (2004) study the impact of these types of taxes on horizontally integrated international organizations which consider investing in another country. They conclude that investments abroad are very sensitive to the tax rates and this sensitivity is higher in the case of developing countries compared to the developed countries; it also grows in time. Paretto (2007) provides a different view on corporate tax, this work is based on modern Schumpeterian growth theory. He concludes that higher dividend taxation has a positive impact on economic growth as it balances the deficit of government budget.

The investment activities of companies can be influenced by different taxation as well. It is easier to verify the impact of the direct taxes. Brett and Weymark (2008) believe that the immediate effect on capital accumulation and savings creation have also individual pension taxes – lower pension reduces intended savings; and also via lower yield from the savings. Lubian and Zarri (2011) mention the negative and positive impact of pension taxation. The negative impact is represented by (i) the decrease of disposable income and savings (ii) tax evasion in the case of capital incomes. The positive impact is based on the idea of growing work effort with the aim of achieving a particular value of pension before taxation. The pressure on salary growth as a result of

growing labour taxation makes work offer rigid and therefore creates pressure on the decrease of corporate profits and later on the investment decrease. As a result the structure of capital accumulation is disrupted.

Taxation of dividends represents another approach to the investment activity of economic subjects. On a theoretical level there are three approaches. The traditional one views marginal source of investments in the new own capital where the investment yields are used for dividend payments. The new one sees it as the source of investments undivided profit. It can be noted that whereas the traditional approach attributes impact of the dividend taxation on the investment activity, the new approach holds the opposite opinion (e.g. Bradford, 1981; King, 1977; Poterba and Summers, 1985). The third approach applies the theory of tax insignificance. Its supporters claim that investors aren't facing different dividend and capital yields taxation (e.g. Miller and Scholes, 1982; Miller and Modigliany, 1961). Under the assumption of the validity of the theory the change of dividend taxation doesn't influence investment decision making and taxation is considered as non-distorting.

Savings represent the most important factor determining long-term economic growth and based on the above mentioned it is obvious that corporate taxation is, in parallel with labour taxation, a key factor influencing capital accumulation.

In the case of endogenous models of economic growth it is also necessary to mention approaches to the impact of taxation on technological advances and investment in the human capital. The number of studies handling this issue is not so vast. Some papers support the idea of immediate impact of taxation on accumulation both of physical and human capital (Leibfritz et al., 1997; King and Rebelo, 1990). On the level of corporate taxation the conclusions vary and a clear impact has not been confirmed on the empirical level. For example Tremblay (2010) highlights the non-existent neutral relation between corporate taxation and investment to human capital. He shows a negative impact in the case that both

employees and corporations are engaged in the investments to the human capital. On the other hand, if only corporations are involved the impact is positive. But if we analyse the issue from the side of public finances (tax incomes) there is a positive correlation between economic growth and taxation (Lin, 2001). This relation exists mainly if the tax incomes for the accumulation of human capital are used. Myles (2007) or Erosa and Koreshkova (2007) state that mainly personal income tax has an essential impact on the return of investments to human capital and decision making about future education. Tremblay (2010) adds that if the investment in human capital is performed both by employee and corporation, the level of the investment in human capital will increase in the case of higher taxation of personal income; conversely the effect of corporate taxes is opposite.

Zeng and Zhang (2001) study the growth effect of taxes within Howitt's (1999) growth model where the main sources of growth is innovation. They conclude that tax of capital income is harmful for growth as it discourages creation of savings and capital investments. In the case of technologically advanced countries where innovation is key for the long term growth they recommend focussing on consumer and labour taxes instead of investment taxation. The impact of taxes on economic growth is studied mainly in the sense of tax incentives aimed on research and development. The economic literature confirms that short-time incentives in research and development are relatively non-elastic, in the long-term their elasticity is close to one and there is a positive relation between economic growth and tax incentives (Bloom et al., 2002; Hall and Van Reenen, 2000).

For government expenditures two aspects are important – their productivity and their efficiency. To evaluate the impact of government expenditures on economic growth properly it is necessary to perceive the above mentioned aspects and connection between taxation and government expenditures. It can be assumed that growth-supporting effect belongs to government expenditures which are financed by

non-distorted taxes. On the other hand, non-productive government expenditures which are financed by distorted taxes have an anti-growth effect (for more details e.g. Afonso and Furceri, 2008; Agénor, 2010). Devarajan et al. (1996) point out the significance of the difference between productive and non-productive government expenditures. They support the opinion that there is a positive relationship between economic growth and public investment expenditures; the relation between consumer related public expenditures and economic growth is negative. As productive government expenditures are considered mainly investment expenditures and expenditures to the education. Non-productive expenditures are represented by mandatory expenditures (mainly social expenditures). Drobiszová and Machová (2015)

add that government expenditures also indirectly support economic growth by the creation of suitable institutional conditions for private investments. If the private investments were absent or non-realized in the economy it would disturb its functioning.

From the above mentioned literature review it is obvious that the impact of corporate taxation on economic growth is realised within the saving and investment channel; and its impact is negative. The impact on the economic growth within the human capital is rather negative and the impact of technological progress is not clear. For government expenditure their composition is crucial; in the case of productive expenditures the impact is positive, in the case of non-productive negative.

3   METHODOLOGY AND DATA

The presented paper is based on the Mankiw et al. (1992) growth model which represents the basic neoclassical growth model of economic growth extended by human capital. The model also includes other fiscal variables, which together with delayed explained variable characterizing the dynamic of economic relation, modify the whole model.

Economic variables can be perceived as dynamic processes within the time. It can be therefore expected that the current growth rate is determined among others by its delayed value. Integration of taxation to the model needs to be performed complexly. Because of that the model also includes other taxes which exist in the tax systems of the chosen countries. This approach is consistent with the modern approach of economical agents as they are defined by e.g. Kotlán and Machová (2014a). Judd (1987) claims that it is desirable to estimate impact of all taxes on economic growth. Denaux (2007) or Izák (2011) add that it is also necessary to quantify impact of other fiscal variables, mainly government expenditures. Because of that, the model is extended by control of tax variables and government expenditures.

Analysis of the relation between corporate taxation and economic growth is based on the dynamic of panel regression. Panel regression as a statistical-econometric method investigates relations in two dimensional space. Panel data enables the connection of time and cross-section dimension of data and at the same time the statistics are more reliable and robust. With respect to the used data, the estimation is performed under Generalized Method of Moments (GMM) specifically the Arellano-Bond estimator (Arellano and Bond, 1991) which uses instrumental variables. To obtain consistent estimation and to remove possible homogeneity the first differentiations are used; so the special differentiation form of GMM with institutional variables is applied (details in Baltagi, 2010).

Baltagi (2010) states that dynamic relations are usually characterized by delayed variable, so the model can be defined as following (1):

$$y_{it} = \delta y_{i,t-1} + x'_{it}\beta + u_{it}, \tag{1}$$

where $i = 1, 2, \ldots, N$, $t = 1, 2, \ldots, T$, δ is scalar variable, x'_{it} represents vector of explanatory variables $(1 \times K)$, β is vector of regression coefficients $(K \times 1)$ and u_{it} is random variable

given by equation (2):

$$u_{it} = \mu_i + \nu_{it}, \qquad (2)$$

where μ_i represents individual effects and ν_{it} is idiosyncratic variable; μ_i and ν_{it} are independent on each other.

The above presented model is a model with fixed effects which are commonly used in macroeconomics as the individual effects represent voided variables. It is possible that characteristics for individual entities are correlated with other regressors.

The individual variables are defined below in Tab. 1, the last column states the source of the data. All used data are quantitative and secondary. Their collection was performed in a way to ensure their consistency comparability. A review of descriptive statistic of input data is added in appendix.

With regards on the above mentioned, the mathematical equation of the studied relation is following (3):

$$\begin{aligned} \mathrm{GDP}_{it} &= \delta\,\mathrm{GDP}_{i,t-1} + \hat{\beta}\,\mathrm{CAP}_{it} + \\ &+ \hat{\beta}\,\mathrm{HUM}_{it} + \hat{\beta}\,\mathrm{GOV}_{it} - \\ &- \hat{\beta}\,\mathrm{TAX}_{it} + u_{it}, \qquad (3) \end{aligned}$$

where $i = 1, \ldots, 35$ and $t = 2000, \ldots, 2014$.

As Kotlán (2010) states, in accordance with Barro and Sala-i-Martin (2004) for the sample of chosen countries it is appropriate to apply homogeneity criteria. This request is fulfilled by the membership of all chosen countries in OECD[1]. Time period of the analysis is 2000–2014. Four models are created. These models reflect impact of corporate taxation on economic growth. In the first model the taxation (TAX) is approximated by part of

tax quota representing tax burden of corporations (TQ1200) and control tax variables – taxation of personal income (TQ1100), social insurance (TQ2000), property taxes (TQ4000) consumption taxes (TQ5110) and special consumption taxes (TQ5120). Based on the mircoforward looking approach the corporation taxation is approximated by Effective average tax rate (EATR) and Effective marginal tax rate (EMTR); which represent second and third model. In the case of those taxes there is no equivalent measure considering directly labour, property or consumption taxation which would be based on the same methodology. Taxation of labour and property are considered within the indicators (detailed Spengel et al., 2014). Consumption taxation is reflected by partial tax quota (TQ5110 and TQ5120). Fourth model applies alternative possibility to approximate tax burden by World Tax Index and its sub-index Corporate Income Tax (CIT); control variables are represented by sub-indexes Personal Income Tax (PIT), Value Added Tax (VAT), Individual Property Taxes (PRO) and Other Taxes on Consumption (OTC).

Kotlán and Machová (2014b) point out that fiscal policy horizon and its delay are important for the economic policy efficiency, economic cycle and long-term growth. Therefore it is desirable to reflect dynamic of the model with focus on the possibilities of quantitative methods. Kotlán and Machová (2014b) also note that tax policy efficiency is the most visible with 2–3 years delay. The aim of the following analysis is to reflect fiscal (tax) policy delay and therefore individual fiscal variables will be delayed by 1–4 years. The analysis is performed on E-Views (8).

4 RESULTS AND DISCUSSION

The following part describes the results of the dynamic panel model. To obtain robust estimations of individual's models it is necessary to adjust the data. All time series apart of EATR and EMTR were changed to its logarithmic

form (LOG). It is not possible to transform EATR and EMTR because of the micro-forward looking approach some of their values are negative. Lammersen and Schwager (2005) note that negative values of those indicators are a

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[1]Currently 35 developed countries.

Tab. 1: Characteristics and sources of input data

Variable	Characteristics	Unit	Source
GDP	The dependent variable is approximated in accordance with the Mankiw et al. (1992) study using a real gross domestic product per capita expressed in absolute terms of real GDP per capita in the purchasing power parity in USD	[USD/per capita]	OECD Revenue Statistics (OECD, 2016)
GDP(−1)	The lagged value of the dependent variable	[USD/per capita]	OECD Revenue Statistics (OECD, 2016)
CAP	Capital accumulation – in accordance with the Mankiw et al. (1992) study, it is approximated by the ratio of real investment to GDP, expressed in purchasing power parity per capita	[%]	Penn World Table version 9.0 (PWT, 2016)
HUM	Human capital approximated by the human capital index based based on the average years of schooling and an assumed rate of return to education	[index]	Penn World Table version 9.0 (PWT, 2016)[a]
GOV	Total government expenditure expressed as a share of government expenditure on GDP	[%]	International Monetary Fund - World Economic Outlook Database (IMF, 2016)
TAX	Tax burden expressed by the Tax quota (TQ), World Tax Index (WTI) and Effective tax rate (ETR)	TQ [%]; WTI [index]; ETR [%]	TQ – OECD Revenue Statistics (OECD, 2016); WTI – World Tax Index (WTI, 2016); ETR – Spengel et al. (2014)[b]

Notes: [a] Index was created by Penn World Table 9.0. It is based on the study by Feenstra et al. (2015). [b] Methodology is based on Devereux and Griffith (1998).

result of lower value of capital costs compared to the real interest rate. This suggests that there is indirect tax support of investments which increases the rate of profit after taxation compared to its value before taxation.

This paper applies the Arelano-Bond estimator which ensures elimination of endogeneity issue as it transforms the variable to its first differentiations and transformed variables do not contain a unit root (so they are stationary). It is convenient to obtain stationary data mainly in first differentiations. Stationarity testing for panel data can be performed due to panel unit root test (Levin et al., 2002; Im et al., 2003) and ADF and PP test (Maddala and Wu, 1999). All those tests have the same null hypothesis which is confirmation of a single root existence. An alternative hypothesis varies. In the case of Levin, Lin and Chu test the alternative hypothesis states that there are no

unit roots. Alternative hypothesis of other tests state that some objects have unit roots (detailed in Novák, 2007 or Baltagi, 2010). The existence of a single root was tested both on levels and on first differentiation. All variables apart of human capital were stationary in the first differentiation so due to applied methodology it wasn't necessary to adjust the time series. Therefore to obtain valid results only HUM was adjusted. Its stochastic instability was removed by the transformation of the variable to its first differentiation. The adjusted variable was again tested for unit roots and results show that the variable is stationary in the case of its second differentiation. The above mentioned follows a study of Xiao et al. (2010) or Kitamura and Phillips (1997) who state that even though a dependent variable is non-stationary the GMM method provides consistent estimates.

Tab. 2: Panel models: Interaction of economic growth and corporate taxation in OECD countries

Model 1 TQ		Model 2 EATR		Model 3 EMTR	
LOG(GDP)		LOG(GDP)		LOG(GDP)	
LOG(GDP(−1))	0.746*** (39.697)	LOG(GDP(−1))	0.616*** (23.963)	LOG(GDP(−1))	0.585*** (18.482)
LOG(CAP)	0.164*** (19.935)	LOG(CAP)	0.238*** (6.345)	LOG(CAP)	0.225*** (6.773)
D(LOG(HUM))	1.242*** (2.837)	D(LOG(HUM))	−1.089 (−0.954)	D(LOG(HUM))	−4.288* (−1.668)
LOG(GOV(−1))	0.157*** (14.776)	LOG(GOV(−1))	0.129*** (3.238)	LOG(GOV(−1))	0.089* (1.776)
LOG(TQ1100(−2))	−0.072*** (−6.943)	EATR(−4)	−0.003*** (−2.499)	EMTR(−3)	−0.005** (−2.434)
LOG(TQ1200(−1))	−0.024*** (−3.714)	LOG(TQ5110(−3))	−0.028*** (−2.868)	LOG(TQ5110(−3))	−0.015** (−2.043)
LOG(TQ2000)	−0.016* (−1.633)	LOG(TQ5120(−3))	0.023** (1.905)	LOG(TQ5120(−4))	0.007 (0.887)
LOG(TQ4000(−2))	0.022** (2.361)				
LOG(TQ5110(−3))	−0.088*** (−3.372)				
LOG(TQ5120(−2))	0.042*** (4.055)				
Sargan-Hansen test	27.947 [0.414]	Sargan-Hansen test	17.518 [0.419]	Sargan-Hansen test	10.656 [0.908]
AB corr. test	−0.005 [0.996]	AB corr. test	−0.001 [0.999]	AB corr. test	−0.008 [0.993]
Instrument rank	37	Instrument rank	24	Instrument rank	25
Total observations	373	Total observations	220	Total observations	220

Source: E-Views (8). Note: *, **, *** represent a significance level of 10%, 5% and 1%.

It was empirically proved (e.g. Kotlán and Machová, 2014b; Matsumoto, 2008; De Cesare and Sportelli, 2012) that tax policy has an impact on economic growth with time delay. This delay varies based on the type of tax and its distortion effects. Different delays is also given by calculation of taxation and length of time series. In summary, the delay of individual taxes can have a quantitative effect on economic growth with different delays. To work with different delays within individual models and different tax approximations is therefore relevant and reasonable. As was mentioned before, Kotlán and Machová (2014b) state that the effect of tax policy is the most visible in the case of a 2–3 year delay. The aim of the following analysis is to reflect the delayed effect of tax policy and because of that the individual fiscal variables are delayed by 1–4 years with respect

to the relevance of econometric and economical point of view. For the individual approximations of tax burden the results which reflect the best economical and econometric sides with the respect to time delay are presented.

As it is usual Tab. 2 represents values of estimated regression coefficients of individual independent variables ant t-statistics values – Sargan-Hansen test which verifies the explanatory value of the model and Arellano-Bond test of serial correlation (AB corr. test) which tests the model for the presence of autocorrelation of second order are presented.

The results of Sargan-Hansen test for all four models show that number of instruments is higher than J-statistic and the null hypothesis is not denied. This means that instruments of models are not correlated with residues which confirm correct verification of models. Instru-

mental variables were chosen correctly and removed endogenity from the models. Based on results of Arellano-Bond test of serial correlation no significant evidence of serial correlation in the firs-differenced errors is presented. It is also obvious that all four models are dynamic stable. The stability is supported by high statistical significance of delayed explanatory variables (on 1% significance level). It can be therefore stated that use of dynamic model under GMM method and first differentiation is reasonable.

Relation between economic growth and exogenous variable CAP (physical capital accumulation) confirmed theoretical assumptions. This variable was estimated with expected positive impact on economic growth (on 1% significance level). Contradictory results were received in the case of HUM (human capital). Within the first model which uses TQ and fourth model which uses WTI the HUM is on 1% significance level significant with positive impact on economic growth. But in the case of model 2 using EATR this variable is insignificant. Same result is obtained for model 3 with EMTR where the variable is significant on the border of 10% significance level and estimated impact is negative. Human capital represents variable for which the existence of positive impact on economic growth has been confirmed both on theoretical and empirical level (e.g. Barro, 1999). Its approximation seems to be problematical but as this variable has function of control variable in the model it was decided to leave it in the model to preserve complexity of model.

In the case of fiscal variable there is a conformity between theoretical expectations and obtained results as there is a positive impact on economic growth (on 1% significance level) in the case of all four models. In all cases variable was delayed for 1 year. On the general level it is expected that government expenditures leads to the support of economic growth. Some studies (e.g. Devarajan et al., 1996; Afonso et al., 2005) doubt this statement and point out that it is important to distinguish between productive and non-productive government expenditures. Non-productive government expenditures have

therefore opposite impact on economic growth. Due to lack of available data only the aggregate government expenditures are used. On theoretical level prevailing positive impact of government expenditures is expected; this assumption was confirmed.

Taxation of labour in first model (TQ1100) was verified as significant on 1% significance level and has negative impact on economic growth; variable is delayed 2 years. Corporate tax (TQ1200) was also verified on 1% significance level. The impact of labour tax is higher than impact of corporate taxation. The impact of social insurance, including social insurance covered by employees, was verified on 10% significance level and no delay was used. It can be stated that social insurance has immediate impact on economic growth. The explanation can lay in a fact that social insurance is a tax in a wider meaning and in the case of quasi taxes there are only very limited possibilities to reallocate them mainly in sense of substitution effect as it is in the case of income taxes. It is necessary to consider that tax system represents interconnected systems which influence each other and in the case of change of corporate taxes tax incidence occurs. Tax burden in the form of higher corporations will not only corporations but will be also moved on employees. Fullerton et al. (1980) state that it is obvious that corporations move tax burden but it is very difficult to evaluate real impacts of this phenomenon.

First model haven't confirmed negative impact of property taxes (TQ4000) on economic growth (on 5% significance level). Same result was obtained also for other consumption taxes (TQ5120) on 1% significance level. In this case the results confirm conclusions of other empirical studies which show low distortion effect of those taxes and their negligible impact on economic growth (e.g. Arnold, 2010; Johansson et al., 2008; Widmalm, 2001). On the other side the negative impact of consumption taxes VAT (TQ5110) was confirmed on 1% significance level. The influence of this tax category was out of all tax variables the highest one which indicates that it's increasing bound economic growth within OECD member countries. This

conclusion collides with another empirical papers (e.g. Kotlán et al., 2011; Simionescu and Albu, 2016) which showed either insignificant negative impact or slightly positive impact on economic growth. Ebrill et al. (2001) state that value added tax creates economic deformations which are smaller compared to other taxes as they reflect lower productivity and savings. To obtain optimal economic growth the tax systems should be correctly adjusted. Many empirical papers (e.g. Myles, 2009) advice to move tax burden from direct to indirect taxes and VAT can represent one of the possible solutions as it reduces only consumption and not production or investments. Our results suggest that this shift of tax burden could be inappropriate and could have negative impact on economic growth. It is appropriate to consider characteristics of tax quota. This conclusion can have its reasoning in the efficiencies of tax quota itself (detailed e.g. Baranová and Janíčková, 2012). Because of that it is appropriate to consider also another approximates or tax burden, mainly WTI which have significantly higher explanatory value and are less sensitive on the fluctuations of economy.

Second model presents impact of taxation presented by average effective tax rate on economic growth. As the results show EATR has negative impact on economic growth on 1% significance level and delay 4 years. Control tax variables are represented by consumption taxes and were verified in the case of TQ5110 as a negative on 1% significance level and in the case of TQ5120 as a positive on 5% significance level. The results are in accordance with the results of previous model 1.

In the case of corporate taxation represented by effective tax rate (model 3) the negative impact on economic growth (on 5% significance level) was again confirmed. From the quantitative point of view this impact is not so high. The highest negative impact on the economic growth was verified in the case of control variable presenting general consumption taxation VAT (TQ5100) which was confirmed on 5% significance level and delay 3 years. On

the other hand positive impact was estimated for control variable TQ5120 but this impact is statistically insignificant. To remain complexity of the model the variable wasn't removed.

From the results of model 2 and 3 it is obvious that quantitative effect of corporate taxation within economic growth approximated by effective average and marginal tax rates is relatively weak, compared to the other determinants of economic growth. The reasoning can lie in the aggregation of different data which can have contradictory effect. Effective marginal and average rates were proved to be significant only in the case of investment activity as Janíčková and Baranová (2013) describe.

Based on model 4 results, corporate taxation represented by sub-index CIT has also negative impact on economic growth on 1% significance level and delay 2 years. Compared to impact of personal taxation (PIT) this influence can be considered as relatively low. Personal income taxation shows quantitatively highest negative impact (on 1% significance level) on economic growth. This conclusion is similar with results of model 1 using tax quota. In the case of PRO negative impact is confirmed on the 5% significance level which responds with theoretical assumptions about negative impact of property/direct taxes. This impact wasn't confirmed in the case of model using tax quota.

From the quantitative point of view higher impact compared to corporation taxation is also confirmed. In the case of consumption taxes the positive impact on economic growth was proved both for OTC on 5% significance level and VAT as non-significant. These results dispute with conclusions gained while using tax quota where the impact of VAT was negative and other selective consumption taxes positive on 1% significance level. From above described it can be concluded that impact of indirect taxes is not so obvious as in the case of income taxes. Same conclusion provides e.g. Xu and IMF (1994) or Mendoza et al. (1997) whose studies didn't prove correlation of consumption taxation and economic growth.

5   CONCLUSION

The main objective of the paper was to evaluate the relation between corporate taxation and economic growth on the sample of OECD member countries under a hypothesis of negative impact of corporate taxation on economic growth. Corporate taxation is approximated by the variety of corporate taxation indicators with respect to the dynamic nature of economy.

From the presented empirical evidence, the negative impact of corporation taxation on economic growth was proved, even though as quantitative more significant the impact of labour taxation was determined. This result is probably based on the following explanation. It is necessary to consider fact that tax system is usually very complex its individual taxes interact among themselves. Mainly the existence of substitution effect provides corporations with the possibility to spread their tax burden on different subjects. In the case of personal income taxation the substitution is enabled mainly between work and free time and employee doesn't have many possibilities to distribute his tax burden in a the same way as corporations. Fullerton et al. (1980) point out those corporations obviously shift their tax burden and it is very difficult to evaluate whole impact of this feature. Higher taxation of corporations therefore does not influence only corporations themselves but it can be concluded that changes will affect also employee and price policy of corporations. How much tax burden will be spread depends on many specific features as e.g. size and nature of market, type of product or openness of the economy. It is also important to consider interconnection between corporate taxation and other income taxes. Each change of labour taxation (and also social contributions) has also transferred impact on corporate sector which creates labour demand. Realized changes of personal income taxation will influence chosen marginal values and labour costs for nearly all labour market participants. From the above mentioned it is necessary to perceive both personal and corporate taxes as a complex with functions in synergy in given tax system. It can be assumed that this synergy is robust mainly within mentioned taxes.

In the case of effective tax rates determined by micro-forward looking approach it was not possible to include other direct taxes to the models (model 2 and 3), as these are already partially aggregated in the indicator. For those models only consumption taxes were added. The effective corporate tax rates are related mainly to the investment decision making. Negative impact on economic growth of those rates was proved although quantitative not very strong. Janíčková and Baranová (2013) conclude that this type of tax rates directly influence mainly size of investment.

For other control variables it is necessary to mention huge ambiguity mainly in the case of consumption and property taxes. VAT approximated by tax quota negative and quantitative significant impact was verified in relation to economic growth. When this variable was represented by World Tax Index its impact was proved as insignificant and positive. For the other selective consumption taxes positive impact was determined. Same positive impact was also evaluated for implicit consumption tax rates but only in a few cases as statistically significant. These findings are similar with papers of e.g. Vráblíková (2016). On the other hand Xu and IMF (1994) or Mendoza et al. (1997) haven't proved any impact of consumption taxes on economic growth. Within individual empirical papers the results considering consumption taxation are ambiguous. Interesting point of view on consumption tax provides Alm and El-Ganainy (2013) who state that indirect taxes have mediated effect on economic growth via investments. They describe the fact that consumption influences investment level as there is substitution effect due to lower consumption and higher savings which finally leads to higher economic growth (as opposite to income taxes).

The contradictory results are in the case of property taxes shown as well. Approximation by tax quota points out on the positive impact on economic growth but PRO sub-index provides

opposite results supporting strong negative impact on the same variable. One of the features of property taxes is their low dynamics which can cause some problems while approximating them. Kotlán (2010) states that higher tax quota doesn't necessary imply higher tax burden but it can present higher efficiency in the collection processes. On the other side, as the Laffer curve define, lower tax burden can lead to the higher collection of taxes and increase of tax quota. Kotlán (2010) also adds that it is appropriate to extend the analysis for effective tax indicator WTI as well. This indicator is less sensitive to the economy distortion. Different results of the individual models can be therefore also caused by shortcomings of the indicators.

In the case of government expenditures and supplementary variables the positive impact was verified. It can be stated that the positive effect of government expenditures prevails over negative impact, on the sample of OECD member countries. It can be also assumed that government expenditures financed by non-distort taxes and aiming to productivity part of government expenditures have pro-growth effect On the other side non-productive government expenditures financed by distortion taxes have anti-growth tendency.

Considering the suitability of used indicators the most convenient appears to be World Tax Index and its sub-index Corporate Income Tax both from economic and econometric point of view. This multi criteria indicator shows the most stable evolution in time and till now it hasn't shown any predisposition to deflections of economy compared to the other indicators.

From the above mentioned it is clear that mainly income taxes have negative impact on economic growth. Therefore it is suitable to shift tax burden to consumption and property taxes if the policy makers want to support economic growth.

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7 ANNEX

Tab. 3: Descriptive statistic of input data

		Mean	Median	Maximum	Minimum	Std. dev.
	GDP	34106.4900	34394.1400	90846.8300	10653.3600	13658.3800
	CAP	25.0208	24.5925	56.3843	11.4257	5.4550
	HUM	3.1419	3.2467	3.7343	1.5210	0.4459
	GOV	41.6564	42.3920	65.2700	16.9550	8.8070
TQ	TQ1100	8.1831	7.6280	26.7800	0.9530	4.3753
	TQ1200	3.0614	2.7710	12.5940	0.5810	1.6276
	TQ2000	8.7412	9.9220	17.0060	0.0000	4.6599
	TQ4000	1.7769	1.6740	4.1400	0.2170	1.0297
	TQ5110	6.7044	6.9930	11.7160	1.9530	2.0436
	TQ5120	3.3599	3.3470	6.5490	0.7260	1.0485
ETR	EATR	24.9533	24.6000	41.7000	9.4000	6.9790
	EMTR	19.2521	17.7000	42.8000	−5.1000	9.0528
WTI	PIT	0.2471	0.2616	0.4182	0.0052	0.1006
	CIT	0.0731	0.0574	0.2077	0.0027	0.0473
	PRO	0.0229	0.0144	0.1401	0.0000	0.0258
	VAT	0.1775	0.1728	0.4982	0.0013	0.1060
	OTC	0.0491	0.0292	0.2543	0.0000	0.0506

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- ISSN 2336-6494
- Online submission, open access, double blind referred
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