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Is there a Link between Sustainability, Perception and Buying Decision at the Point of Sale?

Julia Lamberz, Thorsten Litfin, Özlem Teckert, Gunther Meeh-Bunse
Osnabrück University of Applied Sciences, Faculty of Management, Culture and Technology, Germany

Abstract

Background: If retailers and brand manufacturers of food succeed in presenting their products at the point of sale, quickly generating a high level of attention, the likelihood of a purchase is significantly increased. Particularly, in recent years, they have been relying on the megatrend of sustainability. The importance of sustainable food has grown accordingly. Hence, an increasing number of manufacturers are challenged to communicate the sustainability of their products via packaging and displays at the point of sale. **Objectives:** The aim of this article is: to examine to what extent the design of individual packaging and display elements of new sustainable direct juice succeeds in visually communicating sustainability aspects. At the same time the willingness to pay of customers interested in sustainability must be commercialized. **Methods/Approach:** The focus is on a real shopping situation in conditions that are as regular as possible. The perception of a display must be recorded by eye-tracking technology. A preliminary survey must examine consumers' attitudes towards sustainable food in order to relate it to the perception of individual display elements. For this purpose, the eye-tracking technology was combined with a survey of 32 customers. **Results:** The results demonstrate that customers with a positive attitude towards sustainable food behave in the following way: they fix individual packaging and display elements that refer to sustainable components for a longer period of time; they remember product features better and they tend to have a slightly higher willingness to pay for the sustainable direct juice. **Conclusions:** The configuration of an authentic and natural shopping situation provides the manufacturer with concrete recommendations for the design of the display. This communicates the sustainability of its product and thus generates the desired attention.

Keywords: consumer behaviour, eye-tracking, sustainability, visual merchandising, visual attention
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Introduction

If retailers and brand manufacturers of foods succeed in presenting their products at the point of sale in such a way that they quickly generate a high level of attention, their purchase probability increases significantly. This is because most products and brands from the fast moving consumer goods sector spontaneously end up in the shopping cart at the point of sale. According to a number of studies, the share of so-called instore decisions must be around 65 percent. For half of these purchases, the consumer only knows which category of goods he wants to buy a product from (Häusel, 2016). The visual stimuli are of outstanding importance here, since 85 percent of the products seen first are purchased without further consideration of alternatives. Even 90 percent of purchasing decisions are made by only taking a quick look at the front of a product. Consequently, consumers make decisions visually buying the products they see (Nordfält, 2011). While shopping, consumers are influenced by a variety of factors. In addition to the wide range of products on offer, purchasing decisions are also influenced by the presentation of goods on displays, salesroom design and advertising banners. These stimuli are known as bottom-up factors. Like top-down factors - such as attitudes towards a particular product – they help to draw attention to particular products. As a result, retailers and brand manufacturers strive for presenting products and brands in a way that consumers see them first. In particular, displays play a key role in the presentation of fast moving consumer goods. These are also referred to as impulse goods at the point of sale (Behe et al., 2013; Diederichs & Göbl, 2018).

Sustainability is one of the megatrends gradually establishing themselves in our society. Accordingly, the importance of sustainable consumption is constantly growing. Food manufacturers and retailers are adapting this development in order to attract attention and convince customers of their products. In recent years, consumers have therefore increasingly found sustainable foods on the shelves of retail traders. The importance of sustainable foods grew accordingly and so did the turnover, which rose by 15 percent in 2017 to reach billions (Fairtrade Deutschland, 2017). Manufacturers of sustainable foods are faced with the task of communicating the term "sustainability" via packaging and display elements. However, from the customer's point of view there is no clear definition of the term "sustainable foods". This is because, consumers associate the term with many properties such as production without artificial additives or ecological and regional production (Aiking & de Boer, 2004; Grunert, 2011; von Meyer-Höfer, 2016). Von Meyer-Höfer surveyed 570 consumers in Germany and Switzerland on the properties of sustainable foods. According to the survey, consumers expect sustainable foods to have ecological, regional, ethical and social properties. Since these properties have only a limited impact on taste and appearance, they cannot be clearly linked to food. It is therefore difficult for consumers to recognise sustainable product properties at the point of sale (von Meyer-Höfer, 2016). Producers and traders of sustainable foods must communicate the sustainability of their products via packaging and displays at the point of sale to notice the trend towards sustainability and use it for their own benefit.

The objective of this article is to demonstrate how the design of displays can influence the visual perception of sustainable foods at the point of sale. To this end visual perception and shopping behaviour at the point of sale as well as the potential of applying eye-tracking approaches will be examined from a theoretical point of view. Building on this, the extent to which the design of individual display elements succeeds in visually communicating sustainability will then be examined for a new sustainable organic juice. The significance of sustainability for customers will also be determined. Furthermore, extent to what this significance is related to the perception

of individual display elements are in the research focus (Lamberz et al., 2019). It is also considered to what extent the importance of sustainability influences the willingness to pay for one litre of sustainable direct juice. For this purpose, the use of eye-tracking technology will be combined with a questionnaire.

The paper consists of five parts. After (1) the introduction, (2) a literature review of visual perception and purchasing behaviour at the point of sale and its measuring by eye tracking technology are described as a basis for the derived research propositions. Thereafter, (3) the research methodology is presented, including sample description and research instruments. (4) Data analysis and main research findings are provided in the fourth part. Finally, (5) research results are discussed from both the theoretical and the managerial standpoint. In addition, directions for future research are outlined.

Literature review

Visual perception and purchasing behaviour at the point of sale

To assess how products and brands influence the purchase decision at the point of sale, the analysis of customer perception is important (Pieters & Warlop, 1999). Products are viewed with the eye of a customer and the brain processes the perceived images. This visual cognitive processing consists of a series of stops (fixations) and jumps (saccades) (Russo, 1978). Simultaneously, the product fixation processes the information top-down and bottom-up. Consumers are not only influenced by externally perceived stimuli such as the colour design of product packaging and displays (bottom-up factors) but by internal stimuli such as individual goals, product settings and memories (top-down factors). Some stimuli are expected and foreseen and the inner stimuli affects the perception and evaluation of external stimuli (Wedel & Pieters, 2008).

The design of these external stimuli is of particular importance since about 65 percent of decisions are made spontaneously during the shopping process. The consumer only decides for half of his or her purchases based upon previous knowledge about a particular category or brand (Häusel, 2016). In addition, consumers have a decreasing amount of time to shop. Therefore, the viewing times of product packaging are in a range of a few seconds (Huddleston et al., 2015; Pieters et al., 1999,). During this time, 90 percent of all purchasing decisions are made by taking a quick look at the front of the product packaging (Grunert, 2011). Pieters et al. (2002) found in an eye-tracking study that especially the information in the areas fixed by the eyes is remembered. In contrast, the information that is only perceived peripherally remains less memorable.

Therefore, consumers make decisions with their eyes and buy the products they see (Nordfält, 2011). At the same time, consumers can be influenced by many factors while shopping. In addition to the wide range of products on offer, the purchasing decision is influenced by the design of the sales room, the presentation of the goods on displays and the product packaging (Gröppel-Klein, 2007). In an eye-tracking study at the point of sale, Clement et al. (2013) identified the elements on packaging influencing the purchase decision. Based upon these insights they proposed a packaging design with simple features in order to achieve an increased probability of initial attention. Ultimately, this attention also has a positive influence on the purchase decision. For producers this means not only placing the goods in such a way that they are perceived and found by the consumer but also that packaging and displays are designed to be simple and target-group-oriented as an important point of contact to the customer (Huddleston et al., 2015).

Eye-tracking studies

Whether and for how long individual elements of displays and packaging are perceived can be measured by using eye-tracking methods (Duchowski, 2007). While many eye-tracking studies were carried out at the laboratory to examine product packaging (Huddleston et al., 2018), there are only a few studies that were realised in a regular shopping environment. Eye-tracking studies at the point of sale demonstrated that individual display and packaging elements have an influence on visual attention, search and buying intention as well as willingness to pay (Clement et al., 2013; Grunert, 2011; Huddleston et al., 2015; Janssen & Hamm, 2012). Laboratory studies analysing the perception of packaging demonstrated that the logo and images attracted attention, while the product name had little impact (Choloewa-Wójcik & Kawecka, 2015; Wästlund et al., 2018). Van Loo et al. examined the perception of individual labels that visualize sustainability (e.g. Fair Trade and Rainforrest Alliance) in an eye-tracking laboratory study. They also established connections between consumers' attitudes to individual sustainability attributes and the visual perception of sustainability labels. The results confirm that the importance of sustainability attributes for visual attention is relevant. Consumers who are more concerned with and focused on sustainability attributes value them more (Van Loo et al., 2015).

Consumers who associate individual packaging elements (labels) with sustainability have a higher probability of buying this product, and they also place more trust in it (Samant et al., 2016). To measure the perception of individual labels, logos and images, the authors correlated the eye-tracking metrics "total fixation duration" and "total fixation count" (Samant et al., 2016, Huddleston et al., 2015, van Loo et al., 2015, Clement et al., 2013). In addition to bottom-up factors (sustainability labels, label information), van Loo et al. (2015) and Samant and Seo (2015) also incorporated top-down factors (label knowledge, attitude towards sustainability attributes). These factors are considered to influence perception according to the theory of Wedel and Pieters (2008).

Hypothesis resulting from the literature review

In reference to the perception of elements on packaging that visualize and communicate sustainability, an eye-tracking study revealed that 63 percent of consumers looked at the front of the packaging before buying the product and neglected other areas at the same time (Grunert, 2011). The understanding of elements such as sustainability labels often depends on the design of the label. The label must be self-explanatory in order to associate it with "sustainability" at a glance. Grunert et al. (2014) discovered that consumers who value collectivist values more than individual values pay more attention to sustainability issues related to food (Grunert et al., 2014). Van Loo et al. (2015) examined visual attention employing an eye-tracking experiment. They were able to confirm that consumers with a higher sustainability awareness spend more time looking at sustainability labels (e.g. the Fairtrade label) (Van Loo et al., 2015). Based upon this, we formulate the first hypothesis:

H1: *Consumers with a positive attitude towards sustainable and regional foods look longer at individual display elements that address sustainability aspects.*

In addition, it should be examined to what extent consumers regard this direct juice as a sustainable foodstuff and, after shopping, remember the display elements that should visualise the sustainability dimensions. Lee and Ahn (2012) showed in a study that only the total fixation duration and not the number of short fixations counts influences the memory of different elements on advertisements. The longer the

respondents looked at an element of an advertisement, the better they could remember it (Lee & Ahn, 2012). Based on these results, the metric "total fixation duration" is used for the present study in relation to the memory measured in the questionnaires. It was of particular interest to measure differences in behaviour with regard to the memory of individual display elements between customers with a positive or less open-minded attitude towards sustainable foods. On this basis, we establish the second hypothesis:

H2: *Consumers with a positive attitude towards sustainable and regional foods remember more strongly individual display elements that visualise sustainability aspects.*

Previous studies on the willingness to pay of consumers with a high level of environmental awareness and a positive attitude towards buying sustainable foods demonstrated that purchasing behaviour can be influenced (Grunert, 2011; Grunert et al., 2014). Janssen and Hamm (2012) carried out choice experiments and structured interviews with over 2,400 consumers of organic food in six European countries. They discovered that consumers who prefer organic food have a higher willingness to pay than occasional shoppers (Janssen & Hamm, 2012) do. However, another study found that the main obstacle for not buying sustainable foods was the price perceived as too high (Grunert, 2011). Based on these studies, we put forward the third hypothesis:

H3: *Consumers with a positive attitude towards sustainable foods have a higher willingness to pay.*

Methodology

Research instrument

To test these three hypotheses, eye-tracking technology was combined with a survey. The research instrument consisted of two parts. First, the field study examines the perception of bottom-up factors (individual display elements) of consumers. Eye-Tracking technology is applied to measure the perception. Second, consumers are asked about their attitudes towards sustainable food with the help of a preliminary survey. Subsequently, the analysis is designed in a way to relate these top-down factors with the perception of individual display elements. Previous eye-tracking studies demonstrated that bottom-up factors influence visual attention in brand searches significantly more than top-down factors (Chandon et al., 2009; Wedel & Pieters, 2008). Displays play a special role because they have a positive influence on purchasing decisions. Hence, consumers who spend a lot of time looking at displays are more likely to buy the product (Behe et al., 2013).

For this purpose, 32 consumers were recruited before shopping in a supermarket in the town of Nordhorn (Lower Saxony, Germany). All participants were rewarded with a 5 € gift voucher from the supermarket. At first, the test persons were informed about the course of the study, and they were asked to provide information on socio-demographic characteristics (age and gender) as well as their assessment of sustainability aspects (figure 1, step 1: preliminary interview). Based on the results of von Meyer-Höfer (2016), the importance of the sustainability aspects "regionality", "ecological production", "socially committed company" and sustainable product was asked on a five-step Likert scale (from "agree" to "disagree"). In the second place, the test persons were given the task of buying the organic juice "Emsländer", whereby the purchasing area was limited to the vegetable department of the supermarket. The test subjects' eye movements syeres recorded during the shopping process with the help of "Tobii Pro Glasses 2" eye-tracking glasses (figure 1, step 2: verification of the perception). The individual design elements of the display were defined as areas of

interest (AOI) to communicate the sustainability of the organic juice. The visual attention was captured with the eye-tracking metric "total fixation duration" of this AOIs. In the third place, the test persons were asked to answer questions about their memory of pictures, slogans and place of production on the display and the juice bottle on a five-step Likert scale ("I fully agree" to "I do not agree at all") (see table 2). In step 3 it was asked whether consumers with a positive attitude towards sustainability have a higher willingness to pay. Another question focussed on the willingness to pay for one litre of direct fruit juice from the region and form organic production (Figure 1, step 3: subsequent interview). The task was to detect: (1) whether consumers with a positive attitude towards sustainable foods gave the display elements at the point of sale greater visual attention and (2) consumers remember the design elements of the display better. For this reason the "total fixation duration" of AOIs was related to the survey results by means of mean value comparisons (figure 1, step 4: evaluation, visualisation and consolidation of the results).

Figure 1
Alignment of the eye-tracking study
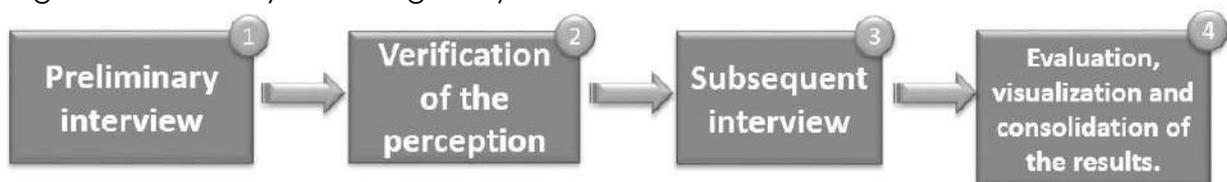
Source: author's illustration

Data and statistical methods

The eye-tracking data collected in the filed study were analysed in the following steps. The display was divided into a total of 6 AOIs visualizing the sustainability aspects displayed in figure 2. A total of 25 out of 32 participants noticed the display. The analysis of the heat map in Figure 2, which displays the intensity with which the test persons looked at the individual AOIs, confirms a total of four focal points of the glances: (1) the image "three bottles", (2) the headline 1 with the brand name "Emsländer", (3) the advertising slogan "local berries" and (4) the picture 1 with "Apples, currants and bilberries".

In order to verify whether consumers with a positive attitude towards sustainable foods looked longer at individual display elements, the questions on the importance of the components "regionality", "ecological production", "sustainable product" and "social company" were first combined into a construct "sustainability as a whole". The corresponding Cronbach alpha value of .802 indicates a high internal consistency of this construct. Based on the overall sustainability construct, the test persons were divided into two groups: "sustainability important" and "sustainability unimportant". The group separation was carried out on a scale of 5 (agree (1.00) to disagree (5.00) at a value of 2.00. The mean values of the two groups of respondents "Sustainability important" (n=15) and "Sustainability unimportant" (n=17) were then compared in relationship to the individual AOIs. Furthermore, the mean values from the surveys on individual packaging or display elements were compared. The t-test was carried out to control the significance of the differences in mean values.

Results

The results of the filed study showed no substantial and significant differences in gender. The distribution between men and women was largely balanced. Due to the low sample size, the eye-tracking metrics only show a tendency towards a stronger consumers' perception of individual images, slogans and headlines with a positive attitude towards sustainable foods. Heading 2 with the slogan "Superfood Blend of Berry Juice", which is intended to express both the special character of the drink and a possible area of use as a mixed drink, is considered less intensively. The same applies to picture 2 with the fruits "elderberry, currant, blueberry". Overall, the lower part of the display, which is no longer at eye level of the test persons, is viewed less intensely. These results support hypothesis 1 (H1): consumers with a positive attitude towards sustainable and regional foods look longer at individual display elements that address sustainability aspects.

The results demonstrate that the "sustainability important" group looked at AOIs for a longer time (average of 0.39 sec). Not all test persons looked at the defined AOIs. As a result, a tendency towards a stronger perception of individual AOIs of the "sustainability important" group can be demonstrated. A total of 22 test persons looked at the picture "three bottles". Exactly 10 test persons of the group "sustainability important" fixed the AOI with an average of 1.36 sec. This indicates a stronger perception. Heading 2 was fixed by the group "sustainability unimportant" at 0.25 sec. On average, this is for a longer period by all AOIs, whereby the sample of 3 test persons is notably small (table 1).

Figure 2
Display: areas of interests (AOIs) (left) and heat map (right)

Note: left: representation of the 6 AOI´s, right: absolute duration is calculated by the duration of fixations, whereas the warmest colour represents the highest value.
Source: Author's illustration

Table1
Total fixation duration (average): poster of display (frontal)

Total fixation duration (in sec./incl. zeros)	Display „Poster frontal"			
	Sustainability important		Sustainability unimportant	
AOI	Mean	SD	Mean	SD
Picture "three bottles"	1.36*	2.19	0.44**	0.50
Slogan "local berries"	0.33*	0.75	0.09**	0.35
Headline 1 "Emsländer"	0.28*	0.54	0.18**	0.39
Headline 2 "Superfood blend of berry juice"	0.18*	0.36	0.25**	0.80
Picture 1 "apples, currants, bilberries"	0.18*	0.43	0.06**	0.15
Picture 2 "elderberry, currants, bilberries"	0.04*	0.10	0.04**	0.15
All	**0.39***	**0.55**	**0.18****	**0.33**

Note: Total fixation duration (average) in seconds to AOI (include zeros)
*picture n=10, slogan n=4, headline 1 n=6, headline 2 n= 5, picture 1 n=4, picture 2 n=2, all n=12
**picture n=12, slogan n=2, headline 1 n=6, headline 2 n= 3, picture 1 n=4, picture 2 n=2, all n=13,
Source: Author's calculation

Overall, the gaze plot on the left in figure 3 visualizes the rather concentrated views of the individual AOI's. Hence, this supports the statement of the stronger perception of the group "sustainability important". This group looked at the display with an average of 3.47 sec. In contrast, the gaze plot on the right displays the rather diffuse and aimless glances of consumers who consider sustainability as unimportant. The average of the total fixation duration of the display with 1.72 sec. supports the result of a weaker perception of this group. The numbering of the circles indicates the order in which the customers view the individual AOI's. The size of the circles visualizes the duration of the view, which appears larger especially on the AOI's in the left gaze plot (Figure 3).

The memories of the special features of the newly introduced organic juice are well (2.00) to moderately (3.41) among all test persons. A comparison of the two groups of respondents shows that the "sustainability important" group remembered individual display elements better (overall 2.27) than the "sustainability unimportant" group (2.93) (see table 2). On average, the "sustainable important" group was also able to remember more distinct images. The mean values of comparison also demonstrates a significant difference between the two groups "sustainability important" (2.00) and "sustainability unimportant" (3.12) with regard to the memory of images on the packaging of the organic juice. Due to the small sample size, none of the other mean value comparisons revealed significant differences between the two groups.

Figure 3
Gaze Plot „sustainability important" (left) vs. Gaze Plot „sustainability unimportant"

Note: left: illustration of the gaze plot "sustainability important" (n=17), right: illustration of the gaze plot "sustainability unimportant" (n=15)
Source: Author's illustration

The results support hypothesis 2 (H2): subjects with a positive attitude towards sustainable and regional foods are more likely to remember individual display elements that visualize sustainability than subjects who are less open to this issue (table 2).

Table 2
Recollection of individual packaging or display elements

Questions	Sustainability important		Sustainability unimportant	
What can you remember?	Mean	SD	Mean	SD
I know what makes the juice special.	2.27	1.16	3.00	1.36
I remember the images on the juice bottle.	2.00*	1.00	3.12*	1.16
I remember the images on the display.	2.73	1.48	3.41	1.06
I know where the juice is produced.	2.07	1.28	2.18	1.07
All	**2.27****	**0.83**	**2.93****	**0.77**

Note: Likert scale where 1 = totally agree, 5 = totally disagree
* t-Test: p=0.007 (p<0.05)   **t-Test: p=0.028 (p<0.05)
Source: Author's calculation

The results of the survey in table 3 show whether the willingness to pay for a litre of direct fruit juice from the region and from organic production is positively influenced by consumers who regard sustainability as important.

Table 3
Willingness to pay [in €] for one litre of direct juice from the region and from organic production

Question What is the maximum price you would pay?	Sustainability important		Sustainability unimportant	
	Mean	SD	Mean	SD
For 1 litre direct fruit juice from a conventional manufacturer, you pay about € 1.80 in the supermarket. How much would you pay at most for 1 litre of juice from the region and organic production?	2.78*	0.99	2.34*	0.92

Note: values in €
* t-Test: p=0.209 (p<0.05)
Source: author's calculation

The group "Sustainability is important" was prepared to pay an average of € 2.78 for a litre of direct fruit juice. Consumers who were less open to sustainability said they would pay an average of € 2.34 for a litre sustainable direct juice. Due to the high standard deviation for the small group sizes, the mean difference between the two customer groups is not statistically significant. Nevertheless, the absolute difference of as much as ¢ 44 in the expressed willingness to pay indicates that customers who pay particular attention to the issue of sustainability tend to be more willing to pay for sustainable products than customers who are less open to this issue. Overall, it can thus be stated that there are at best weak indications that support hypothesis 3.

Discussion and conclusion

The evaluation of the combined eye-tracking/survey study proved the fundamental suitability of this methodology for the analysis of display design for sustainable foods in a supermarket (field study). The study has demonstrated that, in addition to bottom-up factors such as images, headlines and slogans on the display, top-down factors such as attitudes towards sustainable foods also influence consumer perception (Chandon et al., 2009; Wedel & Pieters, 2008). At the point of sale, the results indicate that consumers with a positive attitude towards sustainable foods deal more intensively with the product information. The subsequent survey to remember individual elements on the juice bottle and the display confirms this. Due to the short observation period and orientation phase of consumers during shopping activities, the pictures and headlines on the display should be designed and placed in such a way that they achieve a high thematic significance. The results also indicate that a positive attitude towards sustainable foods tends to have a positive effect on consumers' willingness to pay (Behe et al., 2013). A study that examined the perception of fair trade labels also confirm this (Van Loo et al., 2015). In addition, the gaze recordings confirm that images and headlines in the upper part of the display, at eye level with the consumer, were increasingly perceived. Information, images and slogans on the lower poster were only perceived by a small number of consumers. For this reason, it is advisable to design the display with as little as possible text and images in order to achieve the highest possible initial attention at the point of sale (Clement et al., 2013). For the trader the study therefore provides new approaches for the design of the display. In particular, the display must not be overloaded with various topics that are ultimately not perceived. However, traders should focus on a few concise display elements that represent and communicate "sustainability".

Further studies must analyse additional bottom-up factors such as shape and colour of individual elements and pictures of a display or product packaging in order to detect why an element attracts attention and why it is better perceived and remembered. This should be analyzed to understand why consumers ignore some elements and advertising slogans. The experience with regional food can also be included and, in conjunction with the demographic characteristics, provide clues as to how consumers visually evaluate a display before making a purchase decision (Huddleston et al., 2015). For example, an in depth analysis may be useful to detect whether a sustainability aspect is visualised with a single element. In addition, other metrics, such as fixation counts, can be used to analyse perception (van Loo et al., 2015).

One limitation of this eye-tracking study is the low number of samples. In particular, the eye-tracking metrics could not achieve a significant result due to fewer glances at individual AOIs. This may change with a representative sample size (Lamberz et al., 2019). Another limitation of the study refers to the number of sample supermarkets. The study was conducted in only one single supermarket. The inclusion of further supermarkets has the potential to indicate the effect of different designs of supermarkets and increase the number of respondents. This extended approach may help to provide more insights into the perception of the packaging and display of the organic juice by different target groups at the point of sale.

Due to the weak tendency of consumers with a high sustainability, awareness to be more willing to pay, future studies should have a larger sample size and record the influence of socio-demographic variables. The incorporation of different pay grades, social status and higher education has the potential to provide more detailed insights into the willingness of target groups to pay (Grunert et al., 2014).

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About the authors

Julia Lamberz is currently a Research Assistant at Osnabrück University of Applied Sciences` Lingen Campus with a focus on marketing research. She received her Master's degree in Science Marketing from the Technische Universität Berlin. She can be contacted at **j.lamberz@hs-osnabrueck.de.**

Thorsten Litfin is a Professor of Marketing, Service and Innovation Management at Osnabrück University of Applied Sciences` Lingen Campus. He received his PhD from the Institute of Innovation Management at Christian-Albrechts-University of Kiel. His research interests include product and pricing strategies for innovative products and services. He can be contacted at **t.litfin@hs-osnabrueck.de.**

Özlem Teckert is currently a Research Assistant at Osnabrück University of Applied Sciences` Lingen Campus with a focus on marketing research. She received her Master's degree in Economics and Laws from the University of Oldenburg and is currently a PhD candidate in the Department of Business Administration, Economics, and Law. She can be contacted at **o.teckert@hs-osnabrueck.de.**

Gunther Meeh-Bunse is a Professor of Finance and Accounting at the University of Applied Sciences at Osnabrück` Lingen Campus. He studied business administration at the University of Saarland and received his PhD from the University of German Armed Forces in Munich. His research interests include managerial accounting and corporate social responsibility. Author can be contacted at **g.meeh-bunse@hs-osnabrueck.de.**

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How Impulsivity influences the Post-purchase Consumer Regret?

Katarina Sokić, Đuro Horvat, Sanja Gutić Martinčić
EFFECTUS - College for Law and Finance, Zagreb, Croatia

Abstract

Background: The role of impulsivity in post-purchase consumer regret is unclear and intriguing because of the negative emotions that underlie both constructs. It is particularly important to examine the impact of impulsivity on the relationship between regret and the Emotionality dimension of the HEXACO model of personality. **Objectives:** The purpose of this paper was to investigate the associations between consumer regret components: outcome regret and process regret, attention, motor and non-planning dimensions of impulsivity and Fearfulness, Anxiety, Dependence and Sentimentality domains of Emotionality. **Methods/Approach:** The sample consisted of undergraduates from Zagreb, Croatia (M_{age} = 25.93, 56% females). The correlation and the regression analysis were performed. We used the Baratt impulsivity scale (BIS-11), the HEXACO-PI-R Emotionality scale and the Post Purchase Regret Scale (PPRS). **Results:** The PPCR total score was associated with the BIS-11 total score, attention and non-planning impulsivity. Regret due to foregone alternatives was related to attention and non-planning impulsivity, while regret due to a change in significance was related only to attention impulsivity. Regret due to under-consideration positively correlated with non-planning impulsivity. **Conclusions:** The results indicate that relations between impulsivity and consumer regret have an important role in understanding consumer behavior and that impulsivity has a moderate association between consumer regret and Emotionality.

Keywords: consumer regret, attention impulsivity, motor impulsivity, non-planning impulsivity, Emotionality
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Introduction

Customer satisfaction is getting a lot of attention from marketing managers. One of the key issues in consumer behavior refers to the understanding consumer emotions. Consumer regret plays a significant role in consumer behavior because it influences future consumer decisions for a particular product (Michenaud, 2008) and decreases the level of consumer satisfaction (Bui et al., 2011). Specifically, negative emotions

such as regret, remorse and anxiety, associated with a particular product lead to the avoidance of this product in the future as well as to the avoidance of a place of purchase (Lee & Cotte, 2009; Zeelenberg & Pieters, 2007).

Regret is a complex distressing emotion, which can be experienced about decision processes and decision outcomes (Zeelenberg & Pieters, 2007). Some of the most important components of regret are responsibility, self-accusation, and counterfactual thinking (CFT) (Lee & Cotte, 2009). CFT is a psychological construct that involves the tendency of creating alternative outcomes for what has already happened (Kahneman & Dale, 1986). Regret includes affective and cognitive elements. The affective elements of regret are related to negative mental health symptoms such as emotional distress, depression, anxiety and low level of well-being; Cognitive elements of regret are associated with positive and functional outcomes such as the positive impact on future behavior and improve decisions-making (Buchanan et al., 2016).

According to Decision Justification Theory (DJT) (Connolly & Zeelenberg, 2002) which is one of the most dominant theories of regret, decision regret consists of two components: self-blame regret and comparative outcome regret. Based on this theory, Lee and Cotte (2009) have developed the Post-Purchase Consumer Regret scale (PPCR).

Impulsivity is the predisposition for rapid, unplanned reactions to internal and external stimuli, regardless of the negative consequences (Moeller, 2009). Besides, it is a complex psychological construct, which includes different emotional and behavioral features (i.e., low inhibitory control, irresponsibility, impatience, a lack of planfulness and foresight, alienation and distrust) (Moeller et al., 2001; Stanford, et al., 2009). Multidimensional nature of impulsivity encompasses a range of maladaptive traits such as problems with the attention, thrill adventure-seeking, inability to delay gratification, antisociality, aggression (Smith et al., 2006), but also with depression, self-harming, suicide attempts (Swann et al., 2005; Swann et al., 2008) and substance abuse (Lane et al., 2007). According to these findings, it can be assumed that impulsivity is associated with both, externalizing problems (e.g. conduct disorders, antisocial behavior, rule breaking, aggression, defiance, substance dependence) (Achenbach & Rescorla, 2001; Verona et al., 2004) and internalizing symptoms (e.g. depression, anxiety, withdrawal) (Forns et al., 2001). Moreover, impulsivity and self-regulation is related to negative emotions such as regret (Shalev & Sulkowski, 2009).

The complex nature of impulsivity includes attention deficits, motor restlessness and lack of planning (Patton et al., 1995). One of the most used self-report measures of impulsivity, the Baratt impulsivity scale (BIS-11; Patton et al., 1995) measures three dimensions of impulsivity: attention, non-planning and motor impulsivity. Attention impulsivity manifests as an inability to pay (focus) attention, non-planning impulsivity reflects a lack of self-control (planning and careful deliberation), and poorly expressed cognitive complexity (enjoying complex mental tasks), and motor impulsivity is a combination of imprudence and inconsistent lifestyle.

The HEXACO model of personality (Lee et al., 2004) is a relatively new model in personality research consists of six dimensions: Honesty-humility, Emotionality, Extraversion, Agreeableness, Conscientiousness, and Openness to experience. This model is similar to the Big Five model of personality (McCrae & Costa, 1987). However, one of the key differences between these two personality models relevant to regret is Emotionality dimension. In the HEXACO model Emotionality dimension includes facets of Sentimentality and Fearfulness not represented in the Emotional stability dimension of the Big Five. Except for these facets, Emotionality dimension of the HEXACO model includes Anxiety and Dependence facets (Ashton et al., 2014).

"High scorers on anxiety tend to become preoccupied even by relatively minor problems" (Ashton et al., 2014, p. 142). Dependence facet of Emotionality reflects individual differences in tendencies to seek emotional support from others (Lee et al., 2004). Previous studies have showed that impulsivity was related to Neuroticism, Openness, Conscientiousness, Extraversion and Agreeableness (eg. Mao et al., 2018).

In order to extend what we know about the post-purchase consumer regret, it is valuable to examine consumer regret in relation to some relevant personality traits such as impulsivity and emotionality.

Literature review

The complex nature of consumer regret

The constructs of the consumer regret, as operationalized by the Post-Purchase Consumer Regret scale (Lee & Cotte, 2009) have previously been examined in relation to the Big Five model of personality. To date, only one study has examined relationships between PPCR and The Big Five Inventory (McCrae & Costa, 2008). This study (Zulkarnain et al., 2018) found positive but low correlations for all five Big Five personality dimensions (Neuroticism, Openness to experience, Agreeableness, Conscientiousness, and Extraversion) with outcome regret (r = .24 to .29) and with process regret (r = .19 to .24). Additionally, results of regression analysis in this study showed that Neuroticism and Agreeableness significantly positively predicted outcome regret ($ß$ = .18, .17, p < .01), and that only Neuroticism positively predicted process regret ($ß$ = .24, .17, p < .01). Bui et al. (2009) found significant direct effect between consumer regret and negative emotion ($ß$ = .53, S.E. = 0.11, p < .001) and satisfaction level ($ß$ = - .54, S.E. = 0.09, p < .001). Moreover, this study has shown that there is a mediating effect of negative emotions on the link between regret and the extent of satisfaction levels.

The link between impulsivity and emotionality

The relationship between impulsivity and emotionality is intriguing. At first glance, impulsivity could be related to some aspects emotionality. Findings from recent studies have shown that impulsivity as well as similar constructs such as disinhibition, and antisocial tendencies are mainly related to some indicators of emotional distress such as mood disorders (Swann et al., 2008), suicide attempts (Dougherty et al., 2004), depression (Van Den Eynde et al., 2008), anxiety (Xia et al., 2017), personal distress (Sokić & Ljubin Golub, 2019), negative emotional states (e.g. stress, anxiety and depression) (Međedović et al., 2018), anxious and avoidant attachment (Sokić & Wertag, 2018), emotion dysregulation (Garofalo et al., 2018), food addiction (Meule et al., 2017).

Various studies indicate that the BIS scales and Emotionality domain of the HEXACO model, demonstrate similar associations with relevant external correlates, such as antisocial and criminal behavior (Maneiro at al., 2017; Međedović, 2017a) and disinhibition (Gatner et al., 2016; Ruchensky & Donnellan, 2017). BIS scores are associated with normal and pathological personality traits. All three BIS subscales were negatively correlated with Conscientiousness; motor impulsivity was positively related to Extraversion, whereas attentional impulsivity was positively related to Neuroticism (Lange et al., 2017).

The BIS dimensions accounted for a significant amount of variance in criteria conceptually relevant to consumer regret. In percentage terms, BIS-11 total score and Difficulties in Emotion Regulation Scale (DERS; Gratz & Roemer, 2004) explained

variance in personality disorders (PD) as follows: 39% in borderline PD, 24% in schizotypal PD, 18% in paranoid PD, and 15% in schizotypal PD (Garofalo et al., 2018).

The present study and hypotheses

First, it is of particular interest to study the relationship between impulsivity dimensions, post-purchase consumer regret and Emotional domains in light of recent findings that have shown similar relationships between these psychological constructs and indicators of emotional distress (see Bui et al., 2011; Garofalo et al., 2018; Lange et al., 2017; Međedović et al., 2018; Zulkarnain et al., 2018). The second reason for studying the relationship between the impulsivity dimensions and the post-purchase consumer regret is that the BIS model of impulsivity may help to clarify how and why dimensions of impulsivity differently predict certain aspects of consumer regret. A more specific aim of the study was to clarify the influence of impulsivity on the relationship between Emotionality and its domains (i.e., Fearfulness, Anxiety, Dependence and Sentimentality), and consumer regret. Finally, consumer emotions greatly influence consumer behaviour and attitudes, it is therefore important to understand the mechanisms underlying these emotions. Impulsivity is associated with an unhealthy lifestyle such as addictive, risky and hedonistic behaviors (Goodwin et al., 2016). Furthermore, impulsivity is positively associated with negative correlates of happiness, such as mood disorders (Swann et al., 2008), depression (Van Den Eynde et al., 2008) and anxiety (Xia et al., 2017). Furthermore, consumer regret is negatively associated with levels of satisfaction, and positively with negative emotions (Bui et al., 2009).

To the best of our knowledge, the relationship between the HEXACO dimension of personality and PPCR as well as the relationship between the BIS dimensions of impulsivity and PPCR components has not been investigated so we examined these relationships in this study. It is reasonable to assume that impulsivity and some other personality traits such as Emotionality influence on regret considering that these traits, as well as regret, include emotional reactivity and anxiety.

Consistent with the findings that BIS total score is associated with anxiety apprehension and preoccupation (Taylor et al., 2008); we expected that: *H1. PPCR total score will be positively associated with BIS-11 total score.*

Since Regret due to foregone alternatives is associated with a choice regardless of how good it was and includes self-blame and a sense of responsibility for making bad decisions (Lee & Cotte, 2009), and based on empirical evidence showing that attentional impulsivity is positively related to neuroticism (Lange et al., 2017), and non-planning impulsivity is related to depressive episodes (Swann et. al., 2008), we predicted that: *H2. Regret due to foregone alternatives will be positively associated with BIS-11 total score, attention and non-planning impulsivity.*

Regret due to a change in significance is a part of outcome regret. The focus here is on whether a product can meet the changing needs of consumers. Based on the theoretical description that non-planning impulsivity reflects an inability to plan (Patton et al., 1995), we expected that: *H3. Regret due to a change in significance will be positively associated with BIS-11 total score and non-planning impulsivity.*

Regret due to under-consideration is a form of process regret for insufficient thinking before buying. This component of process regret occurs when an individual thinks that should have been made more effort in the decision-making process (Lee & Cotte, 2009). Based on findings showing that motor impulsivity is related to low conscientiousness (Malesza & Ostaszewski, 2016), low planning and low organization (Spinella, 2005), non-planning impulsivity is negatively related to index of executive function (Spinella, 2005), and that attention impulsivity includes cognitive instability (Patton et al., 1995), we predicted that: *H4. Regret due to under-consideration will be*

positively associated with BIS-11 total score and with attention and non-planning impulsivity.

When an individual feel regret for too much time and effort put into the buying process, it is about Regret due to over-consideration (Lee & Cotte, 2009). Based on the theoretical description of impulsivity (Patton et al., 2005) and regret (Connolly & Zeelenberg, 2002), we expected that: *H5. Regret due to over-consideration will be unrelated to BIS-11 total score and all of the BIS-11 dimensions.*

Based on a theoretical description that regret is aversive emotion (Lee & Cotte, 2009), empirical evidence showing that Neuroticism from Big Five model of personality positively predicted outcome and process regret and (Zulkarnain et al., 2018), as since regret is linked to symptoms of emotional distress such as depression and anxiety (Krainess et al., 2017) we predicted that: *H6. PPCR total score will be positively associated with Emotionality (particularly Sentimentality, Anxiety and Dependence facets).*

Methodology

Participants and procedure

The sample consisted of 311 students from various universities in Zagreb (Croatia). The questionnaires of 39 participants were excluded from analyses due to missing data, and the final sample consisted of 272 students (56% females), ranging in age from 19 to 30 (M_{age} = 25.93, SD = 4.78). Consumer behavior, impulsivity and emotionality are often tested on the student population (e.g. Bui et al., 2009; Gatner et. al., 2016; Međedović, 2017b; Stanford et al., 2009). Based on the above, we consider students sample as suitable in this study (see Pejić Bach et al., 2018).

The students participated on a voluntary basis and gave their written consent before completing the questionnaire. They were asked to complete a battery of self-report measures anonymously and they received no compensation for their participation. Respondents were informed that they could withdraw from the survey at any time. Average time to complete the questionnaire was 30 minutes. The study was approved by the ethics committee of the Faculty of Humanities and Social Sciences, University of Zagreb, Department of Psychology.

Research instruments

In this research, we used self-report questionnaires.

Consumer regret was measured by Post Purchase Regret Scale (PPCR; Lee & Cotte, 2009). PPCR is a 16-item self-report questionnaire assessing two regret components i.e., outcome regret which consists of two dimensions: regret due to foreign alternatives (e.g. *I now realize how much better my other choices were)* and regret due to a change in significance (e.g. *I wish I hadn't bought the product because it is now useless to me*), and process regret which captures regret due to under consideration dimension (e.g. *I feel that I did not put enough consideration into buying the product*) and regret due to over-consideration dimension (e.g. *I wasted too much time in making my decision*). Each dimension consists of 4 items. Items are rated on a 7-point Likert scale. Scores for each PPCR dimensions were calculated as sums of ratings on associated items.

To measure impulsivity, we used the Barratt Impulsivity Scale -11 (BIS-11; Patton et al., 1995). This 30-item self-report questionnaire assesses total score on impulsivity and three dimensions of impulsivity: attentional (8 items, e.g. *I do not "pay attention"; I "squirm" at plays or lectures*), motor (11 items, e.g. *I do things without thinking; I change jobs),* and non-planning impulsivity (11 items, e.g. *I save regularly; I am more*

interested in the present than the future). The items are rated using a 4-point Likert-type scale (from 1= *Rarely/Never* to 4 = *Almost Always/Always*). *The sum of the scores on the subscales shows the total level of impulsivity. The scale was used on samples from the clinical, forensic and general populations proved to be very reliable* (Stanford et al., 2009).

The Emotionality dimension was measured using is a 10-item self-report scale from HEXACO-60 (Ashton & Lee, 2009; for Croatian version see Babarović & Šverko, 2013) conceptualized Emotionality. This scale yielding scores on four subscales of Fearfulness, Anxiety, Dependence, Sentimentality and a total emotionality score, by using a 5-point Likert scale, from 1 (*strongly disagree*) to 5 (*strongly agree*).

Statistical methods

The relationship between impulsivity, consumer regret and Emotionality was investigated through zero-order correlations. The contribution of impulsivity and emotionality in the prediction of consumer regret was explored through hierarchical multiple regression analysis in which scores for the three BIS-11 and Emotionality subscales were entered as predictors of criterion variables consisting of the four components of PPCR. Since there were gender differences on impulsivity and Emotionality, gender was included as control variable in each analysis. In all regression models, gender was entered at Step 1, Emotionality subscales were entered at Step 2, and BIS subscales at Step 3.

To explore potential significant interaction effects between dimensions of impulsivity and facets of Emotionality in predicting consumer regret, a series of hierarchical linear regression models were computed, using each criterion measure as the dependent variable, while impulsivity dimensions and Emotionality domains were entered as predictors. The standard scores on the BIS-11 and Emotionality subscales, gender and age scores were entered as predictors at Step 1, and BIS-11x Emotionality subscales interactions were entered in Step 2.

Results

Descriptive statistic

Results shown in Table 1 demonstrated corresponding psychometric characteristics for used scales; all skewness and kurtosis measures were in a range from -2 to +2, which is within acceptable ranges for these values (see Gravetter & Wallnau, 2014). Therefore, we can conclude that the normality distribution was not a problem in this study. The measures of consumer regret and emotionality showed adequate reliability except for measures of impulsivity, which showed some lower Cronbach's a values.

The variance inflation factors (VIF) through regression analyses ranged from 1.20 to 1.79, which indicates that multicollinearity was no problem in this study.

Table 1
Descriptive statistics and psychometric characteristics of all scales and subscales (N= 272)

	M	SD	Sk	Ku	a
PPCR	52.29	18.86	0.16	-0.21	.93
Regret due to Foregone Alternatives	12.32	5.54	0.56	-0.07	.92
Regret due to a Change in Significance	12.72	5.93	0.28	-0.80	.90
Regret Due to Under-Consideration	14.20	6.16	0.06	-0.70	.90
Regret Due to Over-Consideration	13.18	6.16	0.39	-0.56	.92
BIS-11	60.92	8.76	0.10	-0.30	.76
Attentional impulsivity	16.82	3.36	0.44	0.09	.60
Motor impulsivity	21.31	3.92	0.45	0.14	.61
Non-planning impulsivity	22.67	4.19	-0.08	-0.36	.60
Emotionality	31.72	6.28	-0.32	0.24	.76
Fearfulness	8.53	2.52	-0.15	-0.46	.60
Anxiety	7.40	1.85	-0.74	0.41	.56
Dependence	5.62	1.99	-0.03	-0.49	.63
Sentimentality	10.15	2.60	-0.23	-0.21	.70

Note: a = Cronbach's a. Sk - skewness, Ku – kurtosis, M - mean, SD - standard deviation.
Source: Authors' work

Relations among the PPCR, BIS-11 and Emotionality
As shown in Table 2, the results of bivariate correlations analysis partially supported our hypotheses. In accordance with Hypothesis 1, PPCR total score showed positive relationship with BIS-11 total score.

Table 2
Pearson's correlation coefficients among all variables (*N*= 272)

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1.	-												
2.	**.86**	-											
3.	**.86**	**.73**	-										
4.	**.86**	**.69**	**.75**	-									
5.	**.61**	**.36**	**.30**	**.28**	-								
6.	.17*	**.19**	.15*	.17*	.04	-							
7.	.13*	.15*	.14*	.08	.08	**.76**	-						
8.	.08	.10	.09	.09	-.01	**.79**	**.49**	-					
9.	.15*	.16*	.09	.16*	.02	**.74**	**.32**	**.32**	-				
10.	-.01	-.05	-.09	.01	.04	-.03	-.15*	-.08	.12*	-			
11.	.04	-.01	.00	.03	.03	.09	-.02	-.02	**.21**	**.73**	-		
12.	.02	-.03	-.03	-.01	.13*	-.13*	-.08	**-.17**	-.06	**.60**	**.33**	-	
13.	.01	.04	-.01	.06	-.04	.09	-.03	.06	.14*	**.68**	**.33**	**.21**	-
14.	-.07	-.10	-.17*	-.03	.02	-.12*	**-.27**	-.10	.04	**.75**	**.32**	**.26**	**.42**

Note: 1. = PPCR total, 2. = Regret due to Foregone Alternatives, 3. = Regret due to a Change in Significance, 4. = Regret Due to Under-Consideration, 5. = Regret Due to Over-Consideration, 6. = BIS-11, 7. Attentional impulsivity, 8. = Motor impulsivity, 9. = Non-planning impulsivity, 10. = Emotionality, 11. = Fearfulness, 12. = Anxiety, 13. = Dependence, 14. = Sentimentality. Bolded values are significant at *p* < .01.**p* < .05.
Source: Authors' work

We expected that regret due to foregone alternatives would be positively associated with BIS-11 total score, attention and non-planning impulsivity what was fully confirmed (Hypothesis 2). In line with Hypothesis 3, regret due to a change in significance was positively associated with BIS-11 total score and non-planning impulsivity. As expected, regret due to under-consideration showed positive

associations with BIS-11 total score and non-planning impulsivity but not with attention impulsivity (Hypothesis 4). In line with Hypothesis 5, results of the current study did not show bivariate correlations between regret due to over-consideration and impulsivity. Hypothesis 6 was not confirmed on the bivariate level.

Results of hierarchical multiple regression analyses (Table 3) demonstrated that, after controlling for age, gender, Fearfulness, Anxiety, Dependence and Sentimentality, dimensions of impulsivity additionally explained 4% of the variance in PPCR total score, 4% of the variance in regret due to foregone alternatives, and 4% of the variance in regret due to under-consideration. Multiple regression analysis also showed that only non-planning impulsivity uniquely and positively related to total results on PPCR total (β = .19), Regret due to Foregone Alternatives (β = .19), and Regret Due to Under-Consideration domains (β = .20). Results showed that Anxiety uniquely positively predicted regret due to over-consideration (β = .15), and that Sentimentality uniquely negatively predicted regret due to foregone alternatives (β = -.18) and regret due to under-consideration (β = -.19).

Table 3
Hierarchical multiple regression analysis of relationships between PPCR, BIS-11 and Emotionality dimensions and facets (N= 272)

			Regret due to…		
	PCSR total	FA	CS	UC	OC
Model 1					
Gender	-.13	-.11	-.01	-.06	-.15*
Age	-.02	-.05	-.12	-.05	.09
R²	.02	.02	.03	.01	.02
Model 2					
Gender	-.11	-.10	-.08	-.06	-.14
Age	-.03	.01	-.09	-.07	.06
Fearfulness	.07	.01	.10	.07	-.01
Anxiety	.07	.02	.02	.01	.15*
Dependence	.03	.10	.03	.05	-.07
Sentimentality	-.13	-.18*	-.19*	-.05	-.02
R²	.04	.04	.06	.02	.05
Change *R²*	.02	.03	.03	.01	.02
Model 3					
Gender	-.11	-.09	-.08	-.06	-.13
Age	-.04	.00	-.11	-.10	.07
Fearfulness	.03	-.03	.07	.03	-.03
Anxiety	.11	.06	.06	.06	.16*
Dependence	.00	.08	.00	.03	-.08
Sentimentality	-.11	-.16	-.17*	-.04	.00
Attentional impulsivity	.02	.05	.00	-.04	.08
Motor impulsivity	.03	.02	.06	.07	-.03
Non-planning impulsivity	.19*	.19*	.13	.20*	.04
R²	.08*	.09*	.08	.06*	.06
Change *R²*	.04*	.04*	.03	.04*	.01

Note: This table shows the standardized beta coefficients are presented. R2 = coefficient of determination. Change R2 = change for impulsivity dimensions entered in a separate step after controlling for gender, age and emotionality facets.
FA= Regret due to Foregone Alternatives, CS = Regret due to a Change in Significance, UC = Regret Due to Under-Consideration, OC = Regret Due to Over-Consideration
*p<.05, **p<.01.
Source: Authors' work

Impulsivity as a moderator of the relationship between post-purchase consumer regret and Emotionality

Results of this study showed four significant interaction effects between dimensions of impulsivity and facets of Emotionality in predicting consumer regret.

As can be see in the Figure 1, attentional impulsivity moderated the relationship between Emotionality and regret due to foregone alternatives (β=-.18, ΔR^2=.03, p<.01). On the high level of attentional impulsivity, Emotionality showed a negative effect on regret due to foregone alternatives, while low-level attentional impulsivity showed a positive effect on this relationship.

As shown in Figure 2, attentional impulsivity moderated the relationship between Dependence and Regret due to foregone alternatives (β=-.15, ΔR^2=.02, p<.05). On the high level of attention impulsivity, the negative relationship between Dependence and regret due to foregone alternatives was more pronounced, while the low-level attention impulsivity showed a positive effect on the relationship between Dependence and regret due to foregone alternatives.

Figure 1
Interaction between Emotionality and attentional impulsivity in the prediction of regret due to foregone alternatives
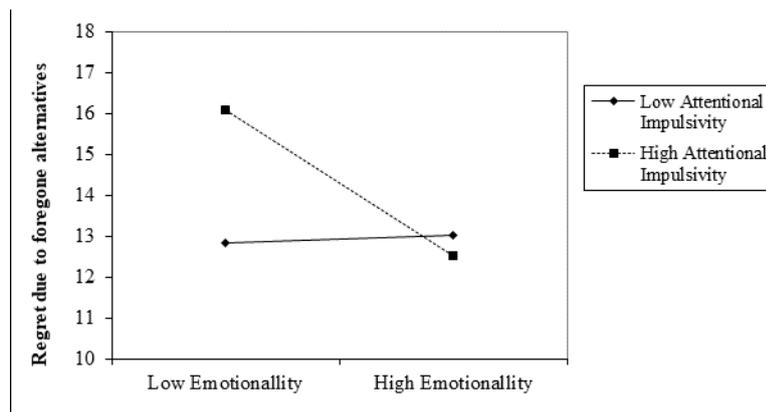
Source: Authors' work

Figure 2
Interaction between Dependence and attentional impulsivity in the prediction of regret due to foregone alternatives
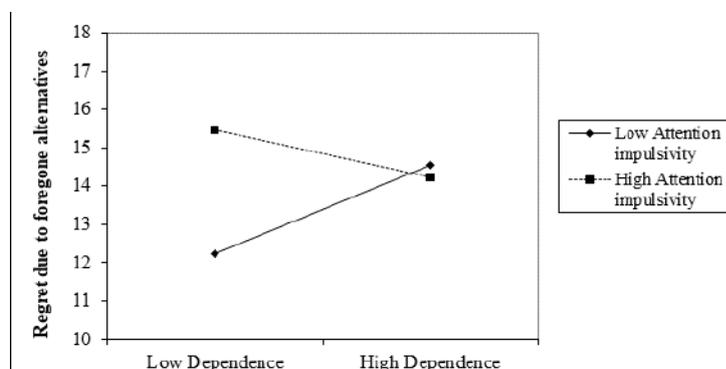
Source: Authors' work

Figure 3
Interaction between Sentimentality and attentional impulsivity in the prediction of regret due to foregone alternatives
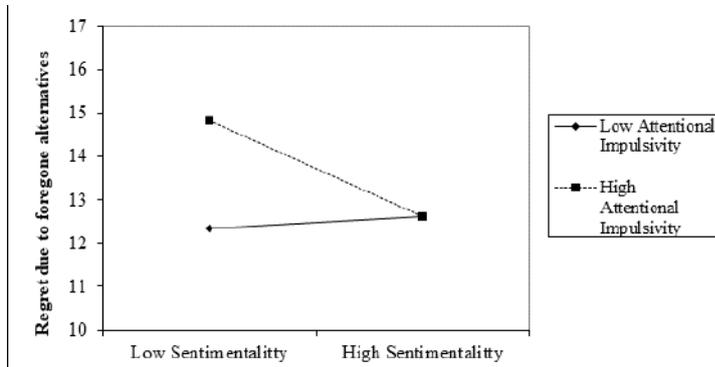
Source: Authors' work

Furthermore, as we can see in Figure 3, on the high-level attention impulsivity showed a negative effect on the relationship between Sentimentality and regret due to foregone alternatives ($β=-.13$, $ΔR^2=.02$, $p<.05$).

Figure 4
Interaction between Dependence and motor Impulsivity in the prediction of regret due to over-consideration
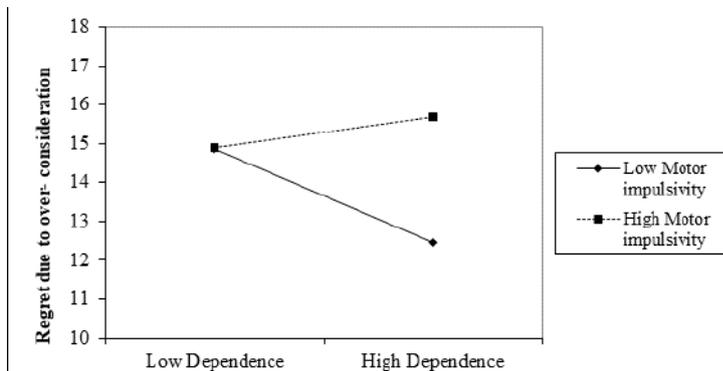
Source: Authors' work

In contrast to attentional, motor impulsivity as moderator has the opposite effect on the relationship between Dependence and regret due to over-consideration (Figure 4); on the high-level motor impulsivity showed a positive effect on the relationship between Dependence and regret due to over-consideration ($β=.13$, $ΔR^2=.02$, $p<.05$).

Discussion

The current study's aim was to investigate associations between consumer regret components, impulsivity dimensions and Emotionality domains. Considering that the PPCR scale was used in the Croatian language for the first time in this research, we will analyze internal psychometric characteristics and internal consistency of the PPCR scale All PPCR subscales demonstrated adequate reliability (Cronbach's a was from .90 to .93), what is consistent with earlier studies (Lee & Cotte, 2009; Zulkarnain et al.,

2018). In line with the study by Zulkarnain et al. (2018), bivariate correlations between PPCR subscales were high, and ranged from .69 to .86, at the .01 significance level.

In general, the results partially supported the hypotheses and showed that the consumer regret components were differently associated with impulsivity dimensions, while there was no direct relationship between consumer regret and Emotionality.

As predicted, the PPCR total score was found to be positively associated with BIS-11 total score. This result is consistent with the conceptualisation of impulsivity as a specific personality trait underlying increased internalization characterized by negative emotions and distress (Evenden, 1999; Stanford et al., 2009). In addition, this result is in line with recent findings (Garofalo et al., 2018) showing a positive association between BIS-11 total score and all measures of emotion dysregulation (Garofalo et al., 2018). According to the theory of regret regulation (Zelenberg & Pieters, 2007) and in line with previous findings (Landman et al., 1995), regret is a complex distressing emotion associated with negative emotions and internalization symptoms (e.g. anxiety, depression, self-blame). Finally, our results showed that emotional dysregulation is a key link between impulsivity and consumer regret.

In accordance with Hypothesis 2, regret due to foregone alternatives was positively associated with BIS-11 total score, attention and non-planning impulsivity. This result is coherent with Decision Justification Theory (DJT) (Connolly & Zeelenberg, 2002) based on which Lee at al. (2009) developed the PPCR scale. Namely, regret due to foregone alternatives includes self-blame and a sense of responsibility for making bad decisions (Lee et al., 2009). Attentional impulsivity is positively related to neuroticism (Lange et al., 2017), and non-planning impulsivity is related to depressive episodes (Swann et. al., 2008). These correlates of impulsivity encompass negative feelings such as self-blame which is one of the main components of regret due to foregone alternatives.

Hypothesis 3 was partially supported; the result showed that regret due to a change in significance positively correlated with BIS-11 total score and non-planning impulsivity, but not with attentional impulsivity. Given non-planning impulsivity reflects an inability to plan (Patton et al., 1995), these findings are in line with theoretical description by which regret due to a change in significance reflects regret caused by an individual's inability to predict the usefulness of a product in the future. Also, these findings are consistent with preview findings (Ekici & Dogan, 2013) showing that regret concerning after the process of purchasing which includes regret due to change insignificance, was associated with self-assessment planning ability.

As predicted, regret for under-consideration was associated with BIS-11 and non-planning impulsivity but not with attention impulsivity, thus hypothesis 4 was partially confirmed. This result is in line with theoretical conceptualization regret due to under-consideration which assumes insufficient thinking before buying (Lee & Cotte, 2009) and findings which showed negative associations between non-planning impulsivity and indexes of executive functioning (Spinella, 2005).

As expected, (Hypothesis 5), regret due to over-consideration was unrelated to impulsivity. This is in line with the evidence which shows that impulsivity is related to low conscientiousness (Malesza & Ostaszewski, 2016) and "impulsive" decision-making (Reynolds et al., 2006), characterised by an incapacity to prevent adverse decisions.

Hypothesis 6 was partially confirmed. Our results showed that emotionality was not associated with regret at the bivariate level. However, results of regression analyses showed that anxiety uniquely positively predicted regret due to over-consideration and that Sentimentality uniquely negatively predicted regret due to foregone alternative and regret due to a change in significance. This is in line with notion that regret is aversive, irrational emotion (Lee & Cotte, 2009) linked to symptoms of

emotional distress such as depression and anxiety (Krainess et al., 2017), and evidence showing that neuroticism positively predicted consumer regret (Zulkarnain et al., 2018).

The lack of a stronger connection between Emotionality and regret is partly explained by the results of the moderating analyses. It seems that this relationship depends on the level of impulsivity. Namely, interactions between the impulsivity and Emotionality predicted different levels of consumer regret.

We found a negative effect of high attention impulsivity on the relationship between Emotionality and regret to due foregone alternatives. In the same way, high attention impulsivity moderates relations between Dependence and Sentimentality and regret to due foregone alternatives. Contrary, motor impulsivity has the opposite effect on the relationship between Dependence and regret due to over-consideration; on the high-level motor impulsivity relationship between Dependence and regret due to over-consideration showed a positive trend. These results indicated that motor impulsivity has a protective effect against negative emotions such as regret, while attention impulsivity increases these emotions.

Conclusion

Overall, the results indicate that impulsivity has an important role in understanding consumer regret as a multidimensional construct. Non-planning impulsivity has a particular impact on consumer regret because it uniquely predicted PPCR total score, regret to due foregone alternatives and regret due to under-consideration. Furthermore, attention impulsivity indirectly affects the relationship between consumer regret and emotionality: high level of attention impulsivity reduces the intensity of the connection emotionality and its facets of dependence and sentimentality with regret to due foregone alternatives. Motor impulsivity has the opposite effect on the relationship between dependence and regret due to over-consideration. High level of attention impulsivity enhances the relationship of these variables.

Results of this study showed importance of examining the impulsivity and consumer regret as complex constructs. Relationship between these constructs is influenced by some personality traits such as Emotionality and its domains. These findings are important for our understanding of consumer emotions that significantly affect their future consumer behavior. Furthermore, the results have practical and theoretical implications as they help create clearer insights into the mechanisms of irrational, impulsive buying that provoke negative post-purchase feelings and cause great financial problems for both, individuals and wider community.

Despite all the benefits, this research has some shortcomings and limitations. First, we used only self-report questionnaires, but not behavioral tasks that should be used in future studies. Second, the samples used are undergraduate students, which limits external validity. Therefore, future studies should also use general population samples and examine gender differences that can reasonably be expected from the measures used. Third, consumer regret was measured only by the PPCR Scale, which should be further validated by the comparative use of other measures of this construct.

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About the authors

Katarina Sokić works as the senior lecturer at the EFFECTUS College for Law and Finance in Zagreb. She graduated at the University of Zagreb, Faculty of Law where she got her MA degree in a Civil law. She got her PhD from the University of Zagreb, Faculty of Humanities and Social Sciences, Department of psychology with the topic 'Examination of The Triarchic Model of Psychopathy'. Her research interests are Individual differences, psychopathy, personality, impulsivity, and consumer behavior. The author can be contacted at **ksokic@effectus.com.hr**

Đuro Horvat works as the Assistant professor at the EFFECTUS College for Law and Finance in Zagreb. He got his PhD in Faculty of Economics in Osijek. His research interests are management, leadership and organizational design. He taught at several universities as an associate and guest lecturer. He is an author and co-author of the 53 research and 35 professional work papers as well as a large number of studies in management, organization, new forms of organization-clusters and competitiveness of enterprises. He has published ten books as an author, co-author or editor. The author can be contacted at **dhorvat@effectus.com.hr**

Sanja Gutić Martinčić works as the lecturer at the EFFECTUS College for Law and Finance in Zagreb. She graduated at the University of Zagreb, Faculty of Economics. She got her PhD in University of Modern Sciences - CKM in Mostar with the topic 'The role of the organization in the development of the career of employees". Her research interests are career, management, human recourses and organization behavior. She is an author and co-author of three books. The author can be contacted at **sguticm@effectus.com.hr**

R&D Investments in the European ICT sector: Implications for Business Performance

Jan Hunady, Peter Pisar, Ina Durcekova
Faculty of Economics, Matej Bel University in Banska Bystrica, Slovakia

Abstract

Background: A significant share of business innovation arises from information and communication (ICT) sector. Business investment into research and development (R&D) activities can be seen as an important basis for innovation, which can further lead to better economic performance. This can be especially true for the ICT sector. **Objectives:** The paper examines the share of the ICT sector on innovation and the total R&D expenditure in selected European countries. Furthermore, our aim is to test the potential positive correlation between R&D expenditure, productivity and the value added in the sector. **Methods/Approach:** The goals of the paper has been tested by empirical data analysis using the pane regression analysis. We examined panel data for 24 European countries in the 2008-2016 period. **Results:** The highest share of business R&D expenditure in ICT has been captured in Nordic countries. Firms in ICT appear to be innovative above the average and represent a significant share in the total business R&D expenditure. **Conclusions:** We found a positive correlation between R&D expenditure and both value-added and apparent labour productivity in the ICT sector. We believe that this could be to some extent attributed to the innovation of products and processes. Hence, the government support in the form of R&D tax incentives can be also beneficial for the economic performance of ICT firms. **Keywords:** R&D investments, R&D expenditure, innovation, ICT sector, business performance.

Introduction

Research and development (R&D) are considered as the main requirements for the development of innovation. Enterprises with innovation ambition need to acquire knowledge and apply results from R&D activities. R&D can be performed either in house by their research capacities or acquire from other subjects in innovation systems such as universities or public and private research institutions. In both cases, usually business has to invest certain financial resources to get some R&D outputs. Hence, R&D expenditure is mostly one of the main determinants of innovation performance in the business sector. This is also true in the ICT sector, which is often traditionally considered as one of the most innovative sectors in the economy. Innovation activities play an important role in this type of business. Innovation policies of many European countries, as well as the policies of the European Union, are often focused on support of high-tech and medium-tech industries. Concerning this, ICT together with several other sectors often gains significant attention to public policies.

Our paper deals with the problem of R&D expenditure, with a special focus on the ICT sector in European countries. We examine the share of the ICT sector on R&D expenditure as well as its important for innovation activities in the economy. Hence, the main goal of our paper is to examine the R&D expenditures in European countries and identify the potential relationship between R&D investments and selected business performance indicator. In the next chapter, we describe the background for our research as well as results of previous research focused into some extent on similar problems. Next, we also describe used methodology and data followed by interpretation and discussion of certain results and potential limitation. The final section concludes and summarizes the most important findings.

Literature review

It was proven that R&D investment has a positive impact of economic growth (Akcali & Sismanoglu, 2015; Falk, 2007; Gumus & Celikay, 2015; Huňady & Orviská, 2014) and productivity (Blanco et al., 2015; Nekrep et al., 2018) on a national level. Moreover, studies examining the impact of R&D expenditure spent by a firm were proven to have a positive effect on productivity on firm-level (Pieri et al., 2018). It has also been shown that R&D investment has positive effect on financial performance of a firm, such as on its profitability measured by either ROA or ROE (Apergis & Sorros, 2014; Ayaydin & Karaaslan, 2014; Freihat & Kanakriyah, 2017; Shen et al., 2017; VanderPal, 2015), turnover (Park et al., 2018) or value-added (Tsang et al., 2008). It is therefore apparent that R&D expenditures are a crucial investment for a firm.

However, it is not only important to monitor R&D activities in an economy as a whole, but it is also interesting to examine R&D investment across different sectors. R&D and innovation investment tends to focus on the so-called knowledge-intensive industries in which firms mainly use R&D to gain a competitive edge (Abdal et al., 2016). These sectors are commonly known as high-tech industries and are said to produce up to around 80 % of total R&D expenditure in some EU regions (Czarnizki & Thorwarth, 2012). R&D investment contributes to the increase of high-tech products export (Sandu & Ciocanel, 2014) and the growth of high-tech industries (Karahan, 2015; Wang et al., 2013). These industries include e.g. aerospace, computers, pharmaceutical or electronics and telecommunications industries (Sandu & Ciocanel, 2014). One of the fastest-growing high-tech sectors in many countries in the past few decades has been the ICT sector (Hanna, 2009). It is therefore not surprising that ICT has been proven to have a positive effect on economic growth (Khanna & Sharma, 2018; Sepehrdoust, 2018; Tolica et al., 2015). Even though many papers focus on the

role of R&D and ICT separately, some authors argue that it is important to study the relationship and correlations between these two areas since they were shown to have complementary effects (Pieri et al., 2018; Khanna & Sharma, 2018; Mohnen et al., 2018). Many authors studying the factors affecting the growth of ICT sector agree that one of the key driving forces of ICT industry is R&D and innovation (Canarella & Miller, 2018; Lindmark et al., 2010; Manjón et al., 2016; Monge-Gonzálet & Hewitt, 2010; Stejskal et al., 2018; Tolica et al., 2015). Thus, it is understandable that reports examining the role of R&D in the ICT sector prove that the ICT sector is the largest R&D investor in the EU, USA and Japan (Turlea et al., 2009). This is also shown in the fact that many studies focus on the R&D activities undertaken by firms operating in the ICT industry (Wei et al., 2011).

Table 1
Review of the studies focused on the impact of R&D investment on innovation, growth and profitability of ICT firms

Author	Sample specification		Study specifics
	Country	Period, data source	
INNOVATIVE EFFORTS			
Agramunt and Berbel-Pineda, 2018	Argentina	2011 Questionnaire survey	R&D investment (expressed as innovative effort) is a determinant of innovation
Stejskal et al., 2018	Germany	2010 – 2012 Innobarometer	Influence of internal and external R&D expenditure contributes to the creation of innovation
GROWTH			
Park et al., 2016	Korea	2012 Daejeon Regional Economic Receiving Survey	Innovation effort (including R&D investment) is the factor of firm's successful growth
Schröder, 2012	Germany	2009 – 2010 Questionnaire survey	R&D stimulates growth
Conarella and Miller, 2018	U.S.	1990 – 2013 Compustat database	R&D facilitates growth
Hong, 2016	Korea	1988 – 2013 Korean Statistical Information Service, National Science & Technology Information Service	R&D investment is a driver of growth
PROFITABILITY			
Warusawitharana, 2015	U.S.	1985 – 2006 Compustat database	The model focused on R&D intensive industries, results show that R&D investment leads to higher profitability, especially in the software industry
Koutroumpis et al., 2020	Germany, France, Sweden, UK	2004 – 2013 Orbis/Amadeus dataset	R&D capital in ICT firms has a larger effect on revenue in comparison with non-ICT firms
Lee et al., 2018	Malaysia	2009 – 2015 Bloomberg database	Intangible assets (variable related to R&D investment) is shown to have a positive effect on firm profitability
Babkin et al., 2015	Global, 100 largest firms	2010 - 2012 Primary sources – reports of firms in the IT sector	Increasing R&D costs leads to greater firm revenue

Source: Authors' work

Authors often focus on the impact of R&D and ICT investments on growth and profitability separately, comparing the effect of these two variables. Edquist and Henrekson (2017) proved that ICT and R&D capital has a positive impact on value-added growth. Mithas et al. (2012) focused on the impact of R&D and ICT investment on the profitability on a sample of global firms and founds that while both of these expenditures have a positive effect on revenue of a firm, impact of ICT investment is greater than that of R&D expenditure. Estrada and Dong (2020) studied coopetition on a sample of Spanish manufacturing firms and found that R&D investment positively affects ICT investment and ICT investment in turn positively affects profitability. Hall et al. (2013) concluded that while both R&D and ICT investment are strongly associated with innovation and productivity, R&D is more important for innovation, while ICT is more important for productivity. The positive impact of both R&D and ICT investment on innovation and productivity was confirmed by many other studies (Álvarez, 2016; Khanna & Sharma, 2018; Martin & Nguyen-Thi, 2015; Pieri et al., 2018).

However, there can also be found studies focused on the impact of R&D investment on various growth variables in the ICT sector specifically. The main findings of these studies are summarized in Table 1.

In general, we can conclude that most of the studies found some positive consequences of R&D activities on firms' growth, profitability and other financial and economic performance indicators.

Methodology

Concerning innovation, the ICT sector still has a special place within all different sectors. Hence, we focused our attention on research and development expenditure in this sector. Our main goal is to examine the R&D expenditures in European countries and identify the potential relationship between R&D investments and selected business performance indicators. In line with the aim we developed three research hypotheses as follows:

- H01: The share of innovative firms in ICT sectors is higher than the average of all sectors in the economy.
- H02: The share of business R&D expenditure in the ICT sector is higher in Nordic countries compared to most of the new EU member states.
- H03: Higher business R&D expenditure is positively related to higher apparent labour productivity in the ICT sector.
- H04: Higher business R&D expenditure is positively related to higher business value-added in the ICT sector.

In order to test all four hypotheses and fulfil our main aim, we analyse available secondary empirical data. In this section, we describe our methodology as well as data in detail. Our dataset consists of macro-level business sector panel data from the Eurostat database. Hence, every indicator was captured yearly at a country level during the period 2008 - 2016. All variables used in the regression analysis are described in more detail in Table 2.

The list of countries in the dataset originally consisted of EU28 countries plus Norway. However, Malta, Cyprus and Luxembourg were excluded from regression analysis due to unavailability of several indicators.

Table 2
Description of variables used in the analysis.

Variable	Description	Source (codes)
BERD on GDP	Business expenditure on R&D (BERD) % of gross domestic product (GDP)	Eurostat (rd_e_berdindr2)
BERD in €	Business expenditure on R&D (BERD) in Euro per inhabitant	Eurostat (rd_e_berdindr2)
Apparent labour productivity	Apparent labour productivity (Gross value added per person employed) - thousand euro	Eurostat Code: tin00152
Value Added	Value-added at factor cost in production value (in %)	Eurostat Code: sbs_na_ind_r2
Personnel costs	Average personnel costs (personnel costs per employee) - thousand euro	Eurostat Code: sbs_na_1a_se_r2
GDP per capita	GDP per capita in PPP: Volume indices of real expenditure per capita in PPS (EU28=100)	Eurostat Code: TEC00114

Source: Authors' work

We analysed selected indicator related to business innovation and business investment to R&D. In line with our first two hypotheses, we are especially focused on the share of innovative firms and share of business R&D expenditure. We compared these indicators among selected European countries and come to several interesting findings. Furthermore, we constructed panel regression models to examine the potential link between business R&D expenditure and selected financial business performance indicators. With respect to our main aim, results of previous studies and data availability we decided to focus on two main indicators: apparent labour productivity and value added at factor cost. We believe that especially these two indicators could be affected directly or indirectly by business investment into R&D and potential innovation. Innovation could lead to both higher labour productivity as well as to higher value-added in production. However, it is likely that due to often long-lasting innovation processes these potential effects on performance indicators can be delayed by several years. Hence, we also take into account time-lagged independent variables. In each case, we use either fixed effect or random effect panel regression models. Fixed effects models appear to be the more suitable ones. Despite this fact, we also have shown the results of the random-effects model due to robustness check. Moreover, we used independent variables capturing R&D expenditure in two different forms (as % of GDP and in Euro per capita) to further check the robustness. The results of the analysis are described in the next section.

Results

Based on our aim we examine business R&D expenditures and innovation in the ICT sector. To get more detail view we separately compare the manufacturing and services sectors. In the first part of the analysis, we examine the share of innovative firms in ICT manufacturing and manufacturing sector in general. This has been done based on the sample of European OECD countries. As can be seen in Figure 1, the share of innovative firms (calculated as a share of firms that introduced product/process or marketing/organizational innovation) is higher in ICT manufacturing in all countries except Slovakia. In Slovakia, the share is almost similar in both types of manufacturing sectors.

Figure 1
The total share of innovative firms in manufacturing in selected European countries
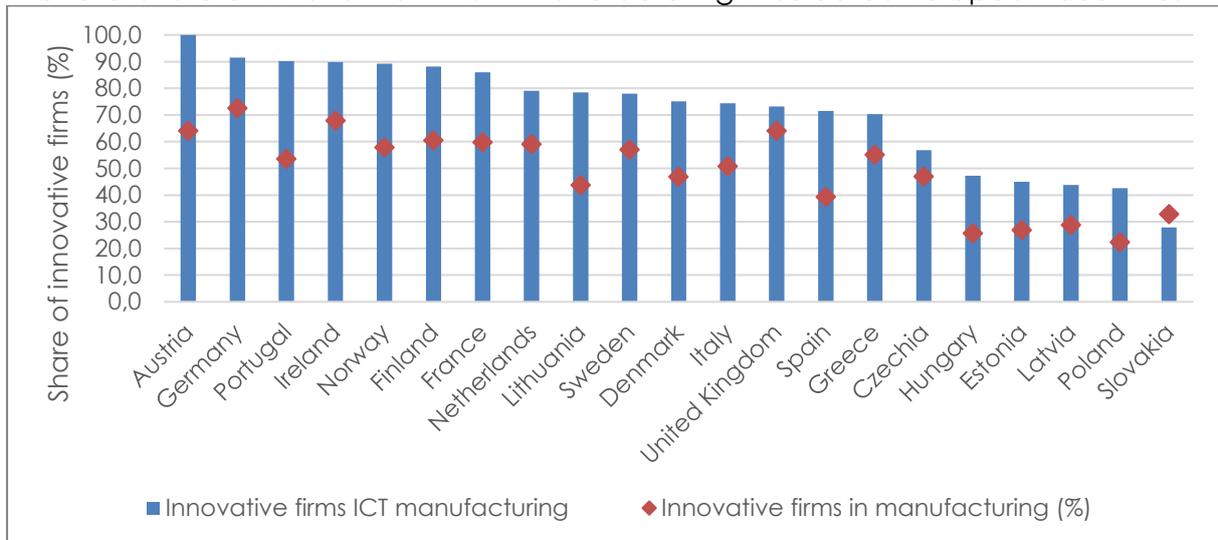
Source: Authors, based on "Innovation Indicators 2017" OECD database

Similarly, we also compare the share of innovative firms in IT services with the share of innovative firms in the services in general. As can be seen in Figure 2, firms with activities in IT services are on average more innovative in all selected countries. The difference is especially evident in countries such as Lithuania, Czechia, Latvia or Spain.

Figure 2
Share of innovative firms in services and IT services in European countries
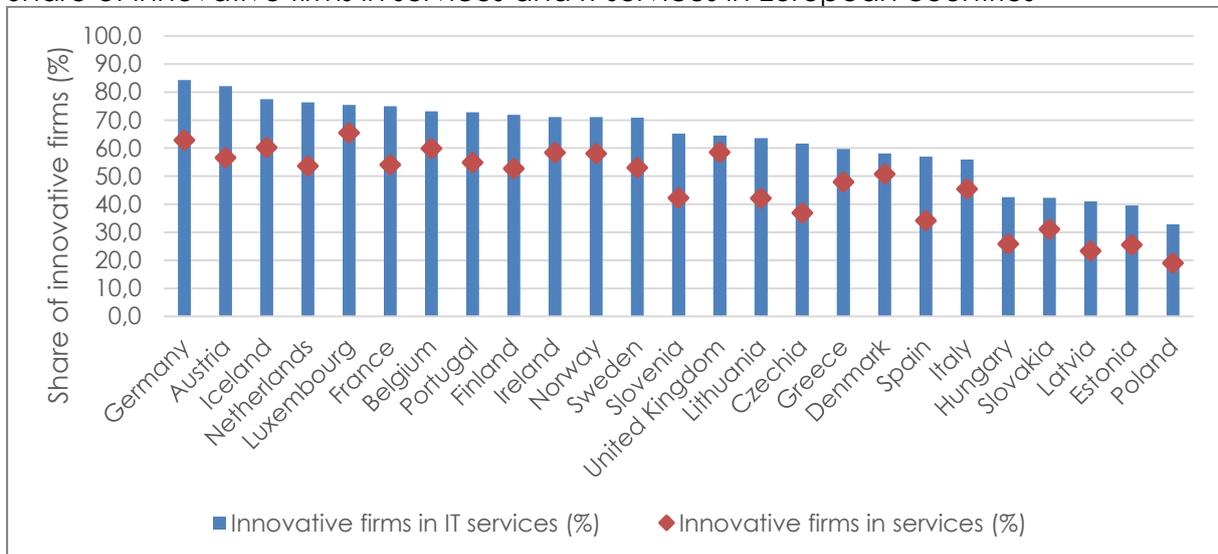
Source: Authors, based on "Innovation Indicators 2017" OECD database

In general, we can say that the ICT sector is more innovative than the average of the total economy. The differences between ICT firms and total economy are also particularly significant in countries such as Hungary, Poland, Latvia and Estonia, where the innovation performance, in general, is rather low.

In Figure 3 we compare business R&D expenditure in ICT. This indicator was captured in euro per inhabitant as well as in percentage of GDP. Business R&D expenditures are especially high in Nordic countries such as Island, Norway and Finland. Relatively high level of business R&D expenditures to GDP is captured in

Estonia, Bulgaria and Czechia. On the other hand, business R&D expenditures in Latvia, Lithuania, Croatia, Greece and Slovakia are rather low in both indicators.

Figure 3
Business R&D (BERD) expenditures in selected European countries in 2016
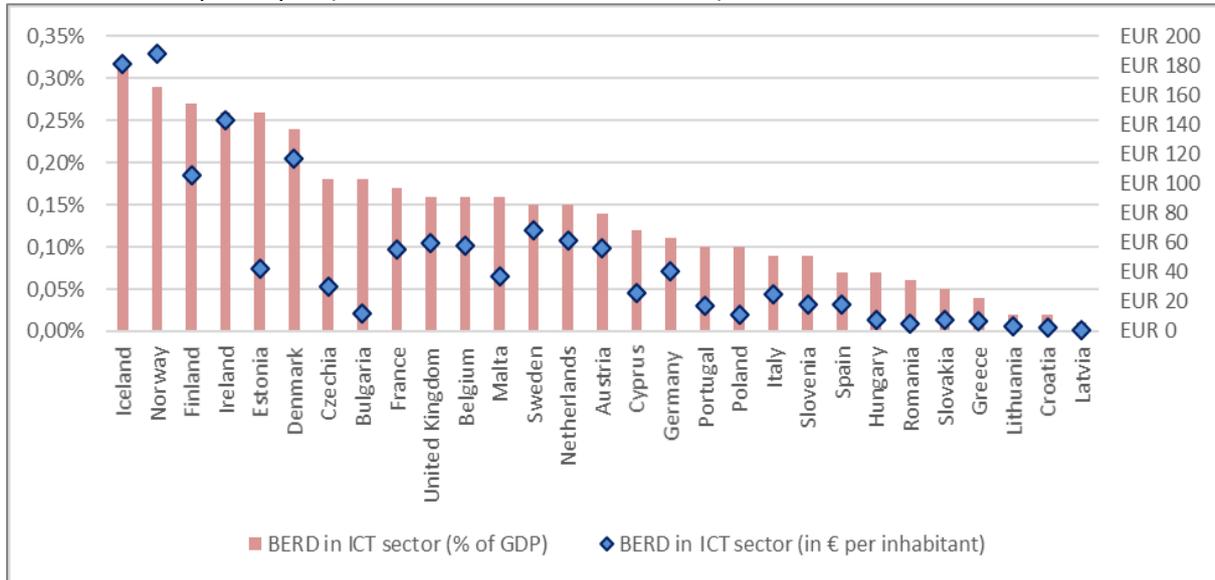
Source: Authors, based on Eurostat database (code: rd_e_berdindr2).

We also compared the share of business R&D expenditure in the ICT sector to total business R&D expenditure in each country. This is especially interesting when also comparing with the share of ICT sector production on total GDP. Both of these indicators can be seen in Figure 3. However, the data capturing the share of ICT on GDP was not available in Cyprus, Iceland, Ireland and Luxembourg. Despite a rather low proportion of ICT sector on the total economy in some countries, the share of R&D expenditures in this sector is very high. This is particularly true in Cyprus where approximately 60 % of total R&D business expenditure is spent by firms in the ICT sector. Share of ICT sector on total R&D expenditures is also very high in Malta, Estonia, Bulgaria and Ireland. This situation can be on one hand the result of lower R&D investments in other sectors, which seems to be the case of Cyprus, Malta and on the other hand, this could be the reflection of very high R&D expenditure in ICT sector despite the rather high business R&D investment in the economy.

The ICT sector represents the highest share of the national economy in Malta followed by Sweden and the United Kingdom. In all three countries, the share of the ICT sector on GDP is higher than 6 %.

Figure 4
Share of ICT sector on BERD and GDP in 2016
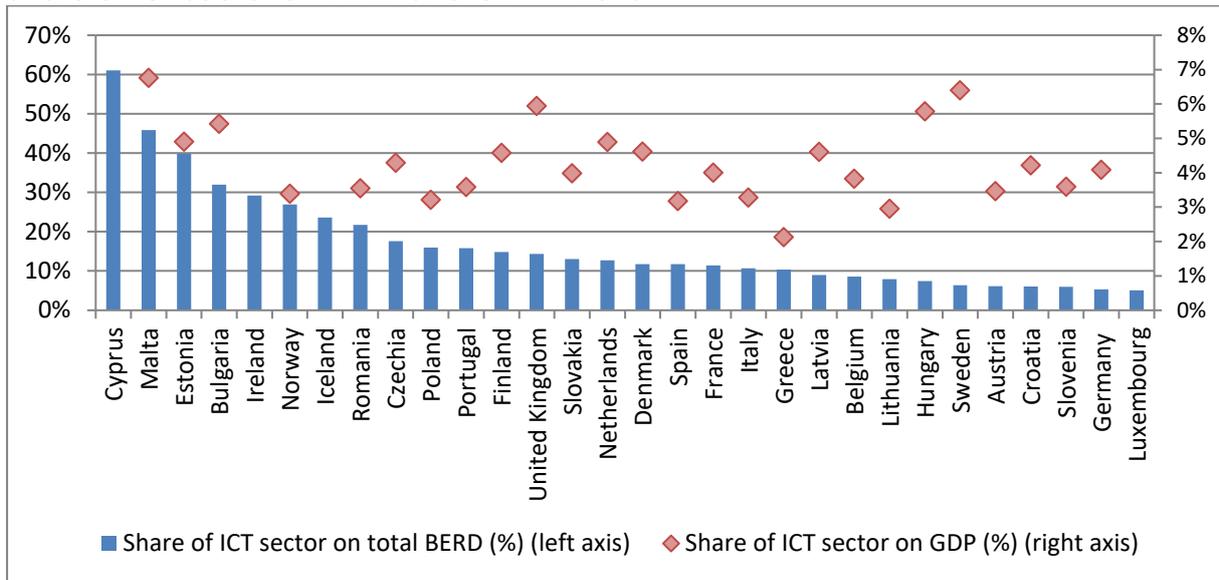
Source: Authors, based on Eurostat database (codes: rd_e_berdindr2; soc_bde15ag).

We conducted regression analysis. Based on the results we can examine potential relationships between R&D expenditure and selected business performance indicators. Firstly, we test the weak stationarity of our variables by several panel unit-root tests. The results are shown in Table 3. According to the majority of tests, we can conclude that all variables except personnel costs seem to be stationary at their levels in the selected period. In the case of personnel cost, we used first differences instead of level values to maintain weak stationarity of these variables.

Table 3
Results of panel unit root tests

	LLC test	**IPS test**	**ADF test**	**PP test**
Apparent Labour productivity	-6.120***	-2.36***	70.33**	77.43***
Value added	-12.25***	-2.58***	72.83***	82.29***
BERD(GDP)	-9.07***	-0.639	82.42***	67.70*
BERD(€)	-7.327***	-0.04	69.92**	120.30****
Personnel costs	-1.903**	2.175	42.62	35.40
ΔPersonnel costs	-10.58***	-4.01***	88.30***	86.68***
Log(GDP per capita)	-19.454***	-6.14***	135.1***	98.28***

Note: */**/*** denotes statistically significant at the 10/5/1 percent level.
Source: Authors based on the data from the Eurostat database.

Fin the first set of models we focus our attention on apparent labour productivity in the ICT sector. This indicator represents the dependent variable in the first set of regression models. The results of these panel regressions are summarised in Table 4. We constructed seven fixed-effects regressions and one random effects regression. To capture potential delays in the actual impact of R&D expenditures on labour productivity we also use lagged values of the main independent variable. The maximum number of lags were four due to a limited number of observations. This

means that we captured the potential effect of R&D expenditure on labour productivity delayed by one to four years. In addition to the share of business R&D expenditures in the ICT sector on GDP, we also used the value of R&D expenditures in euro per capita in some regressions. However, the results were very similar in both cases. This confirms the robustness of our results. We also used GDP per capita and personnel costs as two control variables. GDP per capita captures the potential effect of the economic cycle as well as differences in economic performance between countries. Personnel costs are used as a control variable for the potential effect of changes in salaries on productivity. These changes in personnel costs may also be the result of innovation and pressure on the use of highly skilled labour.

Table 4
Results of panel regression models

Lags/ years	Dependent variable: Apparent Labour productivity(in %)							
	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8
BERD(GDP) Lag=0	24.13*** (2.43)							
BERD(GDP) Lag=1 year		18.26** (3.14)	21.86** (2.21)					
BERD(GDP) Lag=2 years				6.54 (0.83)				
BERD(GDP) Lag=3 years					26,47* (1.70)			
BERD(GDP) Lag=4 years						16.53** (2.06)		
BERD(€) Lag=1 year							0.18*** (8.12)	
BERD(€) Lag=2 years								0.11*** (3.27)
ΔPersonnel costs	0.77*** (3.66)	0.76*** (3.67)	0.70** (2.29)	0.54*** (3.14)	0.56*** (2.98)	0.60** (2.32)	0.96*** (5.38)	0.68*** (3.77)
Log(GDP per capita)	-5.2 (-1.77)	-5.1 (-1.24)	35.4*** (3.93)	-6.4 (-0.64)	-28.7* (-1.69)	-57.7*** (-14.29)	-7.2 (-1.48)	-9.9 (-1.02)
C	84.05*** (4.23)	84.4*** (4.56)	-93.18** (-2.48)	91.68*** (2.09)	187.8 (2.55)	316.8*** (17.99)	89.9*** (4.06)	104.2** (2.44)
Cross-section Fixed effect (FE)/ Random effects (RE)	FE	FE	RE	FE	FE	FE	FE	FE
R2	0.98	0.98	0.21	0.98	0.99	0.99	0.98	0.99
Adjusted R2	0.98	0.98	0.19	0.98	0.98	0.98	0.98	0.98
F-statistic	343.3***	337.3*	13.2***	352.5***	463.9***	403.2***	367.8***	363.3***

Note: symbols (.) denotes t-statistics and */**/*** denotes statistically significant at the 10/5/1 percent level. Standard errors have been corrected for heteroscedasticity. The maximum number of observations in panel data is 168.
Source: Authors based on the data from the Eurostat database.

As can be seen in Table 4, business R&D expenditure in ICT sector seems to be positively correlated with apparent labour productivity in the ICT sector. This is true in all models, even though in the model with a two-year time lag, this relationship appears to be statistically not significant. The positive correlation on labour productivity is evident even in the same year R&D expenditure has been invested. This relationship is significant at 5 % level of significance in this instance as well as with one-year time lag. We also find evidence that this effect can persist for several next years, which is captured by a positive and statistically significant coefficient in the third and fourth year. In the case of R&D expenditure in euro per capita, this is evident in the

case of both one- and two-year lags and it is statistically significant even at 1 % level of significance.

Similarly, we also found a positive correlation between an increase in personnel costs and labour productivity. The variable GDP per capita was mostly statistically insignificant.

In the second set of regression models, we use value-added as the dependent variable. This time we used a log of value-added because value-added is the variable expressed in euro and we need to reduce the extreme values and into some extent normalise the distribution of this variable. The results of regressions are summarised in Table 5. We assume that higher business R&D expenditure in ICT sector should be positively correlated with the higher benefit in the sector. This again may be more evident with a certain time lag. Hence, we again applied also lagged independent variables. We used eight regressions with fixed effects and one regression with random effects to check the robustness. In one case, we also used the common logarithm of the independent variable to capture potential non-linear relationships in log-log form and further test the robustness of our results.

Table 5
Results of panel regression models

Lags/ years	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
Dependent variable: Log(Value added) (in mil. €)									
BERD(GDP) Lag=0	0.374 (1.38)								
BERD(GDP) Lag=1 year		0.92*** (3.34)	0.64* (1.67)						
Log(BERD(GDP)) Lag=1 year				0.05*** (3.98)					
BERD(GDP) Lag=2 years					0.76** (2.05)				
BERD(GDP) Lag=3 years						0.71* (1.95)			
BERD(GDP) Lag=4 years							1.01*** (3.12)		
BERD(€) Lag=1 year								0.002*** (2.68)	
BERD(€) Lag=2 years									0.002*** (3.68)
ΔPersonnel costs	-0.0002 (-0.14)	0.0002 (0.19)	-0.002 (-0.10)	0.0009 (0.006)	-0.0001 (-0.07)	0.002* (1.88)	0.0002 (1.51)	0.09 (0.44)	0.002 (0.94)
Log(GDP per capita)	0.11 (0.46)	-0.03 (-0.11)	0.05 (0.31)	-0.05 (-0.15)	0.33*** (4.11)	0.25** (2.02)	-0.14 (-1.25)	0.09 (0.44)	0.37*** (4.02)
C	3.24*** (3.07)	3.81*** (3.01)	- 93.2** (-2.48)	4.09** (3.07)	2.20*** (6.19)	2.60*** (4.58)	4.03*** (8.98)	3.27*** (3.46)	2.09*** (5.32)
Cross-section Fixed effect (FE)/ Random effects (RE)	FE	FE	RE	FE	FE	FE	FE	FE	FE
R2	0.88	0.89	0.04	0.90	0.92	0.92	0.9	0.89	0.91
Adjusted R2	0.87	0.87	0.02	0.88	0.90	0.90	0.88	0.87	0.89
F-statistic	43.1***	46.69*	12.22*	45.69***	47.93***	42.37***	42,6***	43.19***	47.38***

Note: symbols (.) denotes t-statistics and */**/*** denotes statistically significant at the 10/5/1 percent level. Standard errors have been corrected for heteroscedasticity. The maximum number of observations in panel data is 168.
Source: Authors based on the data from the Eurostat database.

As can be seen from the results, we again found evidence for the positive correlation between R&D expenditure and value added at factor cost in production. As we assumed the relationship is not evident in the same period, but R&D expenditure from previous years appears to be positive and statistically significant. This is true in the

case of all four lagged independent variables. Similarly, a positive and significant correlation with value-added is evident for both indicators expressed as a percentage of GDP as well as in euro per capita.

Our findings help us fulfil our main scientific aim and based on them we can test four main scientific hypotheses as mentioned in the methodological section of our paper. Concerning our research hypotheses, we can make these conclusions.

Firstly, we cannot reject the hypothesis H01 that the share of innovative firms in ICT sectors is higher than the average of all sectors in the economy. In fact, our results strongly suggest that this is true in all selected European countries.

Secondly, the hypothesis H02 that the share of business R&D expenditure in the ICT sector is higher in Nordic countries compared to most of new EU member states is not rejected. Most of the Nordic countries such as Norway, Island and Finland reach the highest business expenditures on R&D in our sample.

We fail to reject the third hypothesis that the higher business R&D expenditures are positively related to higher appetent labour productivity in the ICT sector. Our data support the existence of relationship between these two variables in the same period as well as with a certain time delay.

Finally, we also found no evidence that the hypothesis H04 should be rejected. Our results suggest that higher business R&D expenditure is positively related to higher business value-added in the ICT sector. The business R&D expenditure is positively correlated with value added at factor cost in ICT. This time we found a positive correlation of business R&D from previous periods and value-added in the current period.

Higher business investment in R&D seems to be at least positively correlated with selected business performance indicators namely labour productivity and value-added in the ICT sector. These results are in line with the results of several other previous studies. While the positive effect of R&D expenditures on productivity has been previously found for example by Pieri et al. (2018), Khanna and Sharma (2018) and Martin and Nguyen-Thi (2015), the positive impact on value-added has been reported for example by Edquist and Henrekson (2017). Potential effect on labour productivity can likely be achieved mostly by the innovation of processes in the ICT sector. On the contrary, an increase in value-added can be to a certain extent explained by the innovation of ICT product or services.

It is also important to mention several limitations of our approach. It should be taken caution when interpreting the results of our regression model strictly as causalities. Despite our best effort in reducing the endogeneity problem by including control variables and using lagged values of independent variables, this problem could not be completely ruled out. Hence, it is still more accurate to perceive our results as correlation or as potential causal effects. Next limitation lies in our dataset. We have been limited by data availability as well as the structure of the data. Due to this fact, we decided to use macro-level data for the sector rather than micro-level data for individual firms. Additional analysis of similar indicators on the firms' level could significantly complement our results and provide some additional findings for the causes and consequences of examined issues.

Conclusion

Based on our results we can conclude that the ICT sector represents an important element of innovation performance in the country, Firms in the ICT sector are more innovative than the average of firms in the total economy. This is true in all European countries in our sample. Furthermore, firms in the ICT sector account for a significant share of total business R&D expenditure in the economy in most countries. The highest

proportion of R&D expenditures in ICT on GDP was captured in Nordic countries such as Island, Norway and Finland. However, several Eastern European countries such as Estonia and Bulgaria are also performing very well in this indicator despite lower business R&D investment in Euro per capita. On the other hand, countries such as Latvia, Lithuania, Greece, Croatia and Slovakia still have only a very small proportion of business R&D in the ICT sector.

In line with our findings, we can also conclude that business investment in R&D is positively correlated with certain business performance indicators. In our case, we found evidence of a positive relationship between R&D expenditure and apparent labour productivity as well as value-added in the ICT sector. Both indicators seem to be potentially affected by R&D expenditures in previous years. However, the relationship with productivity was evident also in the same period. We assume that the mentioned results can be to some extent attributed to the development of process and product innovations. This can have several consequences for the business sector as well as for innovation policies. Business investment in R&D expenditure can improve the economic performance of firms in the future. This can be also reflected in the governmental innovation policy. Increase in business R&D expenditure can be achieved by indirect innovation support. For this purpose, special tax treatment can be applied such as immediate write-off of current R&D expenditures or R&D tax credit. Our research shed some light on the current state and potential consequences of business R&D investment. However, even more, empirical research especially is needed in this area to examine this problem in more detail.

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About the authors

Jan Hunady, PhD. is an assistant professor at the Faculty of Economics, Matej Bel University in Banska Bystrica, Slovakia. He received his PhD in public economics and services. He has published a number of papers in journals such as Transportation Research Part A: Policy and Practice, Information Polity and Engineering Economics. His research interests are focused on public finance, institutions, innovation and technology. He participates in several research projects in the area of research policy and innovation. His expertise is also in econometrics and econometrics programs, particularly panel data and time series analysis. The author can be contacted at **jan.hunady@umb.sk.**

Peter Pisar, PhD. is an associate professor of finance, banking and investment at Matej Bel University. He was the Head of Department of Finance and Accounting from 2015 to 2018. His research is focused on European public finances, especially innovation, innovative financing and the evaluation of regional policy and public expenditure programs. In practice, he is also a consultant for the development and implementation of projects supported by EU funds and is particularly concerned with public policies supporting innovation. The author can be contacted at **peter.pisar@umb.sk.**

Ina Durcekova is an internal doctoral student at the Faculty of Economics, Matej Bel University in Banska Bystrica, at the department of finance and accounting. Her research is focused on innovation and public funding of innovation. The author can be contacted at **ina.durcekova@umb.sk.**

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Testing the Twin Deficit Hypothesis: Evidence from the Republic of North Macedonia

Vesna Bucevska
Ss. Cyril and Methodius University in Skopje, Faculty of Economics-Skopje

Abstract

Background: An econometric analysis of the twin deficit hypothesis is of special importance for the Republic of North Macedonia in view of its perspective membership in the European Union and from the point of view of its macroeconomic stability in the long run. **Objectives:** The objective of this paper is to test empirically the validity of the twin deficit hypothesis in the Republic of North Macedonia. **Methods/Approach:** To achieve this objective, we used actual quarterly data on Macedonia's budget and the current account deficit in the period from the first quarter of 2005 until the fourth quarter of 2017 and applied several econometrics methods: the Granger causality, a vector autoregressive (VAR) and a vector error correction model (VECM). **Results:** These findings point to the conclusion that efforts focused on improving the current account imbalances through fiscal policy will be inefficient in the short run. **Conclusions:** However, the existence of a long run relationship between the budget deficit and the current account deficit indicates the necessity of policy initiatives focused not only on reducing the budget deficit, but also on improving the external position of the country though export promotion.

Keywords: Twin deficit, Granger causality, VAR, VECM
JEL classification: C22, E62, F32, F41, H62.
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Introduction

The twin deficit hypothesis implies a long-term positive relationship between the budget and the current account deficit running from the budget deficit to the current account deficit. This phenomenon gained prominence in the 1980s because of the rapidly growing twin deficits in the United States and many other countries in the world. The latest global financial crisis of 2008, when many countries faced the challenge of reducing budget deficits and preventing the recurrence of high and long-term current account deficits as well as the European debt crisis of 2010 has spurred the academic interest in studying the twin deficits hypothesis.

The empirical investigation of the budget and current account deficit relationship is of special importance for the EU candidate and potential candidate countries. In the last two decades the Republic of North Macedonia, simultaneously experienced

budget and current account deficit (budget deficit averaged -2.32 percent of GDP from 1993 until 2018 and current account deficit averaged -4.07 percent from 1998 until 2018). The problem of twin deficit is not only important in view of perspective membership of the country in the European Union, but also from the point of view of its macroeconomic stability on a long run.

In this context, the purpose of this paper is to test empirically the validity of the twin deficit hypothesis in the Republic of North Macedonia using actual quarterly data on Macedonia's budget and current account deficit in the period from the first quarter of 2005 until the fourth quarter of 2017. To achieve this goal, we employed the following econometric methods: Granger causality, a vector autoregressive (VAR) model and a vector error correction model (VECM).

The paper is organized as follows. After the introduction, we explore the theoretical background and review the empirical literature on the twin deficit hypothesis. In the methodology section, we describe our research methodology and data. In the third section, we perform econometric testing of the validity of twin deficit hypothesis. We estimate the VAR model, carry out Granger causality testing, impulse response function testing as well as variance decomposition, stationary testing and finally we perform a VECM analysis. In the last section, we discuss the obtained empirical results and their implications for policy makers, draw conclusions, analyse the limitations of the paper and suggest directions for future research.

Theoretical framework and literature review

In economic literature, there are two major theories that explain the relationship between budget deficit and current account deficit: the conventional Keynesian theory (Keynes, 1936) based on the Mundell-Fleming framework and the Ricardian Equivalence Hypothesis. The traditional Keynesian proposition asserts that an excessive government borrowing for financing of government expenditures results in a budget deficit. A rise in budget deficit would induce an increase of domestic interest rates, causing more foreign capital inflows to the home country. The increased demand for financial assets in the country would lead to an appreciation of the home currency. The appreciated exchange rate would make exports relatively more expensive and imports cheaper and more attractive, which in turn would lead to deterioration of the current account balance into current account deficit under both fixed and flexible exchange rate regimes. How the budget deficit affects the current account deficit under a certain exchange rate system is explained in the Mundell–Fleming model (Fleming, 1962; Mundell, 1963). In other words, according to Keynesian conventional theory, there is a positive relationship between a budget and a current account deficit and that relation is a unidirectional Granger causality running from budget deficit to current account deficit.

Unlike the Keynesian proposition, the Ricardian Equivalence Hypothesis (REH), which was articulated first by the British economist David Ricardo and further developed by Robert Barro (1989), asserts that, there is no Granger causality relationship between the budget and the current account deficit and that the budget deficit would not cause a current account deficit. The perfect REH implies that taxpayers are rational forward-looking persons who will not respond to tax cuts by increasing their spending, but rather by increasing their savings in order to be prepared to pay future tax liabilities (Barro, 1989, p. 39; Hashemzadeh and Wilson, 2006). The increase of private savings would offset any change in the government budget (whether its debt financing or taxes) and would not cause a current account deficit (Khalid and Guan, 1999, p. 390). According to Baharumshah et al. (2006), the above outcomes are not the only possible outcomes of the relationships between the budget

deficit and the current account deficit. There might be a unidirectional causality running from current account to budget deficit. This is the case when worsening of the current account balance causes slower economic growth, which results with a budget deficit. This is especially true for small open developing economies that are very much dependent on foreign capital inflows. There might be also a bidirectional causality between the budget deficit and the current account deficit. Theoretically, the relationship between budget deficit and current account deficit can be represented by the national income identity (NII) for an open economy:

$$Y = C + I + GS + (EX - IM) \qquad (1)$$

where Y is national income, C is private consumption, I is investment, G is government spending, EX is exports of goods and services and IM is imports of goods and services.

Current account is defined as

$$CA = EX - IM + NTP \qquad (2)$$

where NTP is the net transfer payment i.e. the difference between payments from a country to abroad and payments from foreigners to the country.

By rearranging the variables, Equation (1) becomes:

$$CA = Y - (C + I + G) \qquad (3)$$

where the term (C + I + G) represents the national spending.

National saving in an open economy equals to:

$$S = (Y - C - G) + CA \qquad (4)$$

where, Y – C – G = I represents investment, so equation (4) can be rewritten as

$$S = I + CA \qquad (5)$$

National saving consists of private savings (SP) and government savings (SG):

$$SP = Y - GR - C \qquad (6)$$

and

$$SG = GR - G \qquad (7)$$

where GR is the government revenue. Using equations (6) and (7) and substituting into equation (3) yield:

$$CA = SP - I - (G - GR) \qquad (8)$$

It is evident from Equation (8) that if private savings equal investment than the current account and budget deficit are "twinned" i.e. an increase in the budget deficit will worsen the current account deficit. If government revenues and the saving-investment gap (SP – I) are held constant, a temporary increase of government spending will directly increase the budget deficit and will lead to worsening of the current account balance, which is the essence of twin deficit hypothesis.

Not only in the theoretical literature, but also in the empirical studies there is no consensus regarding the causal relationship between budget deficit and current account deficit. Most of the empirical literature refers to the developed economies and especially to the United States because of its simultaneous budget and current account deficit in the 1980s and 90s.

Darrat (1988), using both bivariate and multivariate models, confirmed the existence of tax-and-spend hypothesis in Turkey with a negative causal relationship running from government revenues to expenditures. Zietz and Pemberton (1990) and

Bachman (1992) found that the twin deficit hypothesis holds for the US. Kulkarni and Erickson (2001) concluded that in India and Pakistan trade deficit was driven by the budget deficit. Lau et al. (2010) confirmed the twin deficits hypothesis for Cambodia based on cointegration and Granger causality testing. Banday and Aneja (2016, 2017, 2019) confirmed the twin deficits hypothesis for India and China by applying cointegration and Granger causality testing. Using ARDL model, Bhat and Sharma (2018) examined the association between current account deficit and budget deficit for India over the period of 1970–1971 to 2015–2016 and found strong evidence in support of the Keynesian conventional theory.

On the other hand, Evans (1988), using data for the US found empirical evidence in favour of the Ricardian Equivalence Hypothesis (REH). Kaufmann et al. (2002) rejected the twin deficit hypothesis for Austria. Rafiq (2010) examined the interaction between budget deficits, current account balances and real exchange rates in the United Kingdom (UK) and US and provided empirical evidence in favor of REH. Nazier and Essam (2012) studied the Egyptian economic data from 1992 to 2010 and revealed twin divergence instead of twin deficits, thus supporting the REH. Ratha (2012) found that REH holds for India in the long run, and Algieri (2013) empirically validated the Ricardian theory for five countries (Greece, Ireland, Italy, Portugal, and Spain).

Other researchers gave support to the bidirectional causal link between the budget and the current account deficit. Bolukbas et al. (2018) found out a bidirectional causality between budget and current account deficit in sixteen of the twenty-eight countries (Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Italy, Netherlands, Romania, Spain, Turkey and the UK) and a unidirectional causality from budget to current account deficit was also noticed in five EU countries (Cyprus, Latvia, Lithuania, Poland and Slovakia). Rajasekar and Deo (2016) found a long-run relationship and bidirectional causality between the two deficits in India.

Another group of economists found a reverse relationship running from the external imbalance, i.e. from the current account deficit to the internal deficit i.e. the budget deficit. The reasons for these divergent results lie in the different sample periods and different econometric methodologies. For example, Kim and Kim (2006) found a unidirectional causality running from current account deficits to fiscal deficits in Korea using data for the 1970 to 2003 period. According to Marinheiro (2008) causality runs from current account deficits to fiscal deficits only. On the other hand, Litsios and Pilbeam (2017) using the ARDL model found a negative relationship between saving and current account deficit in Greece, Portugal and Spain.

Despite the extensive literature on the twin deficit hypothesis, there is relatively little research on the twin deficit hypothesis in the Central and Eastern European (CEE) countries. Vyashnyak (2000) and Herrmann and Jochen (2005) confirmed the existence of the twin deficit hypothesis in this group of countries. Aristovnik and Zajc (2001) made unclear conclusions about the relationship between the budget and the current account deficit, and Fidrmuc (2003) confirmed the existence of twin deficits in Bulgaria and Estonia, but in reverse form running from the current account to the budget deficit.

Using various econometric methods Ganchev (2010) tested the validity of the twin deficit hypothesis in Bulgaria. The results of the Granger causality test confirmed the existence of dual causality between the budget and current account deficit. On the other hand, conclusions based on the vector autoregressive (VAR) and the vector error correction model (VECM) both rejected the twin deficit hypothesis in the short run, but the long-term results showed evidence in support of this hypothesis.

Ganchev et al. (2012) found a positive relationship between budget deficit and current account deficit in most of the CEE countries, except Bulgaria and Estonia. On the other hand, Tosun et al. (2014) explored the relationship between the budget deficit and the current account deficit on the long run in selected Central and Eastern European economies and obtained no empirical evidence in favour of twin deficit hypothesis, except for Bulgaria. Turan and Karakas (2018) investigated the relationship between budget deficit and current account deficit in seven CEE countries and found that changes in budget deficit had a significant effect on the current account deficit in Czech Republic, Hungary and Slovakia in the long run and in Czech Republic, Slovakia, Hungary and Romania in the short run. Grubisic et al. (2018) studied the impact of government balance and exchange rate on current account in 16 CEE countries in the period 1999-2012 and contrary to the twin deficit hypothesis, they found that government balance had non–significant and negative association with current account balance. Boljanovic (2012) investigated the relationship between government budget deficits and current account deficits for the Southeast European countries in the period 2005-2010 and found a negative correlation between government budget deficits and current account deficits, indicating that the twin deficit hypothesis could not explain current account deficits in these countries.

Margani and Ricciutii (2004) analyzed the existence of the twin deficit hypothesis in small open economies. Applying dynamic econometric methods, they found that public deficit had a strong and a significant effect on current or on lagged current account balances. Vedris and Rancic (2010) confirmed the existence of the twin deficit in Croatia, which according to them had expanded since 1994 – the time of foreign exchange rate and price stabilization in Croatia. Jošić and Jošić (2011) investigated the validity of the twin deficit hypothesis in a small open economy (Croatia) in the period 1995-2010 using VAR model, Johansen's test of cointegration and the Granger causality test. The results of their econometric analysis confirmed the existence of twin deficit hypothesis in Croatia, but in the inverse direction. On the other hand, the empirical findings of Krtalić and Grdović Gnip (2011) supported the validity of Ricardian equivalence hypothesis in Croatia. Their paper showed that there is no Granger causality amid the trade and budget deficit in Croatia in both directions. Using descriptive statistics, Tesic et al. (2014) confirmed the existence of twin deficit hypothesis in Serbia and found that growing budget deficit and the dominant external financing could not boost Serbia's economic growth.

Sobrino (2013) examined the existence of a causal relationship between the budget and current account deficit for the small open economy of Peru for the period 1980-2012 and found no empirical evidence in favour of the twin deficit in the short run. Šuliková et al. (2014) tested the validity of the twin deficit hypothesis in three small open Baltic countries using VECM model. The obtained results confirmed the existence of the twin deficit hypothesis in Estonia, Lithuania and Latvia. Using panel data analysis and Granger-causality test Eldemerdash et al. (2014) explored the relationship between the current account and budget deficit in a group of small open developing economies. Their results indicated the existence of the twin deficit hypothesis in oil producing countries, and the Ricardian equivalence proposition in non-oil countries. These contradictory results could be explained with the different levels of integration of the countries in the world financial markets (Köhler, 2005), level of the development of the country, its socio-economic and political environment and the employed quantitative methods (Noveski, 2018).

Using co-integration and other econometric techniques Gabrisch (2015) tested the long-term causality between the budget and current account deficits of three post-transition countries in Central and Eastern Europe. The obtained results rejected the

twin deficits hypothesis in the analyzed countries (Czech Republic, Hungary and Poland) due to the effect of specific transition factors (high import intensity and net capital inflows) in the analyzed countries.

Furceri and Zdzienicka (2018) examined the existence of the twin deficit hypothesis in developing economies and found that the magnitude of the effect of the budget deficit on the current account deficit is different across counties and over time. They provided empirical evidence that this effect is larger in economies that are more open to trade.

The empirical literature with regard to the validity of the twin deficit hypothesis in Macedonia is rather scarce. Focus is given on the Republic of North of Macedonia, because Macedonia, like other emerging countries in the process of convergence towards EU, has been forced to finance its investments from external sources, which resulted with current account deficits. In addition to that fact, Macedonia is a small and a highly opened economy with a fixed exchange rate and as such more vulnerable to external shocks. Therefore maintaining an external sustainability is of utmost importance for the country's overall macroeconomic stability. The obtained results for Macedonia can be used as a basis for future research of the existence of the twin deficit hypothesis in small and open emerging countries. Sadiku et al. (2018) applied a VAR model and a Granger causality test on quarterly data to investigate the validity of twin deficit hypothesis in Macedonia. Based on the VAR results they found out a short-term relationship between trade and budget deficit, and the results of the Granger causality test revealed a unidirectional relationship in direction from trade to budget deficit. Stojcevska and Miteski (2016) also employed a VAR model on quarterly data to examine the effect of fiscal policy on the Macedonian current account deficit and found a positive, but contemporaneous relationship between the budget and current account balance. The next section describes the research methodology used in this paper.

Methodology

In order to enrich the existing empirical literature, we analysed the causal link between the budget and current account deficit and tested the validity of the twin deficit hypothesis in the Republic of North Macedonia, using two series, budget deficit to GDP and current account deficit to GDP and employing the following model:

$$CA_t = f(BD_t) \qquad (9)$$

where CA_t is a current account deficit at time t, and BD_t is a budget deficit at time t. Following Fidrmuc (2003) the econometric model can be written in the following form:

$$CA_t = \alpha_0 + \alpha_1 BD_t + u_t \qquad (10)$$

re α_0 is a constant, α_1 is a model coefficient of the budget deficit and u_t is the random error term. We expect a positive sign for the coefficient of the budget deficit indicating that a higher budget deficit worsens the current account balance.

We empirically investigated the long-run relationship and causality between budget and current account deficit in the Republic of North Macedonia using actual quarterly data of budget deficit to GDP and current account deficit to GDP in the period spanning from the first quarter of 2005 to the last quarter of 2017. The quarterly data series for budget deficit to GDP ratio and for current account deficit to GDP ratio were taken from the Eurostat database (2020). Econometric analysis of the relationship between the budget and the current account deficit is usually performed by applying Granger causality techniques and vector autoregression (VAR) models. Unlike Granger causality, the VAR model allows the so-called impulse responses to be

calculated i.e. to determine the dynamic impact of certain variables, including their logarithmic values, on a variable, and allow for variance decomposition, which provides information on the percentage of variation of a particular variable that can be explained by its lagged values or others variables.

Since we used quarterly data for the period from the first quarter of 2005 to the last quarter of 2017, we had to solve the problem of seasonal adjustment of data. By applying a seasonal adjustment technique, we removed the cyclical seasonal components from the budget and current account deficit time series data and extracted their underlying trend components.

Based on Equation (10) we applied time series econometric methods of both the vector autoregression (VAR) and vector error correction (VEC), as well as Granger causality tests to determine the causal relationship between current account deficit and budget deficit.

The VAR model developed by Sims (1980) is one of the most popular econometric methods for investigating the twin deficits hypothesis. Sims (1980) argued that VARs provide a more systematic approach to imposing restrictions and could lead a researcher to draw conclusions, which could not be drawn using standard procedures. The VAR models have a number of advantages: they can be easily estimated, have good forecasting capabilities, they accommodate well for the endogeneity problem among the variables (all variables in the VAR model are endogenous), the results can be easily interpreted and Granger noncausality can be easily tested

The standard or reduced form of the VAR model is as follows:

$$y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \cdots + \beta_k y_{t-k} + \alpha x_t + u_t \qquad (11)$$

where y_t is a vector of endogenous variables, x_t is a vector of exogenous variables, α and β are matrices of coefficients, and u_t is a vector of innovations (white noise).

If the budget and current account deficit time series data are cointegrated, then the VAR model is not the most appropriate presentation and it is necessary to add long-run components to the VAR model. The model transformed in that way is called the vector error correction model (VECM). The application of VECM assumes that variables in the system are cointegrated and that the considered time series are integrated of order 1.

The system of the VECM equations has the following form

$$\Delta CA_t = \alpha_1 + \sum_{i=1}^{m} \mu_{1i} \Delta CA_{t-i} + \sum_{i=1}^{n} \delta_{1i} \Delta BD_{t-i} + \beta_1 \xi_{t-1} + u_{1t} \qquad (12)$$

$$\Delta BD_t = \alpha_2 + \sum_{i=1}^{m} \delta_{2i} \Delta BD_{t-i} + \sum_{i=1}^{n} \mu_{2i} \Delta CA_{t-i} + \beta_2 \xi_{t-1} + u_{2t} \qquad (13)$$

where α_i is the coefficient of the error-correction term (ECT),and β_i is the coefficient of the cointegrating equation of the system. The parameters of the ECT indicate the sensitivity of each of the endogenous variables in each period of time to the deviation from the long-term equilibrium condition ξ_{t-1}. Convergence exists if α_i lies between 0 and −1. A significant coefficient on the error-correction term indicates that the dependent variable is sensitive to any deviation from the system's stationarity on the long-run, and insignificant coefficient suggests that ECT is not sensitive on any deviations on the long-run. The coefficients μ_i and δ_i indicate the Granger causality of the variables with respect to the dependent variable, u_{1t} and u_{2t} are white-noise residuals, *m* and *n* are the lag lengths of the variables, and Δ is the first-difference operator of the corresponding variables.

In our paper, we estimated the models using the econometric computer package EViews 9.

Results

We began our econometric analysis by testing whether the obtained seasonally adjusted time series data are stationary. In order to accomplish this, we employed the augmented Dickey-Fuller (ADF) test on the null hypothesis of nonstationarity.

The results reported in Table 1 clearly show that the seasonally adjusted budget deficit time series data is stationary at level, while the seasonally adjusted current account deficit time series data is not stationary, but is stationary at the first difference, meaning CABSA ~ I (1). In order to determine the magnitude of a correlation between the two deficits, and the type of relationship that could be expected between the budget and the current account deficit in the long run, we will apply the Vector Autoregression Model (VAR) and the Vector Error Correction Model (VECM). The VAR model provides a measure of short-run correlation, while VECM model tests for a long-run relationship between the variables employed, reflecting the features of a long-run convergence of the system towards its equilibrium level.

Table 1
Augmented Dickey-Fuller (ADF) Test Results for Unit Roots

H_0: BUDGETSA has a Unit Root		t-Statistic	Prob.*	H_0: CABSA has a Unit Root		t-Statistic	Prob.*
ADF Test Statistic		-7.760693	0.000	ADF Test Statistic		-3.168182	**0.1131**
Test Critical Values:	1% level	-4.148465		Test Critical Values:	1% level	-4.152511	
	5% level	-3.500495			5% level	-3.502373	
	10% level	-3.179617			10% level	-3.180699	
*MacKinnon (1996) one-sided p-values							

Source: Author's own calculations

The results of the VAR model are displayed in Table 2.

After we have verified that we cannot reject that all variables are I(1), we proceed with the Johansen test for cointegration in order to determine whether there are stable long-run relationships between the budget deficits and the current account deficits. In order to implement the Johansen's procedure, we have to determine the optimum lag length in the VAR model. There are various approaches for selection of the VAR model order. In our case, we select the lag order by minimizing one or more information criteria evaluated over a range of model orders and employing the one of the most commonly used information criteria Schwarz-Bayes Criterion (SBC) also known as the Bayesian Information Criterion (BIC). This selection procedure has led us to choose a lag of 2. None of the variables explaining the budget deficit are statistically significant, while all variables explaining the current account deficit with a lag of one and two quarters are statistically significant. The stability of the VAR model is tested using the root of the AR characteristic polynomial and the results are shown in the Table 3.

Table 2
The VAR Model Results

	CABSA	BUDGETSA
CABSA(-1)	0.550755	0.099113
	(0.14103)	(0.10438)
	[3.90517]	[0.94956]
CABSA(-2)	0.059230	-0.084572
	(0.13845)	(0.10247)
	[0.42780]	[-0.82534]
BUDGETSA(-1)	-0.190774	0.129619
	(0.18174)	(0.13451)
	[-1.04970]	[0.96366]
BUDGETSA(-2)	-0.492272	0.447893
	(0.19099)	(0.14135)
	[-2.57745]	[3.16861]
C	-2.965291	-1.058929
	(0.86057)	(0.63691)
	[-3.44573]	[-1.66261]

Note: (standard errors in brackets); [t statistics in parentheses]
Source: Author's own calculation

Table 3
Stability Analysis of the VAR Model

Roots of the characteristic equation Endogenous variables: CABSA, BUDGETSA Exogenous variables: C Specification of the lag: 2	
Roots of the characteristic equation	Modules
0.771227	0.771227
-0.660622	0.660622
0.511852	0.511852
0.057917	0.057917
No root lies outside the unit circle. **The VAR model meets the stability requirement**	

Source: Author's own calculations

The results of the stability analysis depicted in Table 3 show that no root lies outside the unit circle, i.e. the VAR model meets the stability requirement. Having this in mind, we can proceed with calculation of the value of the impulse response function and with decomposition of the variance of the prediction error. But we first run the Granger causality test with seasonally adjusted quarterly time series data on Macedonia's current account deficit and budget deficit in order to detect how changes in one variable causes the other variable to change. The results of the Granger causality test of the seasonally adjusted CABSA and BUDGETSA series are reported in Table 4.

Table 4

VAR Granger Causality

Dependent variable: CABSA			
Excluded	Chi-sq	df	Prob.
BUDGETSA	9.423063	2	0.0090
All	9.423063	2	0.0090
Dependent variable: BUDGETSA			
Excluded	Chi-sq	df	Prob.
CABSA	0.974107	2	0.6144
All	0.974107	2	0.6144

Source: Author's own calculations

The results in Table 4 show that there is a strong Granger causality running from the budget deficit to the current account deficit. Namely, the probability that the budget deficit does not cause the Granger current account deficit is less than 1%. Contrary to that, the high probability of 61.44% indicates that the current account deficit is not caused by the Granger budget deficit. The same conclusions can be reached if lags of 3 and 4 quarters are applied in testing. These results suggest that the authorities of the Republic of North Macedonia may have indeed followed the policy of short-term targeting of the current account, i.e. they tended to increase the budget surplus based on expectations of an increasing current account deficit. However, in the long run, for example, with a lag of 15 quarter or more, the current account deficit leads to a fiscal deficit. The first result confirms the validity of the twin deficit hypothesis, while the second result complies with the structural gap hypothesis.

In order to analyse the response of one variable to a random shock in another variable we employed the impulse response function (IRF). It detects the effect of a one-time shock on the current and future values of the endogenous variables in the VAR model. To compute IRF we used Cholesky decomposition of the estimated residual covariance matrix of the estimated VAR model. Figure1 shows the impulse responses of each variable (budget balance and current account balance) to shocks in the other variables included in the model.

Row 1 of Figure 1 shows the responses of budget balance to shocks to the variable itself and to shocks in current account balance, respectively. As we can see from row 1 of Figure 1 (upper left-hand panel), the lagged values of the variable BUDGETSA offset the magnitude of BUDGETSA at time *t*, but the effect declines gradually. The increase in the current account balance for one standard deviation affects the recovery of the budget balance, resulting in a budget surplus during the first two periods, followed by a decrease of the budget surplus and converting to zero (row 1 of Figure 1, upper right-hand panel).

Row 2 of Figure 1 shows the responses of the current account balance to shocks to budget balance and to shocks to the variable itself, respectively. Current account balance responds negatively to a shock in the budget balance. The increase of the budget balance for one standard deviation, would gradually, in the following two periods, lead to a current account deficit that slightly improves, but is maintained in subsequent periods. The reason for that is because an increase in the budget balance involves more spending on the foreign sectors (importing more) causing a decrease in the budget balance surplus and therefore a decrease in the current account position.

Figure 1
The Impulse Response Function Results of the variable budget deficit (BUDGETSA) and current account deficit (CABSA)
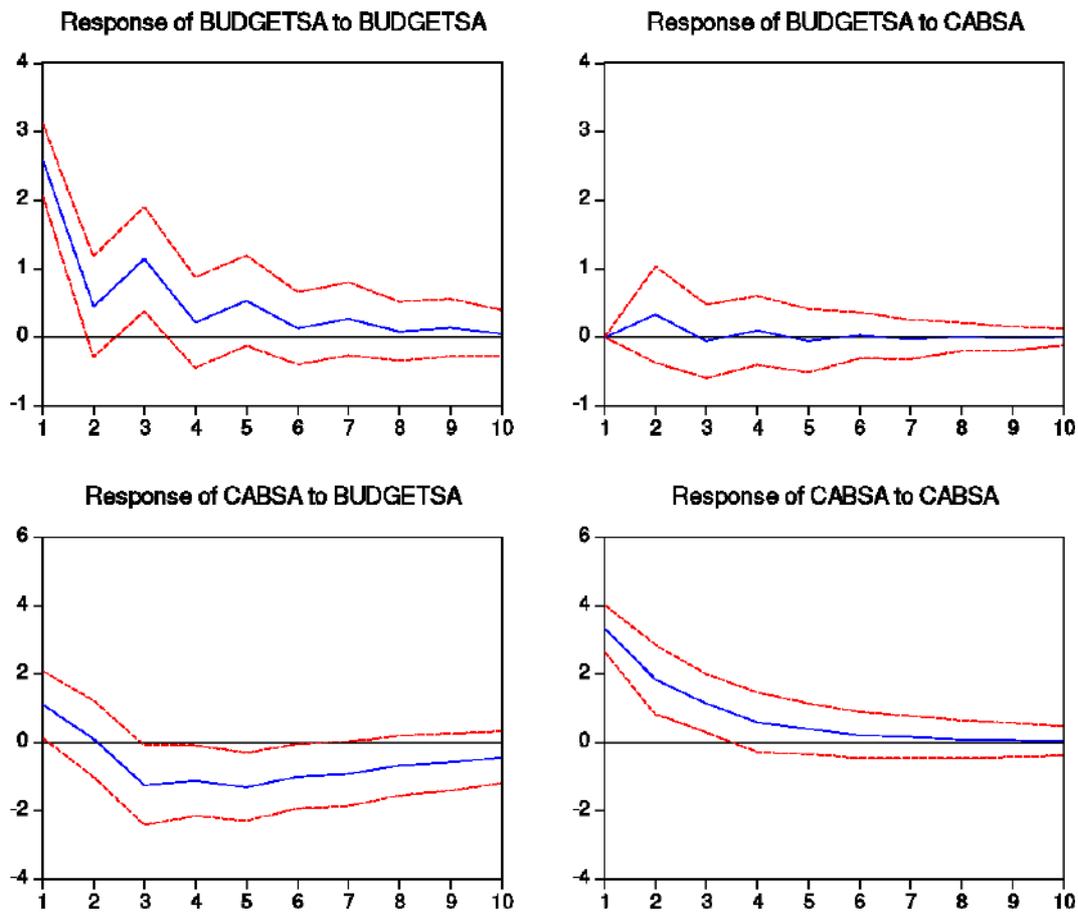
Source: Author's own calculations
Note: Response to Cholesky One S.D. Innovations ± 2 S.E.

The impact of the lagged values of CABSA on itself is quite significant in the first four periods and then converges to zero (row 2 of Figure 1, lower right-hand panel).
The short-term relationship between the budget balance and the current account balance is negative, meaning that budget deficits are associated with higher rather than lower current account deficits, which is contrary to the twin deficit hypothesis. This can be explained with the fact that a budget surplus is recorded as a liability in the balance sheet of the National Bank of the Republic of North Macedonia and as such, it reduces the quantity of money in circulation. To compensate this, companies are forced to borrow money from abroad, which, in turn, worsens the trade and the current account deficit.

However, it is well established that the results of the impulse response function based on Cholesky's decomposition are generally sensitive to the ordering of the endogenous variables and the lag length. To overcome this drawback, we estimated the variance decomposition (Figure 2), taking into account both the short and long-term aspect. The variance decomposition gives information about the percentage of variation of a specific variable that can be explained by its own lagged values or other variables. We can draw interesting conclusions from the variance decomposition. The BUDGETSA variable explains 90.39% of its error in the next period

(k = 1), after which this percentage declines slightly, then after 5 periods it slightly increases and after 10 periods that percentage is 91.9%. CABSA therefore explains a very small portion of the variation in the prediction error of the BUDGETSA variable. On the other hand, the BUDGETSA variable in the first period does not explain the variance of the CABSA variable prediction error, but after that, that share increases significantly and at the end of the tenth period it reaches 56.61% of the variation of the CABSA variable forecast error. These results comply with the results of the Granger causality test for the causal link between the budget and the current account deficit.

Figure 2
Decomposition of the variance of BUDGETSA and CABSA variables
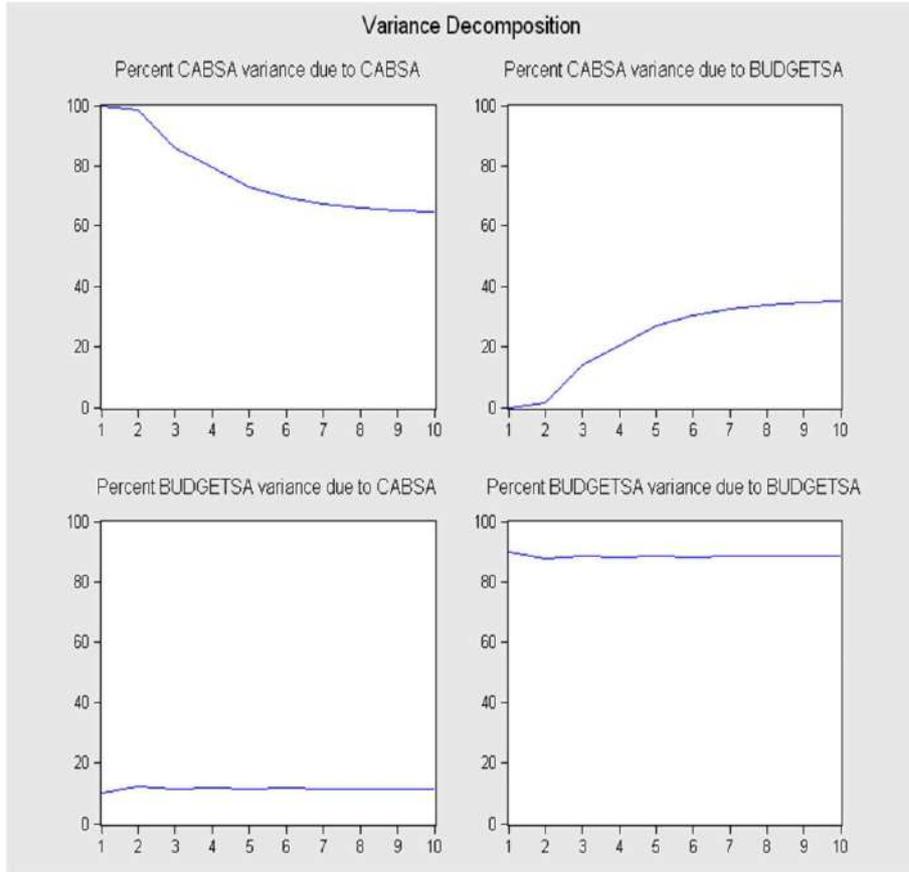
Source: Author's own calculations

The fact that at least one of the time series data was not stationary allowed us to proceed with the analysis of the vector error correction model (VECM). The results of the VECM analysis are presented in Table 5.

Table 5
Vector Error Correction Model (VECM)

Cointegrating Eq:	CointEq1	
CABSA(-1)	1.000000	
BUDGETSA(-1)	1.855149	
	(0.58293)	
	[3.18246]	
C	8.026611	
Error Correction:	D(CABSA)	D(BUDGETSA)
CointEq1	-0.440552	-0.073692
	(0.10452)	(0.07988)
	[-4.21510]	[-0.92251]

Note: (standard errors in brackets); [t statistics in parentheses]
Source: Author's own calculations

The basic cointegration equation has the following form:

$$CAB = \beta BUDGETB \tag{14}$$

where CAB is the current account balance, $BUDGETB$ is the budget balance, and β is the regression coefficient. The magnitude of the β coefficient estimate in the cointegration equation can be considered as a test of the validity of the different theoretical interpretations of the relationship between the budget deficit and the current account deficit. In our case, the estimated value of the β coefficient is greater than one:

$$CAB=1.855149BUDGETB \tag{15}$$

In addition, based on the *t* statistics, it can be concluded that this coefficient is statistically significant at the level of significance of 1%. The magnitude of the β coefficient does not refer to the conclusions based on the New Cambridge School hypothesis that if $\beta >1$ the current account deficit in the long run moves in the same direction as the budget deficit. However, the current account deficit is "overreacting" as the private sector contributes to both the budget and the current account deficit. This is possible if capital inflows, i.e. current account deficits can simultaneously finance private and public sector deficits. The higher the coefficient, the stronger the effect of the budgetary position of the surplus savings relative to private sector investments. This kind of dependence implies a strong influence of the world economy on the domestic economy. However, twin deficits exist in the long run, as it is necessary to observe simultaneously the increase or decrease of both deficits (budget and current account deficit) depending on the direction of capital flows.

In order to draw precise conclusions, we have to interpret the other coefficients in the cointegration equation, i.e. α_1 and α_2 that indicate the rate of adjustment to the long-run equilibrium. The equations taking into account only error correction terms can be displayed as follows:

$$\Delta CAB_t = -0.440552(CAB_t - 1.855149\,BUDGET_t) + ... + u_{1t} \tag{16}$$

$$\Delta BUDGET_t = -0.073690(CAB_t - 1.855149\,BUDGET_t) + ... + u_{2t} \tag{17}$$

Deviations from the equilibrium equation (15) are negatively correlated with changes in the budget deficit and the current account deficit. These results point to the conclusion that the twin deficit hypothesis in Macedonia is rejected in the short run, and in the long run we can expect a positive correlation between the budget

deficit and the current account deficit in direction from budget deficit to current account deficit. These results support the hypothesis of the impact of the global economy on current account and budget deficit in the long run.

Discussion, implication and conclusion

The purpose of this paper was to explore empirically the validity of the twin deficit hypothesis in the Republic of North Macedonia for the period 2005-2017. To achieve this objective, we used actual quarterly data on Macedonia's budget and current account deficit in the period 2005Q1-2017Q4. We tested the validity of the twin deficit hypothesis by estimating a VAR model. We also performed the Granger causality test, carried out impulse response testing and variance decomposition. We also investigated the stationarity of the time series data and since one of them was not stationary, we performed a VECM analysis. Based on the Granger causality test, we found that there is a causal link between the budget deficit and the current account deficit-an increase in the budget deficit would lead to an increase in the current account deficit. The VAR model did not provide evidence in support of twin deficit hypothesis in the short run. However, based on the results of the vector error correction model (VECM) this hypothesis holds in the long run.

The obtained findings are in line with the results of previous empirical studies on the existence of twin deficit hypothesis in Macedonia (Sadiku et al., 2018 and Stojcevska and Miteski, 2016). They are also in conformity with the results of previous research of small opened economies that are highly exposed and sensitive to external price shocks (Margani and Ricciuti, 2004; Sobrino, 2013; Šuliková et al., 2014).

The results of our paper will be helpful for formulating future fiscal policy of the Republic of North Macedonia. Our finding that the twin deficit hypothesis does not hold on a short-term, indicates that in the short run the fiscal policy of the government of the Republic of North Macedonia could not affect the current account balance. On the other hand, the empirically confirmed long run link between the fiscal deficit and the current account deficit implies that the Macedonian government should focus on cutting down the non-development consumption expenditures and implementing a fiscal consolidation in the next years. This would contribute to addressing elevated government debt levels, reducing future growing external vulnerabilities and creating adequate policy space to counter future shocks, which is in line with what the International Monetary Fund has recommended to the Macedonian government. Policy initiatives should be directed not only to reducing the budget deficit, but also to improving the current account position though export promotion (supporting of export-oriented companies in order to increase their real export competitiveness) and import substitution, especially by minimizing the spending on imports of consumer goods that can be produced locally. Additionally, serious attention should also be given to encouraging domestic industry to increase production and employment. If these policies are effectively implemented, the current account balance will improve, and the budget deficit will be reduced.

In spite of the fact that our estimated model can be considered as statistically significant, the obtained results should be taken with caution, due to the relatively short time series and structural breaks in the analysed period. The latter are a result of external shocks, such as the global financial crisis of 2008 and the multiyear European sovereign debt crisis. Although the model is estimated based on reliable data sources, we should take into consideration the methodological differences in calculation of fiscal data between Macedonia and the EU member countries. The Macedonian government finance statistics is still not aligned with the EU statistics, which affects the quality of fiscal data and its comparability to EU member countries. The expansion of

the model with inclusion of other exogenous and endogenous variables could lead to other results. In this paper, we could not include other variables due to the short time series data. That is why in our future research we will expand the estimated model with other variables, such as real interest rate, exchange rate regime, and level of indebtedness (both public and external debt), economic cycle, etc. and by applying a more advanced dynamic VAR technique, such as the structural vector autoregression (SVAR) approach.

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About the author

Vesna Bucevska, PhD is a Full professor of Econometrics and Financial Econometrics at the Faculty of Economics, Ss. Cyril and Methodius University in Skopje. She has been professionally trained at prestige European universities. Her main research areas are statistics, econometrics and financial econometrics. She is an author of a number of university textbooks and published more than 100 scientific-research papers. In the period 2013-2019, she was Vice-Dean of Science and International Cooperation at the Faculty of Economics-Skopje. Vesna Bucevska is a member of the Statistical Council of the Republic of Macedonia. The author can be contacted at **vesna.bucevska@eccf.ukim.edu.mk.**

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Mobile Payment in the Connected Car: Developing Services Based on Process Thinking

Lukas F. Petry, Jürgen Moormann
ProcessLab, Frankfurt School of Finance & Management, Frankfurt a.M., Germany

Abstract

Background: The automotive world is on the threshold of a new era. Manufacturers are transforming themselves into suppliers of mobility services. Fundamentals for the transformation are customer processes combined with connectivity driven by the Internet of Things. Mobile payment serves as an enabler to most of these services. **Objectives:** This paper demonstrates promising ways how payment-enabled services in the context of connected cars can be designed based on the process thinking approach. **Methods/Approach:** In this paper, the methodology of use cases is applied as a means to develop services for the connected car through process thinking. The use case studied is validated afterwards with industry experts following a semi-structured interview format. **Results:** The use case investigated in the course of the paper suggests that the core characteristics and challenges of these services are already predictable ex-ante by the theoretical framework on which the paper is built upon. In particular, the paper shows the steps needed for a driver's request for on-demand horsepower for a certain time span along with mobile payment for this service. **Conclusions:** It is concluded that the connectivity paradigm supplemented by mobile payment options enables consistent implementation of customer centricity in terms of process thinking.

Introduction

As a consequence of a connected world, companies across all industries strive to adapt their business models. If this task is not taken seriously, even currently well-established companies will run into problems within just a few years. When looking at

the automotive industry, connectivity has been recognized as a major game-changer besides e-mobility. Against this background, several automotive companies have already acquired payment service providers. While at first glance major synergies between the business models of car manufacturers and payment providers do not seem obvious, mutual benefits in terms of innovative services emerge when looking at the future: the connected car (Brenkers & Verboven, 2006; Eichstädt et al. 2016). However, these mutual benefits are always accompanied by challenges with regard to system design and a fully integrated payment process.

This paper is motivated by the automotive industry's ambition to develop progressive transportation opportunities in the form of connected cars, which provide an immediate value-added from a customer's perspective. The value is generated by the development of services, which are based on connectivity features and enabled by various types of mobile payment.

The enabler for the connected car with respect to the subsequently described particular use case is the technology of electric vehicles. To mention only some major advanatges that are relevant in the context of the use case, electric drive technology bears the potential of a flexible range in terms of horsepower. Morevoer, electric vehicles are especially suitable for leasing contracts or car sharing option due to their high purchasing price and comparably low maintenance cost. This perfectly complies with the societal trend of pay-as-you-use options. Connected cars can have positive impact on traffic safety, efficiency, comfort of transportation, enable environmental benefits and provide services according to individual needs (Cappola & Morisio, 2016). In contrast to this, drawbacks are imminent in terms of battery capacity constraints, e.g. with respect to maximum reach and engine load. Furthermore, these concerns are especially challenging in the light of a relatively long charging process and the network coverage of charging stations.

In the future, it will be increasingly important to identify the key challenges of mobile payment applications in the connected car to make the interaction between mobile payment and automobiles promising. Thus, the core challenges have to be identified, clustered, and analyzed. The next step will be to conceptualize and analyze mobile payment applications in the connected car. This step should be accomplished on the basis of a clear understanding of the customers' processes. The research contributes to an analysis of the relationship of the connectvitiy paradigm and customer centricity in general, and the development of customer-centric, payment-related services in connected cars in particular. Hence, the research question of this paper is: *How can mobile payment-enabled services in the context of connected cars be designed?*

The paper is structured as follows: First, we elaborate on the theoretical foundation, which rests in particular on three pillars: process thinking, connected world theory, and mobile payment. Building on the theory of process thinking is crucial, since services should be developed strictly from a customer's point of view. In order to design customer-centric processes, one has to systematize the challenges these processes are going to face. The challenges are embodied by the term connected world theory (CWT) and highly topical issues centering on the Internet of Things (IoT). These challenges require innovative concepts showing how automotive manufacturers can successfully cope with them. Ultimately, the key concept enabling the implementation of opportunities that a connected world yields is mobile payment. Second, the methodology is explained. We apply use case construction as a systematic approach in the course of the conceptual part of this work. In our research project we have identified several use cases. Each one serves as a representative example of a specific application of mobile payment. As third step, we present one of these use cases to show, how a service based on process thinking can be

developed. Subsequently, fourth, the findings of the use cases will be evaluated using interviews with experts representing different roles within the automotive industry. Fifth, we conclude by emphasizing the connection between the challenges, the conceptual outcome of the use case development, and the extant literature.

Theoretical background

Based on previous analyses in the automotive sector (Eichstädt et al., 2016), a strong connection between the three pillars became evident. These pillars serve as the theoretical framework on which our paper is built upon.

The first of the three pillars is process thinking (PT). In order to meet customer expectations, the automotive industry will have to further change its perspective from product orientation ("inside-out perspective") to customer orientation ("outside-in perspective"). The second pillar deals with connectivity and the connected world theory (CWT). Connectivity, and especially built-in connectivity, constitutes a powerful direction for the connected car of the future. This leads to the third pillar, mobile payment (MP). The importance of mobile payment is understandable as soon as we see the transportation process from a customer's point of view. As customers would often like to make use of services immediately and pay for them in the easiest way possible, this can be implemented in the form of pay-as-you-use models enabled by MP.

Process thinking

Following the traditional product-oriented view ("inside-out perspective"), automotive manufacturers decide on their production line and proceed with large-scale marketing campaigns promoting their cars, connectivity features, and the corresponding mobile payment solutions.

On the contrary, customer orientation ("outside-in perspective") takes the customer's needs as its starting point (Drucker, 1954; Hammer, 2002). Here, the initial input comes from the (potential) customer himself/herself. These customer inputs can, for instance, be evaluated on the basis of product tests, prototypes, and questionnaires. Thus, the manufacturing of the final product is well-aligned to customer needs and has a higher potential to succeed in the market.

The concept of process thinking follows the huge stream of literature in the field of business process management (BPM) which aims at supporting companies in achieving operational excellence (Davenport 1993; Dumas et al., 2018; Hammer & Champy, 1993; Harmon, 2019; Österle & Winter, 2003; Rosemann & vom Brocke, 2015). Common to all BPM concepts is that customers should be the starting point when designing a new process. It is also common ground that each business process should be designed as an end-to-end process; that is, starting and ending with the customer.

Current concepts go even further and start with the process a customer actually performs. These follow the customer-centric approach (Behare et al., 2002; Shah, 2006; Wallace et al., 2010). What characterizes such an approach? Customers and especially car enthusiasts may use automobiles and their connectivity features for the sole reason of pleasure, but they would hardly use mobile payment solutions for the same reason. Hence, the successful usage of mobile payment solutions depends on whether they satisfy the customers' needs in terms of practicability and saving of time.

As a starting point to develop services based on customer processes, the concept of the customer buying cycle (CBC) appears to be suitable. The CBC divides the buying process into four phases: (1) Awareness: in this phase, the customer develops his/her need and becomes aware of it. (2) Evaluation: the customer formulates his/her need and builds intrinsic expectations on the key characteristics that have to be

fulfilled. In addition, he/she begins to search for information and evaluates the findings. (3) Purchase: the customer is ready to decide on one of the available options and purchases the product or service. (4) After-sales: finally, the customer uses the product or service in the intended way and reconsiders whether it was able to satisfy his/her needs.

The CBC can be understood as a procedure to understand customers' requirements, derive customer processes, and consider more thoroughly how business processes can cover these needs in a structured way. Thereby, we are able to identify the most important interface between automotive manufacturer and customer: the connected car, including its support devices. Automotive manufacturers will only turn their vision of a connected car into practice if they are able to implement integral solutions for the whole CBC. This is exactly where mobile payment becomes an indispensable part. Mobile payment applications are important for generating revenues, as they allow pay-per-use solutions and also address customers who are averse to subscriptions.

Connected world theory

Connectivity in the automotive industry comprises any form of internet communication assisting the driver with respect to his/her automobile. However, connectivity, in general, is a much broader concept. In the so-called connected world theory proposed by Rosemann (2014), the IoT plays the predominant role. The concept is strongly linked to process thinking outlined above. Potts (2010) explains the relationship between customer processes and the IoT in a connected world in the sense that it is not about how customers participate in business processes, but about how organizations participate in the customers' processes.

The IoT is the foundation through which the automotive industry is able to further develop the connected car and the corresponding mobile payment solutions. More precisely, the IoT facilitates the connection and integration of physical objects such as automobiles and banknotes in the digital world (Oberländer et al., 2018; Rosemann, 2013). This implies that customer processes can be supported automatically by digitalized objects after the latter receive permission from the customer.

The functionality of how this infrastructure works can be divided into three steps, according to Rosemann (2014):

(1) Ability of the physical object to store a unique ID: The physical object is required to be able to store a certain amount of information, which identifies the physical object in the digital world as the one it is. Applied to connected cars enabled for mobile payment, the customer is not required to open any device or wallet in order to process a transaction anymore.

(2) Ability of the digital representation to interact with the Internet: The digital representation of the physical objects needs to be able to communicate and process interactions with the Internet. This implies that the digital representation can access information provided by other components and trigger further actions (access information on the customer's payment preferences).

(3) Ability of the sensors to detect information about the environment: The physical object should be equipped with sensors collecting and processing information about the environment in order to recommend actions. Due to connectivity and the IoT, sensors can trigger a search process for the nearest gas station, navigate to it, and initiate a MP process for the service.

Mobile payment

These new services bring up the need for instant and mobile payment solutions to support the customer with the desired connectivity services as well as to guarantee frictionless transactions. In terms of process thinking, MP solutions are key components for the success of the connected car, as they promote the fulfillment of customers' needs in the whole process. Thus, MP paves the way for automotive manufacturers to implement customer centricity.

For the aim of this paper, we define MP as the usage of a mobile terminal to pay for goods or services. These transactions occur either business-to-business (B2B), customer-to-customer (C2C), or between a customer and a company (C2B). The latter is, with respect to MP solutions in the connected car, most relevant and has to be examined more closely.

The characteristic feature of MP is that the payment process is usually initiated at the point of sale (POS), supporting the customer with a straightforward payment process (Crowe et al., 2010). However, MP has to be divided into its consumer-activated and its merchant-activated applications (Ivanova et al., 2016). The former is characterized by a customer using his/her mobile terminal to process a payment, whereas the latter is used by a company providing mobile terminals for MP purposes.

The consumer-activated application of MP can occur either at the POS (proximity payment), e.g. within the connected car, or independently of the POS (remote payment) (Ivanova et al., 2016). MP used at the POS is a great advantage for the connected car concept, as these payment procedures enable a completely automatic payment process for which the customer does not even have to actively use a mobile device. Besides, it also facilitates a user-initiated payment process, which requires an additional step of verification from the customer. Both methods are characterized by a high degree of data security and cyber resilience, as the payment data is deposited in the trustworthy environment of the payment provider and not shared with the sell-side party if the payment provider is not already a part of it.

The merchant-activated application of MP is based on either hardware or software solutions. Hardware-based solutions require additional components for the mobile terminal to go through the payment process, such as a NFC (near field communication) reader, whereas software-based solutions facilitate a web-based solution. These software solutions offer huge potential for automotive manufacturers, as it is possible to enter payment data into the on-board computer, which operates like a digital wallet.

Figure 1 illustrates the differences between the types of mobile payment applications. In our research, we structured the design of the use cases according to the three types of consumer-activated mobile payment (#1 to #3) because these types entail technical differences and further allow a clear distinction between scenarios suitable for different customer requirements.

For the implementation of MP in connected cars, like in our use case, a technical infrastructure within and outside the connected car is needed to equip the connected car with all required components for in-vehicle services (Bosler et al., 2017). Conditions for such services are the connection of the driver to the car (human-machine-interface), an integrated wireless network connection of the car, a payment provider that offers and supports in-vehicle payment solutions, and an authentication system in place to offer secure payments. Finally, the service provider is required to have an operating system in place allowing the identification of the car and its driver as well as an MP system to charge the driver for the car-specific in-vehicle services.

Figure 1

Types of Mobile Payment Applications
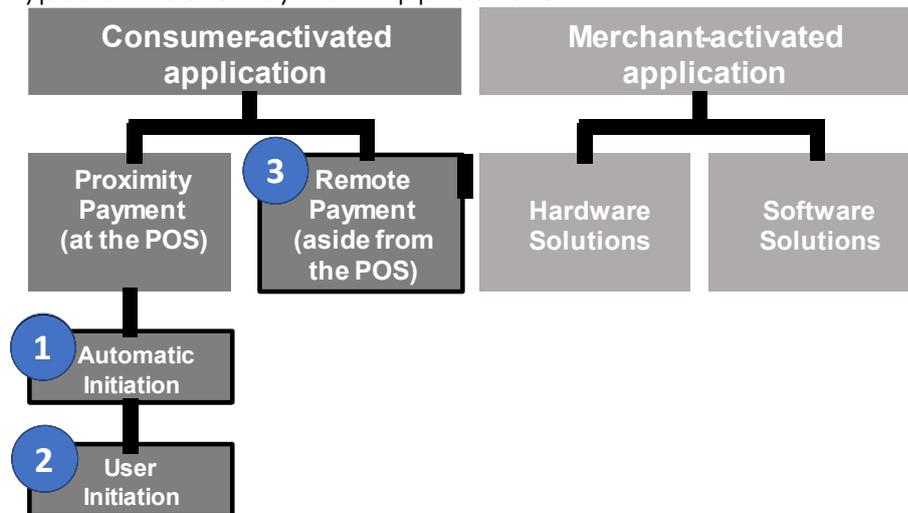
Source: Authors' work

Methodology

In this section, the methodology of use cases is applied to conceptualize relevant cases for MP application in the connected car. A use case is a specific application of a system for the purpose of its stakeholders. It generally describes how the system under discussion reacts under different conditions to the request of a stakeholder or the primary actor (Cockburn, 2000).

Stakeholders include all parties having an interest in the company or its system, whereas primary actors are those in direct contact with the system, e.g. customers. The primary actor usually interacts with the system to reach a specific goal. The system reacts in the interest of all stakeholders and offers solutions. Depending on the kind of request or the circumstances, the system will respond differently, ending up with other scenarios. The use case summarizes all of these scenarios.

The conceptualization of use cases follows Cockburn (2000) in order to conduct a concise and clearly structured analysis of the cases. Therefore, the key components and terms applied in each use case are:

o   **Primary actor:** The individual or object in direct contact with the system when following a certain goal.
o   **Scope:** Concise identification of the system under discussion.
o   **Level:** Definition of whether the target is on the same level or a higher/lower level than the user level.
o   **Stakeholder:** Individuals or objects with an inherent interest in the application and outcome of the system under discussion.
o   **Preliminary conditions, invariants:** Definition of the key characteristics that have to be true prior to the use case.
o   **Post conditions:** Definition of the key characteristics that have to be true after the run of the use case.
o   **Standard process:** Simulation of a case in which there is no error or problem.
o   **Extensions:** Simulation of other possibilities that may occur in the course of the use case (these usually include certain errors or problems).

Following the approach of putting the car into the internet instead of simply accessing the internet from the car, the business-to-thing (B2T) relationship has to be discussed. This relationship has become increasingly important for automotive

manufacturers, replacing a pure business-to-consumer (B2C) focus, as the primary interactions will happen between the driver (consumer) and the car (thing) instead of solely between driver and manufacturer (business) (Manyika et al., 2013).

In the use cases, the primary actor, who is often the customer, usually requests an action or reacts to a request from the car. This process of request and execution can be illustrated in terms of workflow loops according to speech act theory (Denning, 1992; Denning & Medina-Mora, 1995). The standard case is that the customer (driver) starts a request that is "negotiated" with the performer (connected car) and executed afterwards. The customer then accepts the solution or starts a new request (Manyika et al., 2013).

For the design of the use cases, we put the customer in the focus of the process and evaluate the process according to the customer's needs (outside-in perspective). All use cases have been developed based on the steps suggested by Cockburn (2000). Each step has been iteratively validated with industry experts for each use case. The format of these interviews was a qualitative semi-structured one following a set of predefined questions in the same order while leaving a fruitful degree of flexibility to add additional points towards the end of the interview.

In this paper we present one use case as an example: *additional horsepower on demand*. This case represents the automatic initiation of mobile payment used as proximity payment at the POS (Figure 1, #1).

Use case: Additional horsepower on demand

The concept of "horsepower on demand" is technically feasible with an electric engine in the connected car. The general concept can be derived from its name: The driver may be on his/her way home from a meeting on a quiet highway without speed limitations. For the purpose of time efficiency or pure driving pleasure, he/she intends to accelerate and drive faster than the car's technical characteristics currently allow. Presumably, the driver shows a willingness to pay for extra horsepower limited to the remaining time of his/her journey.

In the following, the process of a driver requesting on-demand horsepower for a limited amount of time along with mobile payment for this service is presented. The use case is predefined based on the key components suggested by Cockburn (2000):

- o **Primary actor:** Driver of the connected car.
- o **Scope:** Connectivity system and mobile payment process.
- o **Level:** Objective on user level.
- o **Stakeholder and interests:**
- o *Driver:* Aims to activate additional horsepower on demand, use it for acceleration and a shorter traveling time, and pay for the service in a time-efficient manner.
- o *Automotive manufacturer:* Intends to sell the additional horsepower on-demand service in an uncomplicated way via the onboard system of the connected car and receive the payment promptly.
- o **Preliminary conditions:** The driver has already initiated the onboard system of the connected car and submitted his/her payment data at initiation.
- o **Invariants:** The onboard system has sufficient information about the activation process as well as payment data to detect potential errors or problems and request additional information from the user.
- o **Post conditions:** The onboard system is able to finalize the transaction and produce a report for the driver as well as the automotive manufacturer.

Standard process

Based on the procedure suggested by Cockburn (2000), we developed each step for this specific use case, assuming that all systems and connections work properly:

1. The driver chooses the option to activate additional horsepower on demand in the onboard system of the connected car.
2. The driver decides on the amount of the additional horsepower considering the price.
3. The driver confirms his/her selection and requests additional horsepower.
4. The onboard system establishes an Internet connection and verifies the request with the database of the automotive manufacturer.
5. The onboard system confirms the request and anticipates the driver's confirmation.
6. The onboard system initiates the provision of additional horsepower: READY mode.
7. The onboard system initiates the mobile payment process and prepares the protocols.
8. The driver gives his/her final approval to activate the additional horsepower and, in turn, automatically pays the corresponding amount of money.
9. The onboard system initiates the mobile payment process through the provider.
10. The mobile payment application automatically establishes an Internet connection and retrieves the driver's preferred payment settings and the payment data.
11. The mobile payment application verifies that the chosen payment option is working.
12. The mobile payment application automatically charges the amount to the preferred payment option.
13. The mobile payment application produces a receipt and sends it electronically to the driver's preferred account.
14. The mobile payment application transmits the information to the onboard system.
15. The onboard system processes the completion of the transaction, releases READY mode, and activates the additional horsepower.

Extensions of the Standard Process

Looking at the "ideal" process is naturally not sufficient since errors might occur for a variety of reasons. Therefore, we developed extensions (relating to the numbers of the "Standard Process"):

2a. Due to an error in the onboard system, the driver is able to select a higher amount of additional horsepower than technically feasible.

2aI. The onboard system generates an error report and suggests the closest amount of additional horsepower to the original submission.

2aII. The driver confirms the suggestion or cancels the use case.

4a. The Internet connection crashes and the onboard system is not able to generate a stable connection.

4aI. The system generates an error report for the driver and suggests canceling the request or retrying it.

4aII. The driver retries or cancels the process.

9a. The onboard system is unable to connect to the platform of the mobile payment provider and process the transaction.

9aI. The system generates an error report for the driver and starts an automatic retry.

9aII.   If the retry is unsuccessful, the onboard system cancels the transaction and generates a final report suggesting trying it again later.

10a.   The mobile payment application is unable to retrieve the relevant payment settings or payment data from the system.

10aI.   The mobile payment system requests the missing or incorrect data from the driver.

10aII.   The driver enters the data or cancels the use case.

11a.   The mobile payment application is unable to verify the payment option (e.g. the payment option is blocked, or the authorized limit of the account is exhausted).

11aI.   The system requests the driver to enter another payment option.

11aII.   The driver enters another payment option or cancels the use case.

11aIII.   The system verifies the payment option or starts the process again (from 11aI).

13a.   The mobile payment application is unable to send the receipt to the driver's preferred account (e.g. the email address is invalid).

13aI.   The system suggests the driver enter other contact information.

13aII.   The driver enters other contact information or waives the receipt.

14a.   The mobile payment application is unable to send information to the onboard system.

14aI.   The mobile payment application tries to transmit the information again.

14aII.   If unsuccessful, the mobile payment application generates an error report for the automotive manufacturer.

14aIII.   A customer service representative of the automotive manufacturer immediately contacts the driver in person and manually sends a request to the onboard system to complete the transaction.

15a.   The onboard system is unable to receive the final permission from the mobile payment application or a customer service representative of the automotive manufacturer in order to release the additional horsepower.

15aI.   If not contacted already, a customer service representative of the automotive manufacturer immediately contacts the driver in person and explains that he/she has to cancel the request.

15aII.   The customer service representative of the automotive manufacturer suggests an automatic system update or schedules an appointment with the next repair shop to check the onboard system.

15aIII.   The customer service representative offers the driver a discount or compensation for the inconvenience caused.

In this case, the automatic initiation is a plausible assumption, because the process of activating additional horsepower is not a once-in-a-lifetime process, but a recurring process. Whenever discussing use cases with a highly structured procedure and only two main parties involved, as in this case the automotive manufacturer and the driver, one can categorize the preferable payment solution as an automatically initiated proximity payment in terms of the customer-activated application.

Analyzing the critical aspects upcoming in the extended scenarios of the use case, there are two major challenges that bear consideration: *connectivity* and *information flow*. These aspects are crucial, as most extensions are caused by problems occurring as a result of connectivity issues or insufficient information flow. It is interesting that both of these sources of errors originate from digitalization in the context of industry 4.0. Hence, the implementation of connected world features in the "thing" itself is one of the most challenging issues in the future of mobility.

When referring to connectivity, this issue can be divided into two sources of error. The first one is the connection between the onboard system and the internet, which is naturally based on the long-term problem of mobile network connection and the network coverage of mobile service providers. The second source of error based on connectivity issues arises in the intercommunication between the mobile payment provider and the onboard system representing the automotive manufacturer. It will be one of the major challenges in the automotive sector to integrate a stable connection between the internal processes of the onboard system and the corresponding processes of mobile payment.

Evaluation and conclusion

Evaluation and discussion of use cases

For the purpose of evaluation, in-depth interviews have been conducted with representatives from the automotive sector to be able to assess the plausibility and quality of the use cases. The challenging factors of each use case were discussed and the key characteristics relevant for the respective area deduced from the interviews. The interviewees were selected from automotive manufacturers and regulatory compliance (European Director of Regulations and Certifications of a large European automotive manufacturer), automotive and payment consulting (Partner and Senior Director of a worldwide-operating consulting company); Partner and Head of the Practice Group Automotive of a further worldwide-operating consulting company, and the mobile payment service provider industry (Senior Manager Strategy and Business Development of a large international payment service provider). The interviews reveal that considerations about MP applications in the connected car are already inherent in the minds of the representatives of each area of the automotive industry.

Consultants as well as automotive manufacturers assign the connectivity issues mainly to infrastructural problems, which cannot be solved solely by the parties directly involved in developing connected cars, but require e.g. ministries of transport to join the project.

When referring to the challenge of information flow, the automotive and payment consultants state that commercial banks and traditional payment providers fear the trend towards mobile payment solutions, as both industries are not yet ready to implement highly competitive payment processes in the light of progressive payment solutions.

A major aspect, which was brought up by every industry representative in our discussions, is instant payment. In the European Union the implementation of instant payment is a core project guided and advanced by the European Commission. However, based on estimates by the interviewees, it is unlikely that automotive manufacturers will wait until commercial banks are able to offer a mature service platform for instant payment and will instead develop applications on their own. For this purpose, a variety of car manufacturers have acquired payment service providers or at least formed a strategic partnership with one of them in recent years. Instant payment is seen as a requirement for the application of MP within the connected car. Referring to an assessment of the MP provider industry, customers significantly include the complexity and time intensity of the payment process in their decision-making on whether they conduct a certain purchase. Hence, from their perspective time-efficient MP is becoming increasingly important.

Moreover, the integration of MP processes in the connected car does not only shift car manufacturers' revenue stream from a relatively left-shifted stream towards a

constant revenue stream but also generates additional interaction points with the customers. By assessing telemetry data and the opportunities of mobile payment, car manufacturers will further shift towards service providers.

Conclusion on the research findings

The challenges identified for our use cases are closely related to the three pillars of our theoretical framework outlined in the paper's second section. It is, therefore, highly interesting to investigate which of the critical phenomena our theoretical framework actually predicts ex-ante.

In order to approach this issue in a structured way, we designed a matrix matching the main challenges arising as the result of our use case (Additional horsepower on demand) with the theoretical framework. Table 1 presents key issues derived from the major challenges identified in this use case. Based on this, the table summarizes which elements of these main challenges can be derived ex-ante from the theoretical framework presented in the second section.

In each column of the table, the key issue centering on the respective challenge from the perspective of the theoretical pillar is shown in the upper part. The connections of the key issues to the theoretical framework are shown in the lower part of the table.

Having carefully concluded on the ex-ante predictability of the challenges, it can be summarized that the majority of phenomena can be derived from our theoretical framework. This provides a solid foundation for the probability of detecting future challenges ex-ante, and not only after the broad introduction and dissemination of mobile payment services for the connected car via trial and error. In addition, the fact that theory is able to predict the challenges rather precisely confirms that an appropriate framework has been chosen.

In addition, further challenges to be taken into account can be derived from the extant literature. Particularly, security within connected cars as well as consumer privacy play an essential role (Bécsi et al., 2015; Petit et al., 2018). The integration of car-specific in-vehicle services is enabled by IoT. Thus, the users' acceptance of IoT systems is crucial (Falcone & Sapienza, 2018). A lack of security through cyber-crime, data theft, and cyber-attacks can hence challenge the acceptance of MP systems. Since they deal with financial data this is an area of high sensitivity (Bezhovski, 2016). This is why payment and security standards become increasingly important (Bareisis, 2017).

Limitations and Future Research

Limitations concerning our research might be seen in the use case approach we chose for the conceptual part of the paper. Often use cases are conceptualized as too unspecified and, therefore, are unable to detect the real challenges the originators are looking for. Thus, it is important to define the scope of the respective use case concisely by identifying adequate preliminary and postconditions as well as invariances. This involves the problem of use cases becoming too comprehensive to be able to identify the core challenges of the system under discussion. Especially user acceptance as well as security and privacy issues need to be looked at more closely in future research endeavors.

Table 1
Key issues identified in the use case and their connection to the theoretical framework

Process Thinking	Connected World Theory	Mobile Payment
Identified Challenge: Connectivity		
The issue of *interdependent processes* is highly relevant in terms of the connectivity challenges of the use case: Whenever one party is unable to finish a relevant process for the next step of another party, frictions occur. PT points to a specific way in which we should understand the *world of interactions*, namely interdependent holistic customer processes.	In future, there will not be a need to distinguish in terms of connectivity issues between onboard system/Internet in general and onboard system/mobile payment provider, as all of these issues are related in a *totally connected world* via multiple links. CWT embodies a *structured framework* for all the issues arising with regard to connectivity problems. The theory, therefore, points to the challenges emerging when aiming at increasing the level of connectivity.	Considerations regarding MP show that *frictionless connectivity* is an essential *requirement* and, vice versa, that frictions in connectivity will automatically lead to errors in mobile payment processes. As MP is always based on advanced software/hardware solutions being *connected to each other*, there is an obvious link to the illustrated connectivity problems.
Identified Challenge: Information Flow		
One essential part of PT is a *constant and at best unperceived information flow* of customer information to ensure well-functioning processes. In PT, arising problems focus on *information flow*. Disruptions in it often directly lead to *frictions in the whole process*.	CWT is entirely based on the *exchange of information*. Thinking thoroughly through the conceptions of Rosemann and other scholars, one promptly reaches the conclusion that the requirement to guarantee a *stable information flow* is a key challenge to be solved in the successful implementation of a connected world and the IoT itself.	A sophisticated outside-in perspective demands the design of the payment process to be as *convenient and time efficient* as possible. However, MP can only deliver time-efficient solutions if relevant information is *available at any time*. Otherwise, frictions will occur.

Source: Authors' work

Hence, we chose the initial conditions of the use cases to be as narrow as possible and discuss the occurring frictions in the respective sequence in a very detailed manner, including the extensions. We deliberately chose to proceed with use cases because we see them as advantageous since they are able to deliver a precise and nevertheless holistic view of the applicability of each scenario.

Another limitation is the concise focus on one use case as an example of a certain type of mobile payment application. Thus, our paper cannot provide a complete study of all possible MP applications along with forward-looking analysis of them in the context of the connected car. However, having conducted in-depth discussions with experts, appreciating and sharing the underlying assumptions of the use cases as well as the identified challenges, this points to an adequate structuring and a reasonable selection of the use cases.

Other theoretical pillars relevant for further investigations would be, for instance, the theoretical underpinnings of information technology (IT). Therefore, we suggest juxtaposing the outcomes of the use case discussed in this paper and a theory that

completely focuses on IT by putting the emphasis on technical research. Moreover, future research should focus on the technological aspects that serve as foundation for the implementation of the connected car services discussed in this paper.

Finally, as part of our research project, we developed further use cases on similar connected car services also discussing their advantages and disadvantages with the aforementiomed industry experts. Future work shall also concentrate on describing these services in sufficient detail and providing a synthesis of the pros and cons of all use cases analyzed.

Implications

Customer centricity can be regarded as indispensable when facing the challenges of future product and service design. Without an in-depth understanding of customers and taking on a customer-centric point of view as proposed, innovation projects, for which mobile payment services in the connected car can be seen as an example, are doomed to fail.

With regard to CWT, this paper supports the claim for higher infrastructure investments in decisive components for industry 4.0 in order to counteract connectivity problems and ensure frictionless information flow. The extensive service provision of instant payments (currently being introduced in the European Union) has a powerful impact on conventional MP applications, as it causes the traditional borders of MP categories to become blurred. The introduction of instant payments offers solutions to a number of previous problems, such as refund policy. Thus, it is a decisive element for the success of MP services in the connected car.

A major implication to which the analysis points is that MP considerations and CWT are more closely linked than previously thought. Progress in industry 4.0 and related initiatives, including the connected car, are characterized by an enormous investment intensity so that further advances can only be made if customers are expected to pay for them. MP fills exactly this gap: it enables an efficient provision of services for customers and the payment of those for suppliers.

This leads directly to the economic point of view and the implications for both customers and providers. For customers, MP significantly reduces the effort of using the services associated with industry 4.0. For providers, MP solutions embody the gatekeeper for their revenues and positively influence the timing of their cash flows. While car manufacturers have traditionally made the greatest part of their revenue with the initial sale of vehicles, followed by income from financing and leasing, MP leads to increasing revenue from innovative services that are used during the lifetime of the connected car.

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About the authors

Lukas F. Petry is a Master's student in Management at the Frankfurt School of Finance & Management. His research interests are at the intersections of digital transformation in management science, organization science and strategy design. Lukas holds a Bachelor of Science degree in Management, Philosophy and Economics from the Frankfurt School. He pursued parts of his studies as a full-time student at Harvard University in Cambridge, USA, and was additionally cross-registered with the Sloan School of Management at the Massachusetts Institute of Technology. The author can be contacted at **lukas.petry@fs-students.de**

Jürgen Moormann is Professor for Bank and Process Management at the Frankfurt School of Finance & Management. He has a banking background and, before joining Frankfurt School, has worked for several years as a management consultant. His research areas include Business Engineering, Process Management and Digitalization in banks. He is the founder and co-head of ProcessLab, a research center of Frankfurt School focusing on process management in the financial services industry (www.processlab.info). He has published in various academic journals and has presented widely, nationally and internationally, to academic and practitioner audiences. The author can be contacted at **j.moormann@fs.de**

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Optimizing the Resource Consumption of Blockchain Technology in Business Systems

Vedran Juričić, Matea Radošević, Ena Fuzul
Faculty of Humanities and Social Sciences, University of Zagreb, Croatia

Abstract

Background: Blockchain technology has gained a great public interest due to the appearance of cryptocurrencies, a digital asset used for exchanging funds. Although blockchain calculations offer the benefits of security and reduced costs, blockchain is still strongly criticised for its lack of usefulness and resource-heavy consumption. **Objectives:** The aim of this research is to provide different insights into blockchain technology and to propose NP-complete problems as a suitable alternative to the current consensus algorithm. **Methods/approach:** This research discusses the current state of proposed alternatives, projects such as distributed volunteering for scientific purposes and different consensus algorithms within cryptocurrencies but focusing on incorporating NP-complete problems as a secondary, more useful option. **Results:** Using the properties of NP-complete problems, it is possible to solve various problems in different areas, such as science, biology, medicine and finance, but also to improve business processes, optimize markets, payments and supply chains while decreasing environmental costs. **Conclusions:** This paper shows that the alternative mechanisms are being developed and used to substitute an existing Blockchain algorithm with a more efficient one. It also suggests further investigation in this area because the alternatives greatly improve blockchain's usability and efficiency.

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Introduction

Blockchain technology became one of the most emerging and disruptive technologies in the last decade (Marrara et al., 2019; Hongdao et al., 2019; Leible et al., 2019). Its unique, robust and secure approach along with other advantages has attracted attention from a wider, non-technical audience, creating a system that could potentially solve many problems. With its far-reaching potential, it has extended its capabilities beyond the original intention and affected many different areas.

Initially developed as a system of digital payment in 2008, blockchain found its way to improve many traditional solutions.

Typically described as a distributed ledger of records (Lavanya, 2018) linked through a chain of blocks, blockchain is a decentralised system where a community maintains the whole network and where users are responsible for the system's sustainability. All users within the network are equal and mutually participate in decision making, therefore there is no central unit or any form of authority which can control or influence the system. This made Blockchain technology almost revolutionary in some fields, especially in the world of banking and finance. The lack of authority presented in blockchain has created plenty of possibilities and ideas for the improvement of existing systems, leading with cryptocurrencies as a potential replacement of the traditional payment and billing systems. Unlike the existing payment systems, the blockchain system is trustless (Wood & Steiner, 2016) so users can rely on underlying logic in making fair and secure access. This is due to its infrastructure and cryptographic algorithms involved in the process of creating new blocks. All data once recorded within the block is permanently stored, secured and immutable. Blockchain has also reduced the costs of transaction fees, offered anonymity to its users and provided better efficiency in exchanging funds.

The most popular cryptocurrency of today, with a market capitalization of 128 billion dollars and more than 40 million users in the world is Bitcoin (CoinMarketCap, 2019). Bitcoin facilitates transaction payments and it is the first attempt of cryptocurrency to do so. It uses a specific consensus algorithm which is built into the network and ensures that all payments are resolved, tamper-proofed and recorded within blocks. To achieve this, Bitcoin rewards its most efficient users for participating in validating transactions and maintaining the network. This form of profit creates a powerful incentive and attracts large numbers of users.

Consensus used in Bitcoin keeps the network secure and safe from most network attacks but it is also very resource consuming. Miners have to prove their work by doing an enormous amount of calculations, which require specialised hardware equipment, and vast amounts of electricity. These calculations are used only to maintain the network and validate transactions and do not add value to the system but so far, no adequate alternative has been found.

This paper aims to explore the current state of blockchain technology development, alternatives for future improvements and potential adaptation in helping to solve different problems in business systems. The research focuses on the ability to redirect blockchain computing power into a more useful manner and improving one of its fundamental functionalities to solve meaningful problems. This paper is organized as follows. The second section describes the blockchain technology and its operating principles, focusing on the consensus algorithm. It also gives an insight into computing power and resources used to maintain the blockchain network. The third section describes the potential of using blockchain technology in different fields. Fourth and fifth sections are introducing the NP-complete problems as a suitable alternative to current consensus algorithm. Finally, the last section presents our conclusions.

Blockchain technology

Blockchain technology is based on the principle of connected blocks that contain information about transactions within the network and special cryptographic functions by which they are interconnected to create a continuous array of chained blocks.

It is generally described as a distributed database maintained by all users in a network. A database contains all the transactions and is available to each user. When database changes, it is resent and updated throughout the network so that anyone can see the last state. It serves as a public, non-privatized source of all data within the system. Once stored in the database, data cannot be changed due to cryptographic methods involved in the process of creating new blocks. Because of this inability to modify stored data, blockchain technology is considered to be an extremely reliable source of data and a secure tool for transaction and asset sharing. Users are network nodes that are connected to a peer-to-peer network that connects them all at the same level without a hierarchy. Data is distributed by certain cryptographic protocols to all nodes in the network and all nodes come to a mutual consensus that defines when and how the data will become part of the database.

Blockchain technology is based on blocks that contain information about transactions. In addition, each block contains information that differentiates it from other blocks, and place it in an exact time and position within the chain of blocks. As shown in Figure 1, current block (11) contains information about the previous block (10), while future block (12) will contain information about block 11, which creates a chain that can be traced to the initial, generic block.

Figure 1
A Conceptual Diagram of the Bitcoin Blockchain
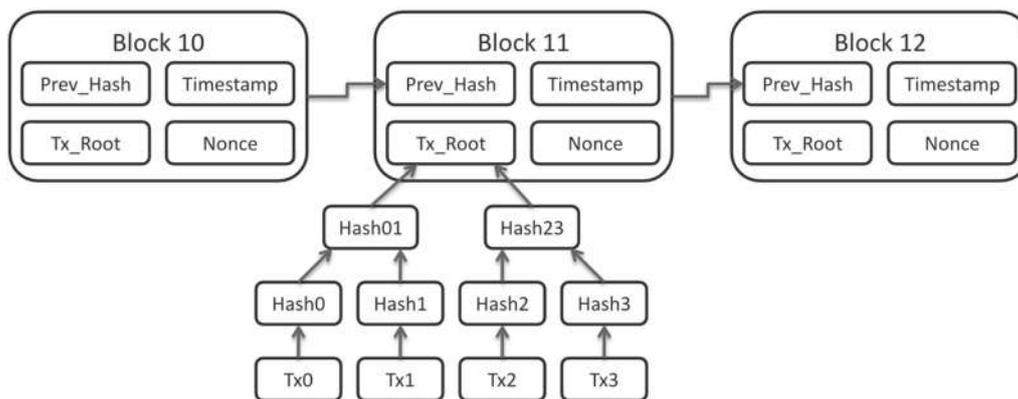
Source: Jones (2017)

Transactions are performed through asymmetric encryption using only public keys that serve as publicly available, personal user addresses. In this way, network users remain anonymous as the address itself does not reveal the user's identity, but the data integrity is preserved concerning the nature of asymmetric encryption. After agreeing on both sides, the transaction is entered into the block. Special users, called miners, group the received transactions into a block. A binary hash tree algorithm is then performed, within which each transaction is encrypted with the hash function. Hash functions have an important role in cryptographic methods within blockchain because they ensure data authenticity and trustworthiness and protect against changes. Apart from the transactions themselves, the block also contains the so-called *nonce*, which presents the value of the solution for the mathematical task obtained, the information on the previous block, the difficulty target, the date and time mark etc. To continue the sequence, the next block records the hash value calculated over the data from the previous block. Through this method, it is very easy for other users to check the order of blocks in a chain and to detect fake and false

blocks. If the block's hash value does not show the same values that are entered in adjacent blocks, the block is false.

Proof of work

The block can be successfully added to the main blockchain only when it is processed by the network miners and then verified by other nodes in the network. Such a process is called a *proof of work* consensus. In the blockchain network, users are divided into multiple profiles. Most users have not downloaded all the data from the initial block, but only their headers that contain enough information to validate new and past Transactions. Network miners are users that contribute to functionality, creating new blocks. The process of creating blocks is called mining. Block mining is a relatively long process that requires a lot of computing power and special hardware equipment, while validation of newly created blocks takes little time for ease of calculating the mathematical operation. After creating the block and distributing it to the other nodes in the network, consensus needs to be achieved to allow the block to be included in the chain.

Block can become a part of a chain only when one of the miners solve a task that is when he finds a value that satisfies a predefined condition. A header of each block contains weight value *t*, which defines the difficulty of mining a block. The miner uses a trial and error method to discover a *nonce* value *n*, that in combination with a block value *b* satisfies a condition defined with *t*.

This value is a number with a value within a range from 0 to 2^{256} (Bowden et al., 2018) and the mining problem is to find a value smaller than the given weight value *t*, that is H(b, n) < t.

Figure 2 shows the simplified version of the operating principles of consensus.

Figure 2
A Simplified Pseudocode of the Proof of Work

```
Input b = SHA256HashFunction(Tx_Root, Timestamp, Prev_Hash)

Input nonce = 0 //start from zero

Start miningBlock:

        Repeat nonce++;

        Until SHA256HashFunction(b, nonce) < targetDifficulty;

End
```

Source: Author's illustration

H function is SHA-256 hash operation, a cryptographic mathematical function that was chosen from Satoshi Nakamoto in implementation of the first cryptocurrency Bitcoin. It ensures authenticity and validity of data and meets several criteria that ensure the quality of encryption and prevention from the collision and double spending problem (Nakamoto, 2008). Because of its unidirectional characteristic, the output of a hash function is easy to calculate, but it is almost impossible to find an input value for a given output value. Each nonce has equal guess probability and the only method that can be used is brute force.

The miners begin to generate nonce from zero, incrementing it in each step until a new hash value satisfies the defined condition, i.e. until the value below the required

number is found. Nonce is a 32-bit number, so several possible iterations is 2^{32}, meaning that a solution to the problem needs up to 4.3 billion attempts. The weight value within a network is not always the same, but the network changes it, adjusting the weight of the solution so that each block takes approximately 10 minutes of mining time.

Computing power

The miners are competing in the speed of finding a satisfying nonce because the first miner that solves a problem gets a prize. The current reward for the new block is 12.5 Bitcoins or about 69 000 US dollars (BitInfoCharts, 2019). Blockchain technology in this way motivates its users to validate transactions and to maintain the network.

Since the growing popularity of cryptocurrencies, mining has become a certain type of industry. Earnings through mining, as one of the motivational factors for using cryptocurrency, resulted in a massive number of users and a massive computing power. At the very beginnings of Bitcoin, the use of the Hashcash (Back, 2002) algorithm could be run on standard equipment on home computers, but today it is necessary to invest large amounts of money in computer equipment so that the user can compete with the rest of the network to be the first to solve a problem and to receive a reward.

Figure 3
Estimated Number of Terahashes per second in the Bitcoin Network (logarithmic scale)
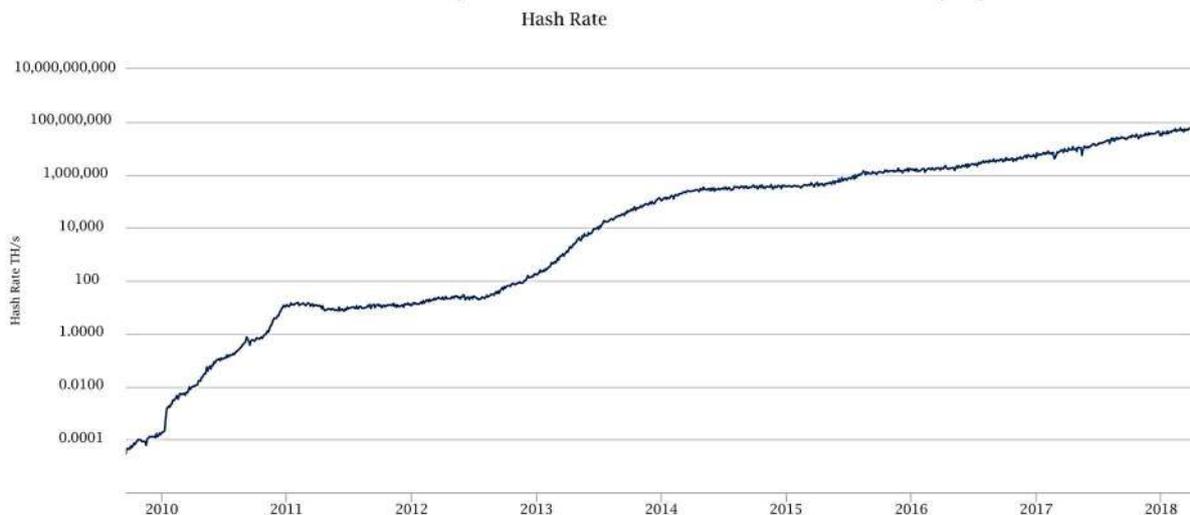
Source: Smith et al. (2019b)

The number of miners has increased over the years and so the total computer power has increased. The graph in Figure 3 shows the growth of calculated hashes in one second. Although short downtrends exist, the overall power of the network is growing, and it is clear that a network like Bitcoin represents an enormous source of power. Today's 500 most powerful supercomputers in the world together have a processor power of about six to eight times smaller than the mining processor's power (Santos, 2019). The estimated value of processor power goes above exaflops, which is about 10^{18} floating-point operations per second. The fastest computers in the world are currently working on petaflops. IBM Summit has 143 petaflops, Sunway ThaiuLight 93, and IBM Sequoia 17 (Strohmaier, et al., 2018), which shows that the most powerful supercomputers match 1-15% of the total Bitcoin power.

Energy consumption

Bitcoin has become infamous for its energy consumption and has thusly raised many concerns amongst the public. Since the Bitcoin inception, the power necessary for mining Bitcoin has grown exponentially, using electric power as its primary resource. This has made cryptocurrencies subject of numerous regulation policies by the many governments.

Mining is an energy-intensive process, which also requires specialised computer equipment. To calculate hash values of the block, in other words, iterate through billions of guesses, a miner needs to run hardware-intensive operations. These operations typically rely on the computing power of the processing units. The common units used in the mining process are central processing units (CPUs) and graphics processing units (GPUs), with the latter showing much better performance in solving complex computer tasks (Böhm et al., 2009). Figure 4 shows Bitcoin energy consumption index through time.

Figure 4
Bitcoin Energy Consumption Index

Bitcoin Energy Consumption Index Chart
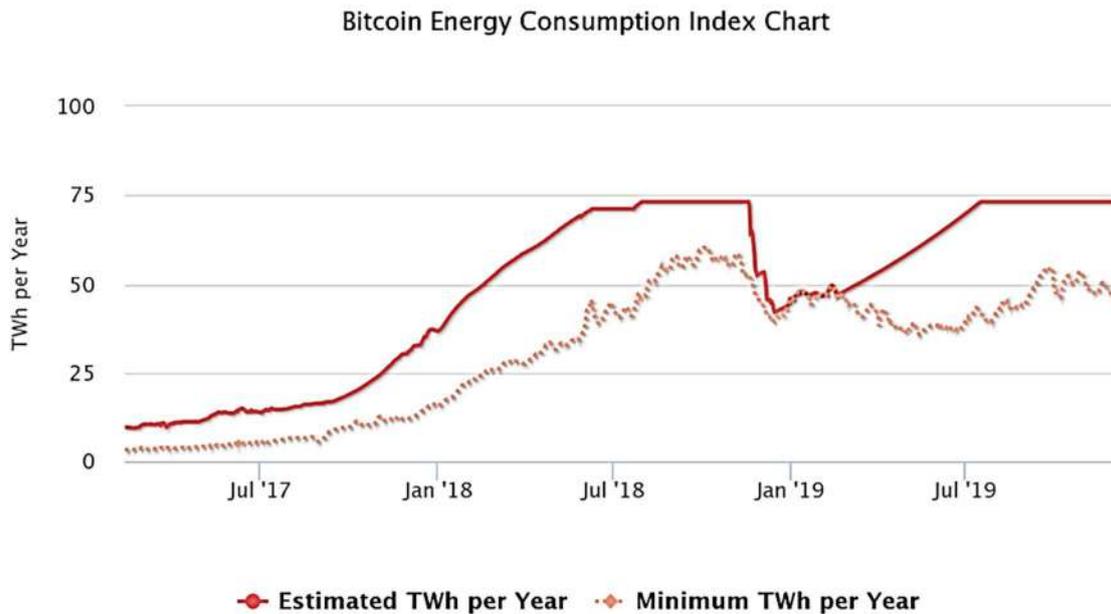
Source: Vries et al., 2019.

However, recent research shows that the Bitcoin network currently consumes leastwise 2.55 GW of electricity and it could reach 7.67 GW shortly - an amount comparable to the energy consumption in Ireland (Vries, 2018). Moreover, the massive power consumption of the Bitcoin network could cause a significant carbon footprint because the regions where most of the mining facilities are located use coal power (Stoll, 2019) and thus face serious environmental consequences in the long term.

Alternative consensus algorithms

As the popularity of Bitcoin grew, the number of experimental alternative cryptocurrencies grew proportionally. The rapid increase of users on the Bitcoin network led to harder mining problems therefore causing the development of new cryptocurrencies, also called altcoins, as an alternative to the Bitcoin. There have been numerous attempts at substituting *proof of work* consensus with more efficient

and less resource consuming algorithms. As a matter, building a currency without flaws related to energy consumption could potentially deliver success and triumph in the cryptocurrency world. Ethereum, which is the second-largest blockchain network in the world by market capitalization (CoinMarketCap, 2019) is trying to shift entirely from the *proof of work* to the *proof of stake* algorithm.

The *proof of stake* consensus largely differs in mining new blocks and rewarding users. It uses validators for block creation and validation of transactions with pseudo-random selection methods for selecting validators for any given block (King & Nadal, 2012). Resource consumption is low since the protocol does not use mining for block creation but instead, the user places their deposit as a stake. Once a validator is selected, he has the exclusive right to create a block. This reduces an enormous amount of calculations since there is no competition between users. The difference between *proof of work* and *proof of stake* also reflects in the rewarding system (Fanti et al., 2018). A potential flaw arises when selecting validators. Only the wealthiest users could be selected as validators because the higher stake has the most potential in the forging process but the problem was addressed by introducing pseudo-random methods in selection (King & Nadal, 2012). Although it is one of the most perspective alternatives in terms of achieving security while decreasing resource consumption and risks of network attacks (Sheikh et al., 2018), it remains largely unadopted. A modified version of this algorithm is the delegated proof of stake (Larimer, 2014).

Nevertheless, other alternatives have been presented to the wider audience and have gained public interest. Another alternative is a consensus algorithm called *proof of space* where users prove their utilization of space. It is similar to some extent to *proof of work* due to its usage of computer storage, but its energy consumption could decrease over time (Alsunaidi & Alhaidari, 2019). Other notable examples are *proof of luck* and *proof of elapsed time* (Nguyen & Kim, 2018; Alsunaidi & Alhaidari, 2019).

Application of blockchain technology

Cryptocurrencies like Bitcoin are the most famous applications of blockchain. There are services similar to currencies that can be based on blockchain, like securities transactions, loyalty point services, prepaid cards, gift card exchange and electronic coupons (NRI, 2015). However, because of its architecture and implementation, blockchain has numerous benefits such as anonymity, persistency and decentralization and can be applied in different fields and problems (Zheng, 2018).

One of those fields is the Internet of things (IoT), a global network that connects smart objects with advanced Internet technology, to provide users with various services (Miorandi et al., 2012). Examples of such technology are systems like smart cities, smart environment, smart water, home automation, logistics etc. Blockchain could provide a safe mean of communication between smart objects, keep an immutable history of smart objects or enable their autonomous work by removing the requirement of a centralized authority or human control (Panarello et al., 2018).

Blockchain can also be used in public and social services, for example in land registration (NRI, 2015) in which the land information like status and rights can be registered and publicised on blockchains, but also enable more efficient services when transferring land or establishing a mortgage. Another example is voting, where the vote data is securely stored in a blockchain and is publicly verifiable and distributed in a way that no one can corrupt it (Ayed, 2017).

Blockchain technology has also found applications in the field of education. Students would have independence and anonymity of their data, independence of institution and immutability of records of official documents. It also offers a different approach in paying tuition, more customized and online studies, and a way to extend

students' profiles, benefiting universities, students and employers (Grech et al., 2017; Juričić et al., 2019).

Figure 5
Blockchain Technology Usage per Sector
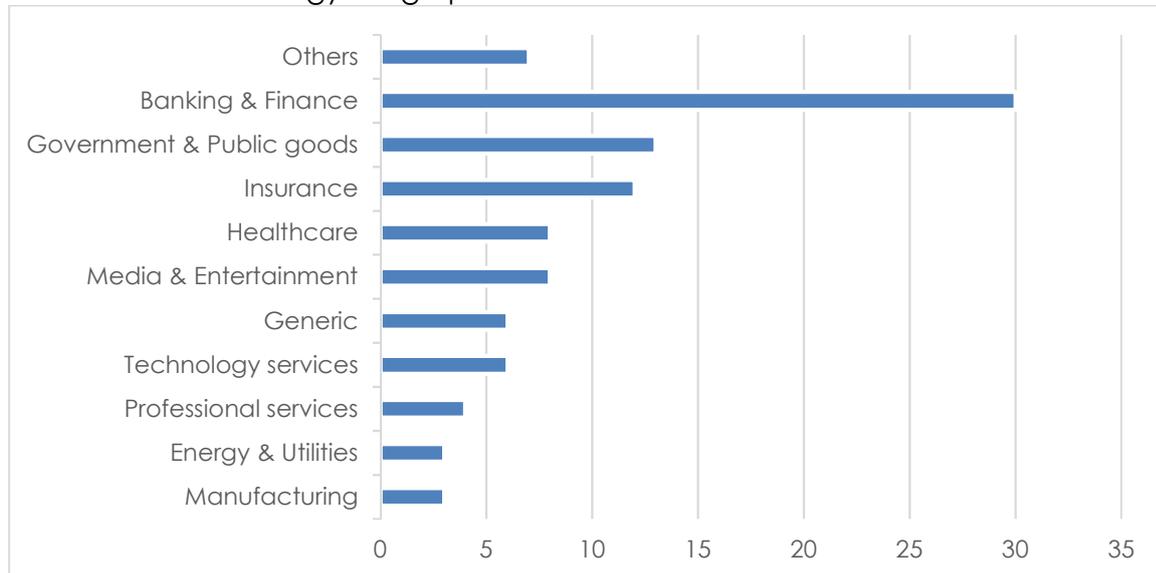
Source: Hileman & Rauchs (2017)

Apart from that, blockchain has found its usage in medicine, sharing services, supply chain and digital asset management, data storage, authentication, communication, transportation, crowdfunding, visualization, legal services etc. Figure 5 shows its usage in different sectors, pointing out that the banking and finance sector is the most represented one, with about 30%.

The main reasons for using blockchain technology in this sector are efficiency, security and lower costs (Blockchain Technologies, 2019). The business is more efficient, because technology enables faster global trade across time zones, offering effective protocol to deal with cross border transactions (Fanning & Centers, 2016). The costs of smart contract-based transactions are minimal because there are no domestic or international wire fees or overdrafts. A smart contract is a transaction protocol that executes the terms of a contract (Tapscott, 2018). Blockchain in the finance sector can have the following benefits: cross-border transactions, smart bonds, point of sales systems, lending and borrowing, trading platforms, clearing and settlements, bookkeeping and auditing, hedge funds, digital identity verification, credit reports, and others (Blockchain Technologies, 2019).

Improvements of blockchain technology

Applications listed in the previous chapter are the common ones and typically discussed in scientific papers, technical reports and literature. They are utilising an existing blockchain implementation using its common consensus protocols. Those protocols are, with the blockchain's increasing computing power, the reason the blockchain technology is being criticized. *Proof of work* consensus is the most widely used protocol and is present in most of the leading cryptocurrencies, and currently, the consensus that consumes the greatest amounts of power, energy and computer resources. The reason for the critique is found in the Hashcash algorithm whose goal is to find a random number that satisfies the given condition and has no greater function

outside the network. For this reason, it is often characterized as an algorithm without a larger purpose or benefit, meaning there is no useful use of computed hashes that in any way improve or assist other than maintaining the network itself. The Hashcash algorithm was initially ideal, whose implementation provided a network without a central authority, prevented double-spending and achieved system integrity. Today, with the growing popularity and strength spent on blocking blocks, it is evident that such a system can bring much more useful solutions and can be utilized for more complex, necessary and more realistic problems.

A good example of such a problem is the folding@home project (Beberg et al., 2008). Folding@home is a Stanford University project that uses a public distributed computer system in the simulation of biomedical processes, such as stacking of proteins that help science in researching various diseases. The volunteers that are included in this network share their computer resources in detailed statistical calculations.

A similar example is the SETI@home project, implemented by the SETI Institute in the United States (Anderson et al., 2002), which aims to research extra-terrestrial life. SETI@home is also a project built on a distributed network of volunteers sharing their computer resources in processing narrowband radio signals from the universe, collected by radio telescopes. SETI@home is just one of these projects in the field of astrophysics research (Knispel et al., 2010; Newberg et al., 2013). Folding@home and SETI@home are listed as two projects in the vast field of complex tasks whose processing needs more than average supercomputers and which can potentially be solved through distributed computing.

Through the theoretical insight into the background and the performance of blockchain technology, it is apparent that each problem does not correspond to a suitable substitution within the *proof of work* consensus. For the system to maintain self-sustainability and decentralization, it is necessary to propose a solution that will fulfil the same functions within the system as the Hashcash algorithm and will not in any way compromise network security. By analysing the current research and realized cryptocurrencies, the criteria of the problem were adopted. For blockchain systems based on a standard *proof of work* consensus, an appropriate replacement of the Hashcash method must meet the following conditions (Ball et al., 2017; Chatterjee et al., 2019):

- Checking solutions for problems should be significantly easier than the problem solving itself
- The problem must require a certain amount of work to guarantee to necessitate work
- The solution or problem must have certain characteristics to determine that the miner has solved the problem
- The mining process must protect the transaction and security of the whole network
- The difficulty of the set problems must be adjustable
- The problem should not have an input string.

As an appropriate alternative to Hashcash, NP problems from the computational complexity theory can be used (Ball et al., 2017; Oliver et al., 2017). NP problems are a set of problems for which a polynomial solution algorithm is not known but confirmation of their solution is reachable in polynomial time. P is another class of problem whose solution can be reached by a deterministic Turing machine in polynomial time and therefore not suitable as an appropriate replacement. NP problems meet the first requirement of checking the solution in a relatively fast time, enabling blockchain users to quickly and easily validate the solution. Due to unknown

methods of solving problems in polynomial time, NP problems make the task of miners much more difficult.

A specially categorized problem category are NP-complete problems (Garey & Johnson, 2002), which are a subset of NP class problems. According to Cooker's theorem (Cook, 1971), there are two NP-complete criteria and we can say that the problem X is NP-complete if it satisfies the following two conditions: X is an element of NP and X is NP-hard. The first criterion indicates that problem X belongs to the NP class problems, that is, that every solution obtained can be verified in a polynomial time. The second criterion means that problem X must also be NP-hard, that is, that NP problem Y can be reduced in polynomial time to problem X. The latter criterion explains that by solving one NP-complete problem it is possible to solve others.

Dunne (2008) created a list of more than 80 NP-complete problems that can be used as a substitute for the current consensus algorithm. There are numerous problems from mathematics like numeric, graph and hypergraph problems, from computing and programming, formal languages, string processing etc. Some of these problems are optimization problems and can be applied in various fields like biology, computing, astronomy and finance (Anastassiou, 2011), including travelling salesman problem, job scheduling problem, knapsack problem and longest path problem.

The travelling salesman problem assumes a list of cities and distances between them and searches for the shortest possible route that visits each city and returns to the origin city. Some generalizations of this problem are travelling purchaser problem, that introduces a list of available goods, and vehicle routing problem, that introduces a list of customer orders. Job scheduling problem assumes a list of jobs with different processing times and a list of machines with different processing power. Problem is to find a schedule that represents a minimum processing time. Knapsack problem assumes a set of items with different weight and value, and the problem is to determine the number of each item so that the collection has the maximum value and the total weight is less or equal to the predefined limit. The longest path problem is the problem of finding a simple path of maximum length in a given graph.

NP-complete problems within the blockchain

NP-complete problems satisfy all given conditions as an appropriate replacement of the Hashcash algorithm and are presented as a potential upgrade in the efficiency of the network. Furthermore, they also fulfil an additional requirement, improving the usefulness of the problem (Ball et al., 2017). The complexity of NP-complete problems makes them a distinct and universal category of computational problems whose solutions could be applied to many different areas. However, incorporating these problems to a blockchain is not simple nor effortless.

Changing the consensus algorithm implies creating an entirely new blockchain network, a new cryptocurrency. The third option is that the blockchain will have to diverge into two branches. Due to blockchain's characteristic of immutability, it is not possible to retrospectively alter blocks or change the current mechanism of the system. Therefore, new cryptocurrencies were made in an attempt to solve problems, which are useful beyond the network itself. Such examples are Gridcoin and Curecoin cryptocurrencies, which reward its users for finding answers to medical, mathematical, and scientific problems (Halförd, 2019; Smith et al., 2019a). Both cryptocurrencies are facing an issue in terms of centralization because problems are delegated by a central authority. There have also been several attempts in constructing theoretical systems that could implement an NP-complete set of problems while maintaining all of the principal properties of a blockchain.

To switch, and entirely devote network power to solving useful, yet undelegated, new blockchain or a fork/branch should be made. One example of such cryptocurrency is Primecoin (King, 2013). Although Primecoin does not solve NP-complete problems, its mining algorithm discovers and verifies new prime numbers.

NP-complete problems can be incorporated into the blockchain in a few different ways. One way is creating a universal problem or set of problems whose solution can be further improved and optimised (Oliver et al., 2017). In this case, all miners in the network are solving the same problem and the miner who has a better solution than the solution in the previously attached block gets the chance to mine the block and submit his result along with it. An example of such a problem incorporated in the blockchain is the Orthogonal Vectors problem (Ball et al., 2017). Blockchain can be modified in a way that its genesis block stores the initial problem state and each new block contains a solution (Oliver et al., 2017). A possible flaw of the system could appear when the solution to the problem cannot be further optimised or when it needs a great deal of effort to find a better result. To address this issue, new solutions are proposed.

The most common approach among researches and explorations is combining two consensus algorithms within the same network. This approach is called hybrid mining. It allows users to choose their preferable mining process between *the proof of work* consensus using Hashcash algorithm or solving an NP-complete problem. Using these method miners can provide solutions for concrete problems while reducing the usage of spent energy without endangering the safety of existing systems.

Figure 6
Public Board with Problem Units
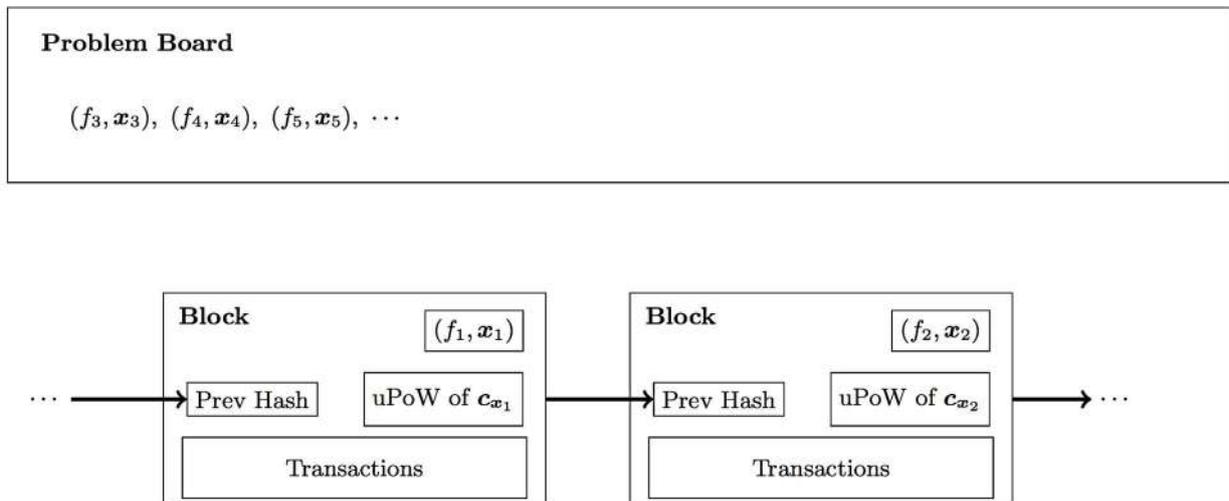
Source: Ball et al. (2017)

To avoid the problem with a limited number of solutions, new problem units can be delegated by users (Ball et al., 2017; Chatterjee et al., 2019). Figure 6 shows the conceptual diagram of the public board that users post problems. Miners are producing proof of useful work (uPow of C_{x_n}) which is attached to the block.

All users in the network are free to delegate their problem to the blockchain in the specified form. Using this method, new problems will be continuously appended thus providing miners with an unlimited source of new challenges. By allowing users to employ the enormous computing power of the network, it opens a vast field of possibilities in solving various problems. From healthcare and government problems, infrastructural and processing issues, finance and business intelligence, such power

could offer solutions in a faster, more convenient and less time and energy consuming manner.

Conclusion

A widespread platform of distributed computing called Bitcoin offers many advantages when compared to traditional solutions. It facilitates payment transactions in a more efficient, secure and reliable manner but it is also taking its toll regarding significant resource consumption. More and more questions are made concerning the usefulness of the network and its mining process. Mining cryptocurrencies has become rather its massive industry with mining facilities all over the world but it became apparent to the public that the network would lack sustainability soon. Despite the many benefits that the Bitcoin network provides, one of the biggest subject to criticism is its Hashcash algorithm commonly used in the *proof of work* consensus. Hashcash algorithm validates the user's transactions and secures the network by preventing double-spending, but it also consumes vast amounts of electric power, time and computer equipment. Alternative mechanisms are being developed to substitute Hashcash with a more efficient algorithm. One of these solutions could be in adopting a special category of NP-complete problems within a blockchain. By implementing NP-complete problems, the network could redirect its power into more useful calculations, solving problems in a variety of different areas, such as technology, medicine, finance and business systems.

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About the authors

Vedran Juričić, PhD, is an Assistant Professor at the Department of Information and Communication Science, Faculty of Humanities and Social Sciences, University of Zagreb. He has a master's degree in Computer Science that he received at Faculty of Electrical Engineering and Computing, University of Zagreb. He received a PhD in Information systems and Informatology at the Faculty of Humanities and Social Sciences Zagreb with the dissertation thesis "Plagiarism detection in the multilanguage environment". His fields of interests are security, plagiarism detection, text similarity and web, Windows and mobile development. He published several scientific papers in international and national journals and participated in many scientific international conferences in the field of information and communication sciences. The author can be contacted at **vedran.juricic@ffzg.hr**.

Matea Radošević is an assistant at the Department of Information and Communication Science, Faculty of Humanities and Social Sciences, University of Zagreb. She has a master's degree in Mathematics and Computer Science Education that she received at the Faculty of Science, University of Zagreb. She is currently enrolled in the Postgraduate doctoral study of Information and Communication Sciences and working on her doctoral thesis. Her fields of interest include the application of information technology in education and blockchain technologies. The author can be contacted at **matea.radosevic@ffzg.hr**.

Ena Fuzul is a student enrolled in the master's degree programme at the Faculty of Humanities and Social Sciences, Department of Information and Communications Sciences, and in the bachelor's degree programme at the Zagreb Polytechnic. Her primary field of interest is blockchain technology in education. Her other interests include cryptography, e-learning, networks and big data. She attended numerous workshops and summer programmes, some of them being Big Data at the National University of Science and Technology in Moscow, and Advanced Optimisation Algorithms at the Gdansk University of Technology in Poland. The author can be contacted at **efuzul@ffzg.hr**.

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Governing IT in HEIs: Systematic Mapping Review

Elinda Kajo Meçe, Enida Sheme, Evis Trandafili
Polytechnic University of Tirana, Albania
Carlos Juiz, Beatriz Gómez
Universitat Illes Balears, Spain
Ricardo Colomo-Palacios
Østfold University College, Norway

Abstract

Background: Higher Education Institutions (HEIs) are aware of the immense importance of achieving their strategic objectives to increase their impact on the society and to be competitive. As a board responsibility, information technology governance (ITG) plays an important role in the overall HEIs performance. Numerous HEIs are making great efforts to properly govern information technology (IT) by using ITG frameworks. **Objectives:** This study investigates the overall adoption of ITG frameworks in different HEIs through a systematic mapping review. **Method:** We analyzed forty relevant papers, filtered from 6 selected online libraries, and answered six research questions on ITG implementations at universities worldwide. **Results:** The results show an increasing number of publications on ITG usage in HEIs in the last decade. The largest number of applications is described in Asian countries, while the most popular used frameworks are COBIT, ISO versions, and in-house developed frameworks. Finally, we describe the top challenges and benefits of ITG implementation mentioned in research papers. **Conclusion:** This paper provides a deep insight into the level of integration of ITG in universities worldwide. The results will be presented to the involved stakeholders at our university to increase the awareness of ITG in HEIs and help its implementation process.

Introduction

With the rapid evolution of Information Technology (IT), today's organizations are using technology in increasing the number of services, so they can assure their competitiveness and survival. Leveraging IT is becoming a guarantee for numerous benefits like the organization's good performance, efficiency, quality of service, improved risk management, increased customer satisfaction, etc. (Ribeiro & Gomes, 2009; Tjong et al., 2017).

Along with the use of IT, many issues regarding its planning, budgeting or controlling, arise, asking for detailed attention and caution from the authorities of an organization. This situation presented the concept of ITG.

Weill and Ross (2004, p.4) describe ITG as "specifying the decision rights and accountability framework to encourage desirable behaviour in using IT". ITG serves as a guide for the proper alignment of IT actions and performance goals. It also increases the level of accountability for actions and results in the IT area, by making clear the responsibilities of each of the actors involved.

According to Weill and Ross (2004), organizations can achieve 20% higher profits if ITG is applied effectively. However, they also point out that there is no single formula on how to implement ITG. Top-performing enterprises, on purpose, spend time to carefully design effective ITG under strategic alignment (Haes & Grembergen, 2010)

Most of the publications discuss the adoption of ITG in business but not in universities. Generally, and despite the recent efforts, there is a lack of research papers regarding ITG on HEIs. According to Tjong et al. (2017), only 17% of the revised studies considered HEIs as the object of their research.

Although there are several systematic literature reviews on ITG (Khouja et al., 2018; Tjong et al., 2017; Yudatama et al., 2017), there is a lack of systematic mapping reviews on ITG issues for universities. Our study aims to help to fill the knowledge gap about ITG adoption at Universities worldwide, choosing a systematic mapping review as a research method.

For our review, we have systematically selected 40 relevant papers and raised six research questions. By these research questions, we would like to reveal: (i) the research interest on the topic in the last decade; (ii) the involved countries in applying ITG on HEIs; (iii) the features of HEIs that have implemented an ITG framework; (iv) the most popular ITG frameworks in HEIs; (v) the reported challenges and benefits of using ITG at universities, and (vi) the most used ITG frameworks and their confusion with IT management framework.

We believe this paper will be useful for all stakeholders in ITG for HEIs to guide them towards the adoption of the best practices and supporting the learning from errors reported by other actors.

This research paper contains five sections as follows. The second section describes the state of the art of ITG for HEIs. The third section defines the methodology we have used to conduct our research, including the search terms, online databases, research questions and the systematic mapping process. In the fourth section, the obtained research results and findings are presented. Finally, conclusions are described and discussed in the last section.

Background

ITG has been explored according to different conflicting definitions since the late 90s. The importance of the topic could be the root of this panoply of definitions (Juiz et al., 2019) giving the increasing set of sectors and activities adopting ITG (Dzombeta et al., 2014). Currently, these definitions are converging to a more consolidated standard:

ITG is the process of directing and controlling from a business perspective the use of IT (Juiz & Toomey, 2015). The aim of IT governance mechanisms is to enhance business/IT alignment with an increased level of IT governance performance.

The earliest research report on ITG belongs to the beginning of this millennium (Van Grembergen et al., 2004). Other research papers emphasize the use of ITG as important for Small and Medium Enterprise, and larger organizations, to increase the performance of the organization (Tjong et al., 2017; Huygh & De Haes, 2020).

Few of the well-known ITG frameworks worthy to be mentioned are ISO/IEC 17799, ISO/IEC 38500, COBIT, etc. The famous nonprofit association, Educause, published in 2008 a reference to COBIT, ITIL and ISO 17799, and their impact on business benefits (Yanosky & Caruso, 2008). ITIL (Information Technology Infrastructure Library) promotes best practices on process management, while ISO 17799 tends to achieve the British Standard for IT Service Management regarding security and protection processes. COBIT, on the other hand, provides IT governance guidance. Composed of 34 high-level control objectives, it ensures an adequate control system for the IT environment. COBIT is used widely in many financial institutions like banking, insurance, audit, risk and security, and others (Vugec et al., 2017).

Although ITG emerged from corporate governance, HEIs are considered a special type of organization in need of IT to support teaching, learning and research activities (Coen & Kelly, 2007). A HEI can be considered as an organization that governs academics for running education as its main business. Certainly, different mechanisms enhance ITG effectiveness in a HEI. The ITG structure type directly impacts the ITG success. The federal structure is claimed to be the most favourable arrangement for ITG in HEIs (Bianchi et al., 2017).

Several ITG frameworks have been proposed and applied by HEIs to improve their overall efficiency. The objectives of these ITG frameworks are to provide guiding principles for directors to efficiently direct and control the use of IT within their organizations. ITG frameworks support the governance of IT regardless of their size or strategy, thus the use of ITG frameworks from the top is strongly advised to generate business value from investment (Juiz & Toomey, 2015).

Apart from the international standards used in IT governance in general, there are a few standards on ITG used specifically by certain countries. As such, Australia universities have applied AS 8015-2005 standard for ITG decision making (Bhattacharjya & Chang, 2006). In the UK, the Joint Information Systems Committee (JISC) Institution has developed its own ITG framework (Coen & Kelly, 2007). ISO/IEC 38500 was first developed and implemented by Spanish Universities (Gómez et al, 2018). Several ITG frameworks implemented in HEIs will be discussed more in details at Research Question 3.

The rest of the paper shows our research and its results-focused on papers related to ITG in HEIs worldwide.

Methodology

Systematic Mapping review methodology

A Systematic Mapping is a research methodology frequently applied to summarize research findings in social sciences and medical studies, which has also drawn interest and awareness in other research disciplines. This methodology aims to classify research publications through visual synopsis (Petersen et al., 2008). The main goal of a systematic mapping is to structure a research area by searching, selecting, analyzing and presenting a thorough overview of the research findings. Figure 1 shows the essential process steps based in (Petersen et al., 2008; 2015).

A Systematic Mapping supports different stakeholders by making evidence of knowledge gaps, research redundancy and by suggesting improvements or best practices (Haddaway et al., 2016). In this paper, we applied a systematic mapping to structure the area of ITG in HEIs. We analyzed the results based on the frequencies and coverage (geographically and thematically) of the selected publications.

Figure 1
The essential process steps of systematic mapping
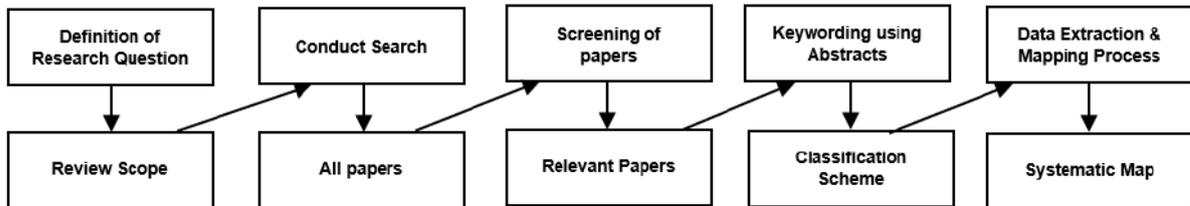
Source: Petersen et al. (2008)

Research questions

To accomplish the goals of our systematic mapping, we raised the following research questions:

- RQ1: What is the evolution of the interest in ITG in HEIs in the last decade?
- RQ2: What is the geographical coverage of ITG effects (in terms of countries and continents)?
- RQ3: What are the reported ITG frameworks used by HEIs?
- RQ4: What IT management frameworks have been reported as ITG frameworks by HEIs?
- RQ5: What are the main features of ITG adopters? (University size, lifespan, public/private, maturity level, etc.)•RQ6: What are the reported challenges and benefits of ITG frameworks? Searching Strategy

The search strategy is composed of three phases: search string generation, online libraries definition, and search process in all databases, as illustrated by Figure 2.

Search string

The search string we composed, made of keywords and Boolean operators, is as follows: ("IT Governance" OR "Information Technology Governance" OR "ICT Governance") AND ("higher education" OR "university" OR "universities"). This initial search string was adapted to work in different databases: IEEE Digital Library, ACM Digital Library, SpringerLink, ScienceDirect, ResearchGate, and Google Scholar. This set of sources was chosen given that they are among the most relevant sources of information in the computing field. Grey literature was covered by the use of Google Scholar. Zotero reference manager was used to store studies and to avoid duplications.

Search process

Our systematic mapping review was conducted as follows. First, we adapted and executed the search string in 6 selected online libraries. Second, we reviewed the list of publications by title and abstract to estimate if they are relevant to the topic. We have prioritized the order of indexing so that: if the paper wasn't found in any of the first 5 databases and was found in Google Scholar, we put it in the latter category. Afterwards, we conducted a full-text review, which generated a set of primary studies. Fourth, we reviewed the primary studies to find any other related paper referred to.

A set of inclusion and exclusion criteria were established to eliminate studies considered not relevant to the set of research questions defined previously.

Figure 2
Studies selection process
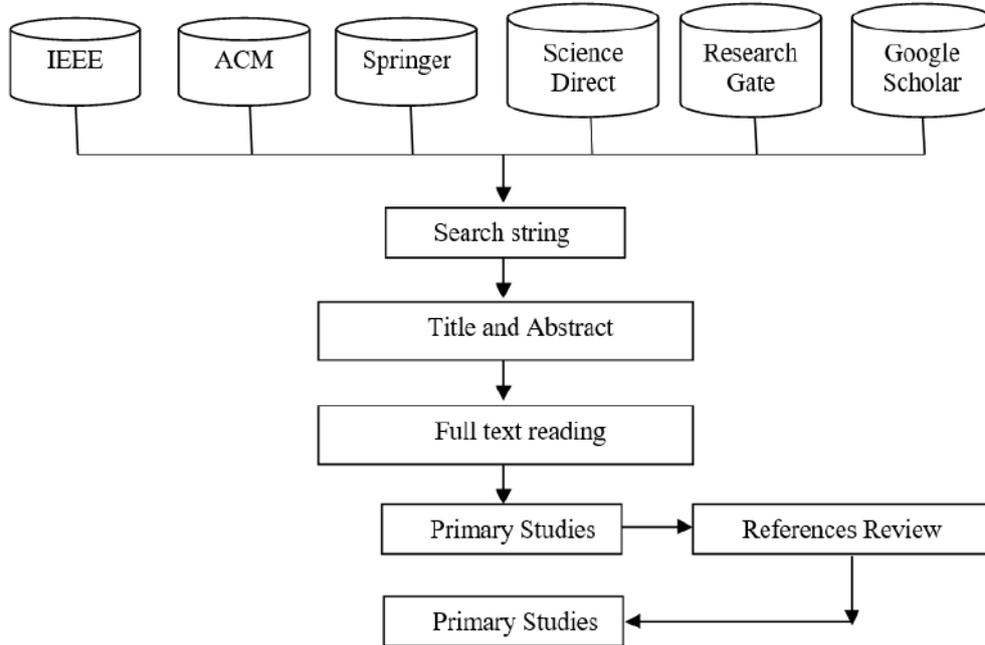
Source: Bisant and Lyle (1989)

The exclusion criteria were defined as follows: (i) the paper refers totally to IT management (no ITG is mentioned), (ii) the ITG framework is not implemented in HEIs but in a company/organization, (iii) the paper doesn't provide information on any of these fields: the ITG framework used or studied, maturity level, or university where the study was conducted, (iv) the paper is not a research paper, so we exclude books, dissertations, private reports.

The data that we extracted from each paper was documented and organized as follows: the paper title, year of publication, source (one of the 6 databases), country where the study is performed, the framework they are studying, maturity level, if reported, if a specific university where the study is conducted is mentioned, we gathered its name, the size, the year of foundation, and if it is a public or private HEI, and challenges and benefits from ITG framework implementation. Once this information was collected, we answered the research questions defined earlier.

Search execution
We searched the databases in early 2019. The initial search included 74 papers. After reading the title and abstract, we excluded duplicated papers and applied exclusion criteria for a set of 65 papers.

Among the papers excluded, there are reports from the University of Waikato, New Zealand, Texas A&M University, USA, and Guelph University, Canada given that they are not meeting the requirements defined in the previous section. Out of the remaining 65 papers, after reading the full content, we excluded 21, as the content was not directly related to our research. Finally, 4 of the papers in the final set were literature reviews, not giving specific answers to our research questions, so a total of 40 papers is the final collection of primary studies. The overall result, showing the number of papers per database, is given in Table 1.

Table 1
Extracted Papers per Database

Database	Number of papers
IEEE	10
ACM	2
Springer	5
Science Direct	1
Research Gate	11
Google Scholar	11
Total papers	**40**

Source: Authors' work

Results and Findings

RQ1: What is the interest evolution in ITG in HEIs in the last decade?

The oldest published paper out of 40 selected papers appeared back in 2003. This paper reports a case at Queensland University, Australia (Fraser & Tweedale, 2003). In total, there are seven papers which are published before 2009. During the last decade, 2009 – 2018, we found a total of 33 papers.

Figure 3 shows the number of publications per year in the last decade. In 2012 there were no papers published about the topic. In contrast, the highest number of papers is produced in 2014 with 9 papers. As the graph shows, the interest in the topic has been increased during the second part of the decade nearly 4 times compared to the first part. The average number of publications during the whole decade is 3.3 papers per year. Out of 33 papers, approximately 75% of them are written during the last 5 years. This indicates the increasing popularity of the ITG topic in HEIs as a field of study.

Figure 3
Number of Publications on ITG per Year in the Last Decade
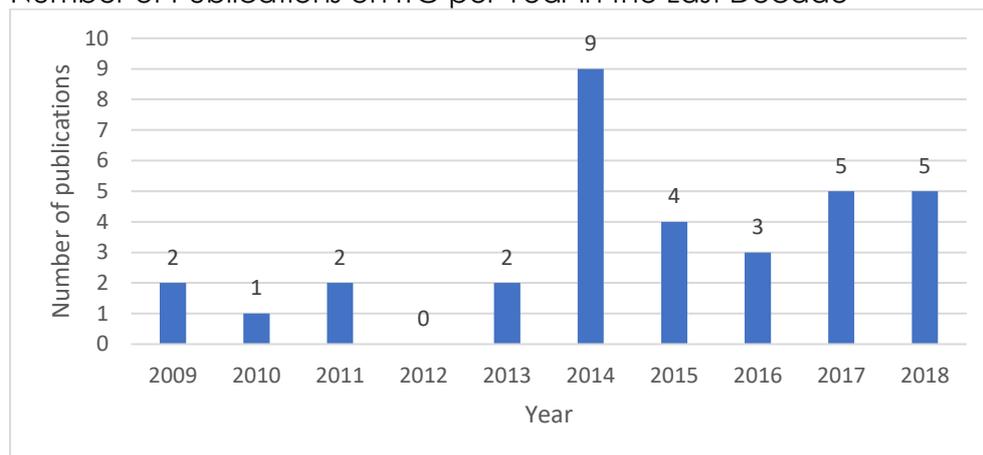
Source: Authors' work

RQ2: What is the geographical coverage of ITG effects?

This section highlights the participation of the countries worldwide in implementing or studying ITG at their University, by producing a paper with results. We have shown this indicator on the country and continental level.

Table 2 shows the number of countries and the number of papers for each continent. The lead is held by Asia while the continent less involved in the topic is North America.

Table 2
Number of Countries and Number of Papers on ITG per Continent

Continent	No. of countries	No. of papers
Asia	8	16
Europe	5	7
Africa	5	6
South America	3	6
Australia	1	5
North America	1	3

Source: Authors' work

Figure 4 illustrates that the countries with the highest number of publications are Australia and Malaysia with 5 papers each, followed by Indonesia with 4 papers. There is a total of 23 countries writing on ITG in HEI's. As the colour varies from yellow to red, the number of papers per country varies from 1 to 5. Table 3 shows the number of papers per continent by a pie graph.

Figure 4
Heat Map Illustration for the Number of Publications per Country in 23 Countries Worldwide, on a scale from 1 to 5

Source: Authors' work

Table 3
Distribution of ITG in HEI's Publications through Continents (in Number of Papers)

Continent	Total number of papers
Asia	16
Europe	7
South America	6
Africa	6
Australia	5
North America	3

Source: Authors' work

RQ3: What are the reported ITG frameworks?

Universities have adopted different frameworks to govern IT within their institutions (Table 4). We noticed from the papers that the adoption of ITG frameworks in HEIs needs further and considerable improvement. Some universities are still evaluating their ITG maturity level to propose an appropriate ITG framework. Other universities are facing challenges in proposing or implementing ITG framework.

Part of the papers on ITG concluded their results based on surveys conducted on different levels. The study of Seyal et al. (2017) elaborates on data obtained from interviews of the directors of ICT centres to four universities in Brunei. COBIT framework was used to evaluate various IT processes. Jairak and Praneetpolgrang (2011) performed a survey of 117 Thai universities, while Sadikin et al. (2014) performed a self-assessment of the Mercu Buana University based on COBIT 4.1 framework. The same framework was used to measure the maturity level of 30 private universities in Pontianak, Indonesia (Kosasi et al., 2017). A web-based CIO and executive survey regarding ITG was conducted in the United States and Canada universities (Yanosky & Caruso, 2008). Johl et al. (2014) seek to explore the presence of ITG in HEIs in South Africa through a detailed analysis of cooperative governance and inter-institutional cooperative governance. At last, promising steps towards ITG development are undertaken after research in a single but large Australian university (Hicks et al., 2010), where key personnel were interviewed, serious shortcomings on ITG were identified and new initiatives were implemented.

Table 4
Number of Papers per Category: Evaluation or Implementation of ITG

	No. of Papers
Universities evaluate their ITG status	6
Universities implement/propose FWs for ITG	34

Source: Authors' work

As shown in Table 5, COBIT is the most popular ITG framework that universities have adopted or had plans to adopt in the future. As such, COBIT is mentioned as a new ITG framework fully implemented in South Louisiana Community College, USA (Council, 2006) and a framework serving as a standard to measure the maturity level of Integrated ITG framework in Indonesia (Kosasi et al., 2017) and Brunei (Seyal et al., 2017). Another use of COBIT was found at a University in Morocco for the implementation of multi-criteria decision-making platform for prioritizing projects at universities (Ahriz et al., 2018).

Many universities find it more appropriate to govern IT in their way. For instance, Tunisian Universities adopted an ITG framework based on ISO/IEC 38500, taking into account their actual situation and the expected maturity level (Gómez et al., 2018). Likewise, in Thailand, they adopted an integrated framework which uses modules from ISO38500 combined with SEP (Sufficiency Economy Philosophy) (Jairak et al., 2015), whereas, Brazil and Portugal (Bianchi & Sousa, 2015) preferred to combine modules from COBIT and ITIL to simultaneously govern and manage IT. An earlier implementation of ITG is reported by Syracuse University in New York (Clark, 2005) by modifying Weill's framework to fit their institution needs.

Table 5
Number of Papers per Framework Used

Documented ITG framework	No. of papers/ universities
ISO	3
COBIT	11
Integrated ITG framework	7
Their own	14
No ITG framework	6

Source: Authors' work

RQ4: What IT management frameworks have been reported as ITG frameworks for HEIs?

We noticed that several universities report IT management (ITM) frameworks as ITG frameworks, that is shown in Table 6.

Table 6
ITG versus ITM Exploration

	No. of papers
Claim to explore only ITG framework	35
Claim to explore ITG + ITM framework	5
ITM framework reported as ITG framework	4

Source: Authors' work

Table 7 shows the list of universities that misinterpret the adoption if IT management frameworks. It is worth mentioning that some of the papers claiming to explore ITG frameworks in some universities, in reality, explore the actual situation of ITG in these universities without discussing a concrete ITG implementation. This is the case of a university in Ecuador (Cajo et al., 2017) where IT is considered more an operational utility than a strategic entity, thus resulting in a lack of ITG. A similar approach is seen in a study conducted in HEIs in Malaysia (Kaur et al., 2011) which attempted to identify the mechanisms for effective ITG but no ITG framework is reported. Furthermore, another paper (Islami et al., 2014) discusses the alignment of the university existing structure with a prototype based on COBIT 4.1 and CISR (Certified Insurance Service Representative). CISR is also used as a base model for ITG for the research conducted to three private HEI's in Bogota, Colombia (Perea et al., 2017). Because of the study, the lack of knowledge on ITG was emphasized and the importance of IT as a key resource of the organization was acknowledged. We want to underline that, this confusion is quite common also in industry. These relevant papers reveal the lack of knowledge in the topic by few researchers.

Table 7
A Short Description for ITG and ITM Confused Papers

Country		Publication year	Description
Thailand		2011	Partially implemented COBIT, ITIL, ISO/IEC 27001, COSO (Jairak & Praneetpolgrang, 2011)
United Arab Emirates (Abu Dhabi)		2013	Proposed theoretical Framework: COBIT + Six Sigma (Ajami & Al-Qirim, 2013)
USA		2008	EDUCAUSE report: COBIT or ITIL or ISO 17799 and ISO 9000 (Yanosky & Caruso, 2008)
Vietnam		2014	Claims to implement its ITG but it is ITM (Le et al., 2014)

Source: Authors' work

RQ5: What are the main features (University size, lifespan, public/private, maturity level, etc.) of ITG adopters?

After reading all the selected papers needed to process our RQs, we have extracted specific Universities information. The metrics we have collected for each mentioned HEI are the number of students, the lifespan based on the year it was founded, if the HEI is public or private, and the maturity level (if mentioned). Within 40 papers, there are 15 specific Universities mentioned where the study has been conducted or the framework has been applied. They represent 10 different countries worldwide. The majority of the HEI's are public (11), while just four of them are private. Regarding the utilized frameworks, six of the identified universities report to have used COBIT, 7 have implemented its framework, and two Universities have applied an integrated framework, by using different frameworks to handle different processes of ITG.

The data we found regarding University size and lifespan is presented in Table 8. The University size varied from 5000 to 60000 students, and the lifespan from 4 centuries up to 16 years old. Regarding the question, if there is any relation between the size or lifespan and the type of ITG framework used, we did not find any valid correlation. The universities that have applied COBIT vary in size from 5000 students at the Viana De Castelo Polytechnic Institute, Portugal (Ribeiro & Gomes, 2009) to 58000 students at the Curtin University of Technology, Australia (Khther & Othman, 2013). Those universities that have implemented its framework vary from 5,500 students at the Independent University Bangladesh (Dey & Sobhan, 2007) to 60,000 students at the University of Pretoria, South Africa (Petrorius, 2006) and Ho Chi Minh City Open University, Vietnam (Le et al., 2014) to 58,000, and those that have implemented its framework vary from 5,000 to 60,000. Equally, the university foundation year varies from 1651, Central University of Ecuador (Valverde-Alulema & Llorens-Largo, 2016) to 1997, South Louisiana Community College, USA (Council, 2006) for COBIT- using universities; and from 1870, Syracuse University, USA (Clark, 2005) to 2003, Gulf University, Bahrain (Sahraoui, 2009).

Table 8
Features' Aspects of Universities that Has Adopted ITG Frameworks

	University Size	University Foundation Year
Min	5000	1651
Max	60000	2003

Source: Authors' work

The maturity level is defined on a scale from 1 to 5 with regards to their ITG processes. Out of 40 papers, only five of them have reported a measured maturity level. According to the survey conducted to four HEIs' CIOs in Brunei, the level of maturity is evaluated from 1.4 to 1.72, which indicates initial phases of ITG (Seyal et al., 2017). The situation in Spain, as of 2008, shows a maturity level of 1.44, before implementing any ITG framework (Fernández & Llorens, 2009). The results of the USA universities survey, which got replies from 438 respondents, shows a maturity level of 2.51(Yanosky & Caruso, 2008). A better level is measured in Indonesia, with an average of 3.25 on 30 private HEIs (Kosasi et al., 2017). Finally, Abu Dhabi Universities have reported the level of maturity of 2.5 to 3 for two Institutions A and B (Ajami & Al-Qirim, 2013).

RQ6: *What are the reported challenges and benefits of ITG frameworks?*

Many Universities have acknowledged the need for an ITG framework to enhance the quality of education and increase the overall performance. Although some of them have achieved and reported the improvements, several difficulties have been met during the implementation of the ITG frameworks. At times, these barriers have slowed down the process, even to the point of having fully stopped the implementation process. The organization's culture too is an influencing factor on the success of the ITG implementation, presented by the study of Stockholm University (Aasi et al., 2017). By detailed reading, we extracted the challenges and benefits mentioned in each of the papers. Afterwards, we sorted them in descending order based on the number of papers they are mentioned.

Specific challenges and/or benefits are reported in 17 papers of the set of studies, presented in Table 9.

Table 9
Challenges and benefits reported in 17 papers

Challenges	No. of papers mentioned	References
Resistance to change (difficulties to break the traditional thinking)	5	(Ajami & Al-Qirim, 2013; Bhattacharjya & Chang, 2009; Hotzel et al., 2016; Jairak & Praneetpolgrang, 2011; Sahraoui, 2009)
Communication problems among all parties involved	5	(Ajayi & Hussin, 2016; Bhattacharjya & Chang, 2009; El-Morshedy, et al., 2014; Fraser & Tweedale, 2003; Nyeko et al., 2018)
Budget constraints	4	(Ajami & Al-Qirim, 2013; Council, 2006; El-Morshedy et al., 2014; Jairak & Praneetpolgrang, 2011)
Lack of knowledge/clarity on ITG principles, and need for continuous training	3	(Ajayi & Hussin, 2016; Jyotirmoyee et al., 2009; Jairak & Praneetpolgrang, 2011)
Lack of organizational vision for IT	3	(El-Morshedy et al., 2014; Fraser & Tweedale, 2003; Sahraoui, 2009)
The very low maturity level on ITG	3	(El-Morshedy et al., 2014; Kosasi et al., 2017; Sahraoui, 2009)
Lack of human resources in terms of delays, size, or knowledge	3	(Ajami & Al-Qirim, 2013; Jyotirmoyee et al., 2009; Council, 2006)
Finding appropriate IT performance metrics.	2	(Bhattacharjya & Chang, 2007; Bhattacharjya & Chang, 2009)
Culture	2	(Bhattacharjya & Chang, 2009; Nyeko et al., 2018)
Existing ITG frameworks are not appropriate with university context	2	(Jairak & Praneetpolgrang, 2011; Montenegro & Flores, 2016)

Source: Authors' work

The most often reported challenges when implementing ITG are resistance to change and communication issues among parties (found in 5 papers). These are followed by budget limitations, lack of knowledge/training for ITG principles, and lack of vision for IT. Meanwhile, the most commonly reported benefits for using ITG are

improved quality of service and user satisfaction (mentioned in 4 papers), along with better alignment in IT planning and management with University and/or business goals. According to the literature review (Tjong et al., 2017), generally, it is accepted from authors that using ITG improves the overall performance and conformance to the regulations. Besides, there is not much difference, in terms of the benefits of implementing ITG, between industry and HEI.

Discussion and conclusions

In this paper, we conducted a systematic mapping review to observe the current situation of research on ITG frameworks in HEIs. To achieve this goal, we formulated 6 RQs. To answer these questions, we executed a search within multiple scientific databases, returning 40 primary studies. Because of the RQ1 results, we can state that the research interest in the last 5 years has been increased nearly 4 times compared to 5 earlier years. These results are also supported by review papers. The authors of (Oñate-Andino et al., 2019) cite similar results as well. The same steady growth is seen for ITG in other areas than universities. However, the number of publications regarding ITG in universities for the year 2014 represents only 3% of the total amount of papers on ITG for the same year. This conclusion addresses the need for a greater interest in implementing and publishing of ITG in HEIs.

The geographical distribution of these research papers is mainly concentrated in Australia, Malaysia and Indonesia according to the number of papers in the topic reporting cases in these countries. This is mainly identified to be due to the present culture of ITG and support and vision from top-level authorities.

COBIT and Ad-Hoc frameworks are the most common ITG frameworks used over all the countries. ITIL and ISO 17799 along with ISO 9000 are also popular frameworks used for ITM, sometimes mixing the concept of ITG and ITM. Therefore, four of the forty selected papers have confused the terminology used for ITG with ITM, which prompts the need for better clarity of ITG, in terms of training and publications.

Regarding the connection between the size or lifespan of the HEI and the type of ITG framework used, we did not find any valid correlation.

Finally, we also provide a list of challenges and benefits of using ITG in HEI's as described in 17 papers. The most common reported benefits for using ITG are improved quality of service and user satisfaction, along with the better alignment of IT planning and management with University and/or business goals. Meanwhile, the most reported challenges when implementing an ITG framework are resistance to change and communication issues among parties.

This paper showed the importance of using ITG in HEIs worldwide, especially in the last few years. Taking the needed time to design, implement, and communicate ITG is worth it, despite the challenges. HEIs can exploit the same benefits from using ITG, as companies or other organizations do.

Furthermore, it is of great importance to identify the maturity level of HEIs and elaborate afterwards the steps to implement an ITG framework, which suits best to the HEIs needs and objectives.

We also have to mention the limitations of our study. First, we chose only research papers and not white papers, book chapters or reports as the primary set of research. Therefore, we disregarded a few countries and Universities from our list. Secondly, only 15 of the research papers stated the University where ITG was implemented, the others were anonymous. So, the answer for RQ5 was based on a limited amount of data.

As future work, we aim to advance in the development of a framework to measure ITG maturity level and suggest actions to reach the needed maturity model. Given that literature presents a good number of such frameworks, we are willing to develop

a way to measure ITG maturity level utilizing a set of semi-automatic assessment. To achieve this, natural language processing will be used to analyze governance documents to elicit aspects supporting ITG (Chief Information Officer Role, committees, decisions).

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About the authors

Elinda Kajo Meçe, Associate Professor, is the Head of Computer Engineering Department, Faculty of Information Technology, Polytechnic University of Tirana. She holds a PhD in Computer Engineering. Her fields of research interests involve Object Oriented Programming, Software Engineering and Machine Learning. She has participated in several international projects supported by DAAD, HORIZON 2020, Erasmus+ and Tempus. She has published several papers in referred journals and international conference proceedings. The author can be contacted at **ekajo@fti.edu.al.**

Enida Sheme, Ph.D. is a Lecturer at the Department of Computer Engineering, Faculty of Information Technology, Polytechnic University of Tirana since 2012. She received PhD in Computer Engineering at the Faculty of Information Technology, Tirana with the dissertation thesis "Energy Efficiency in Datacenters using Renewable Energies". She has conducted staff exchange visits through Erasmus+ and NESUS program to Abo Akademi University, Finland and Paul Sabatier University, France. Her main research interests are cloud computing, green ICT and IT project management. She is actively engaged in several bilateral and national projects. The author can be contacted at **esheme@fti.edu.al.**

Evis Trandafili, PhD. is a Lecturer at the Computer Engineering Department, Faculty of Information Technology, Polytechnic University of Tirana since 2009. She finished her PhD in 2014 in the field of Natural Language Processing. Furthermore, her research interests focus mainly in Artificial Intelligence, Machine Learning, Text Mining and other similar fields. The author can be contacted at **etrandafili@fti.edu.al.**

Carlos Juiz is a professor at University of the Balearic Islands (UIB), Spain. Before joining to the Department of Computer Science at UIB, he had several positions in the computing industry. Carlos Juiz is heading the ACSIC research group and his research interest mainly focuses on performance engineering, Green IT and ITG. He has been involved in several regional, national, European and international research projects. He is co-author of more than 200 international papers. He is coordinator of the workgroup of ITG at AENOR, the Spanish body in ISO and one of the co-editors of the ISO/IEC 38503 standard. The author can be contacted at **cjuiz@uib.es.**

Beatriz Gómez, Assistant Lecturer at the UIB teaching in the area of Architecture and Computer Technology. Before joining the Department of Computer Sciences of the UIB, she served for two years at the chair Telefónica – UIB of Digital Health and Sustainable Tourism. She is member of the ACSIC research group in the Department of Computer Science at UIB. Her research interests are mainly about IT Governance and eHealth. Currently, she is the project manager of both Erasmus+ KA2 projects IT Governance for Tunisian Universities (ITG4TU) and IT Governance for Albanian Universities (ITG4AU). The author can be contacted at **B.gomez@uib.es.**

Ricardo Colomo-Palacios, full professor at the Computer Science Department of the Østfold University College, Norway. His research interests include software engineering, IT project management and service governance. He received his PhD in Computer Science from the Universidad Politécnica of Madrid (2005). He has been working as Software Engineer, Project Manager and Software Engineering Consultant in several companies including Spanish IT leader INDRA. He is also Associate Editor and Editorial Board Member for several reputed journals and conferences and has published in top journals in his area of interest. The author can be contacted at **Ricardo.colomo-palacios@hiof.no.**

BlockChain Platforms in Financial Services: Current Perspective

Pablo Garcia Bringas, Iker Pastor-López
University of Deusto, Bilbao-Spain
Giuseppe Psaila
University of Bergamo, Bergamo-Italy

Abstract

Background: BlockChain technology was invented to support *bitcoin*, currently the most popular virtual currency. **Objectives:** The purpose of this paper is to investigate contemporary BlockChain platforms in financial services. **Methods/Approach:** An unstructured literature review has been used. **Results:** BlockChain in financial services is mostly associated with *bitcoin* exchange. However, this is a partial view of both BlockChain technology and its possible adoption for financial services: in fact, many BlockChain platforms are now available and many different financial services can be effectively supported by BlockChain platforms, even though they are not based on virtual-money exchange. Furthermore, people are attracted by the concept of *smart contract*, i.e., a contract that is automatically executed by computer technology, without human intervention. **Conclusions:** The contribution of this paper is twofold: first of all, we introduce the four BlockChain platforms that are now most popular, discussing how they support the smart contract concept; second, we identify some typical categories of financial services, matching each of them with the platform that provides the best support for each category.

Introduction

The acronym DLT, which stands for *Distributed Ledger Technology*, has become quite popular. However, what is its meaning? The ledger is the registry on which notaries transcript transactions of buildings and any other kind of goods between two parties. Its role is to immutably certify the ownership: the notary must look for records in a ledger to certify the ownership of the good to sell, in order to approve the transaction.

Therefore, the idea of DLT is that the ledger is distributed among many parties, in order to ensure its reliability; not only, the consensus to transactions is cooperative, i.e., many parties have to approve the transactions, based on their copy of the ledger. This is the idea behind the acronym DLT, the absence of a third party responsible for storing the ledger and for giving consensus to transactions (replaced by a plethora of anonymous counterparties) is the key idea to achieve resilience to tampering, because the probability that many parties are corrupted is much lower than the probability that one single party (the unique responsible for consensus, in a centralized schema) is corrupted.

The technology to effectively deal with distributed ledgers is called *BlockChain*, because they are stored as *chains of blocks*: this solution, associated with hashing techniques, ensures the immutability of the ledgers.

The first platform that has introduced BlockChain technology is *Bitcoin*, the platform that supports the *bitcoin* virtual currency. The absence of a third central party that gives consensus to money exchange is (probably) one of the keys of the success of *bitcoin*. Its fame has become worldwide, and its popularity leads people usually think that financial services can take advantage of BlockChain technology only if they are based on the exchange of virtual currencies. However, this view is quite limited and does not consider the current scenario as far as available BlockChain platforms are concerned since its birth, BlockChain technology has significantly evolved and several platforms are now available, each of them providing a specific interpretation of the concept of distributed ledger and different approaches for its application.

During its evolution, BlockChain technology has been extended to support the concept of *Smart Contract*, i.e., a contract between two parties that is automatically executed by and within the platform, without need of human intervention. This idea has opened the way to apply BlockChain technology to a plethora of application contexts that were unexpected, at the beginning; however, it is necessary to properly comprehend how each platform supports this concept.

The goal of this paper is to provide readers that operate in the financial market with an introduction to (nowadays) most popular BlockChain platforms. To do so, we have to discuss the main features that characterize a BlockChain platform: in fact, depending on the features provided by each single platform (for example, the way it supports smart contracts, one of the buzzwords of DLT) several categories of services can be implemented.

The paper is organized as follows. First, the research methodology is presented: we start by reporting a brief history of BlockChain technology; then, we explain the difference between *permissionless* (classical) and *permissioned* platforms; we continue by explaining the concept of *smart contract* and the different approaches to support it. After the investigation methodology is introduced, we analyse the four most popular platforms, i.e., *Bitcoin, Ethereum, Corda* and *HyperLedger Fabric*. Next, a discussion section will address the typical issues concerned with the adoption of DLT for supporting financial services. Finally, we conclude the paper with some final remarks.

Methodology

Brief History of BlockChain

Haber and Stornetta (1990) developed a cryptographically protected chain of blocks in which no one could manipulate the timestamps of the documents. But it was only in 2008 that Satoshi Nakamoto described the first BlockChain system in Nakamoto (2008) named *Bitcoin*, that supports the virtual currency named *bitcoin*. In *Bitcoin*, the

BlockChain constitutes the underlying protocol of any crypto-currency and is a novel peer-to-peer methodology to link a sequence of transactions or events that ensures their immutability.

A few months later, a new open source application implementing the *Bitcoin* protocol was released and the first block of the chain, called *Genesis*, was generated. By installing this application, anyone can become a part of the *Bitcoin* peer-to-peer network.

Even if *bitcoin* is the most famous application of BlockChain technology, many different applications could significantly benefit by its adoption. To this end, in 2013 V. Buterin started working on a BlockChain platform capable of providing advanced functionalities, such as *smart contracts*, executing them directly within the peer-to-peer network (see Buterin, 2014).

Ethereum was presented in Wood (2014) as a new public BlockChain platform that overtakes the simple support to a crypto-currency (named *Ether*), by evolving into a platform to develop decentralized applications as well. This is made possible by natively supporting the concept of *smart contract*, (thus, actually it has implemented the ideas in Buterin (2014)).

The concept of smart contract was originally introduced by Szabo (1997): it combines computer protocols with user interfaces to execute the terms of a contract. Furthermore, in 2014, when BlockChain was clearly emerging, Fairfield (2014) proposed the use of smart contracts to carry out with the transaction processes by automatically executing contracts in a cost-effective, transparent and secure manner.

However, this does not end the history of BlockChain: this is just the beginning of its evolution. In fact, the history continues with the *HyperLedger* project (see Dhillon et al. 2017), by Linux Foundation. It aims at developing a family of BlockChain platforms based on the same basic architecture, whose goal is to support information systems; the most famous platform belonging to this family is *HyperLedger Fabric* (see Sousa et al. 2018). Furthermore, within the financial world, the platform named *Corda* (presented in 2016 in Brown et al. 2016) is gaining a lot of interest, because it supports smart contracts in a specific way that tries to reconcile technical aspects and juridical aspects.

Figure 1 illustrates how, after a long latency period, the births of *Bitcoin* and *Ethereum* have been the disruptive events that have caused the subsequent birth of the *HyperlerLedger* project, which represents the current evolutionary trend as far as new developments are concerned.

Figure 1
Historical Evolution of BlockChain technology
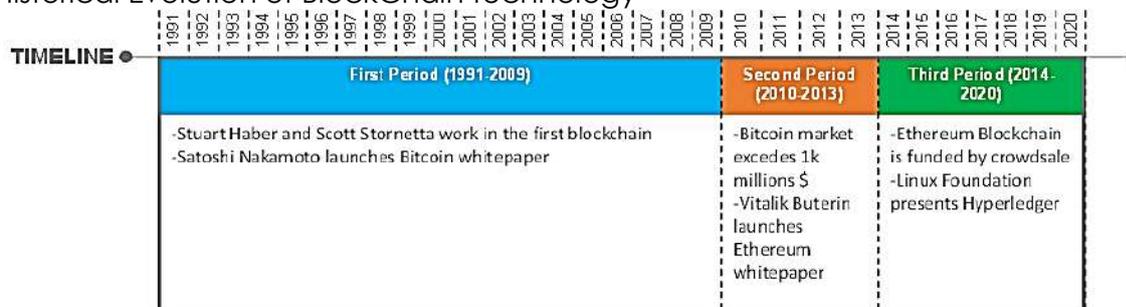
Source: Authors' work

General Concepts Concerning BlockChain Technology

Before carrying on our analysis, we present some basic concepts that underlay BlockChain platforms, so that novices can fully understand our argumentations.

A BlockChain system is a *peer-to-peer network*, where each peer is a computer connected to the other computers involved in the network (see Schollmeier (2001) and Pourebrahimi et al. (2005), for extensive presentations of concepts concerning peer-to-peer networks). Peers are also called *nodes* of the network. They are called *peers* because no node dominates other nodes, i.e., there is not a master that controls slaves; each of them plays an equal role. Figure 2 shows a sample topology of a peer-to-peer network, which clarifies why peers are also called nodes.

Figure 2
Sample of Peer-to-Peer Network
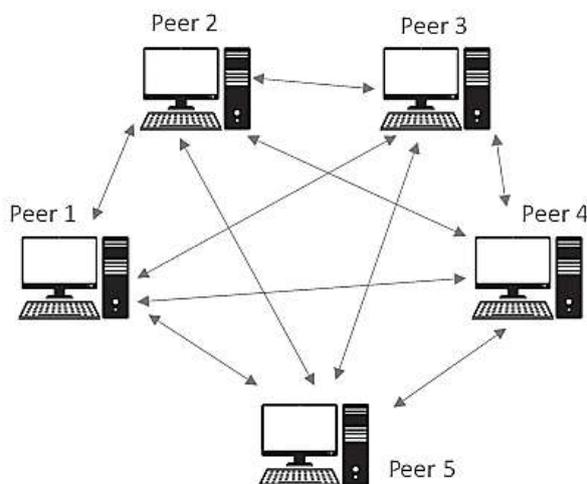
Source: Authors' work

On each node, an instance of the software that provides access to the peer-to-peer network is running.

The term *Distributed Ledger Technology* (DLT) means that a BlockChain platform stores multiple copies of the database (or ledger): the greater the number of copies of the database, the higher the capability of the network to resist to attacks.

Any peer in the network can receive transactions, i.e., requests to change the data. Transactions are performed only if there is consensus by the network, i.e., the overall network must agree.

The name BlockChain originates from the fact that the database is structured as a *chain of blocks*, where each block records a pool of transactions issued to the system and the current state of modified data. Blocks are never removed; in contrast, they are continuously added, so that each block points backward to the top-most block added before itself. The chain implements, in effect, the concept of *immutable ledger*, because the whole history of transactions is stored within the chain, i.e., within the database.

The mostly-used consensus mechanism is called *Proof ofWwork* (see Beccuti & Jaag, 2017 and Garcia-Bringas et al., 2019); we shortly explain it. All transactions issued in a given time period to a pool of peers are validated (i.e., it is verified that the spent amount of money is truly available) and collected into a block, which should be added to the chain: the consensus mechanism is aimed to validate this action. The mechanism is based on the fact that, based on the content of the block, it is possible to generate a hash code to identify the block; such a hash code must respect specific

constraints, that make it very hard to find it. Specific peers called *miners* have the goal of finding the cryptographic key able to obtain a hash code with the desired properties. If the hash code is found, this gives the consensus to add the block to the chain. Why does it work? Because it makes difficult, for a malicious peer, to force some wrong transactions, as well as it prevents the *double spending* attack, i.e., two transactions that are simultaneously issued to different peers, that spend the same amount of money. Since these two transactions are likely to be stored into two different blocks, generated more or less at the same time, they point to the same previous block. However, only one of them can be inserted into the chain; transactions in the other block must be validated again and this allows for discovering that the amount of money has been already spent. In this scheme, miners can be either all the peers in the network or a specialized subset of them; clearly, the larger the number of miners, the higher the speed of the network to validate a block.

Classical vs Permissioned BlockChain platforms

What is the level of trust that each participant to the BlockChain has in relation to other participants? It depends on the application context.

Usually, people think about virtual currencies, like *bitcoin*: in this context, it is necessary to avoid double spending of the same amount of money, in an environment where *nobody trusts anybody*. However, in different application environments, this assumption is not always true. To understand, we classify possible application environments.

No trust. When no trust is possible, i.e., *nobody trusts anybody*, the best warranty that transactions can be performed is given by the largest possible number of nodes. In fact, a large number of nodes (parties), involved both to validate transactions and to store blocks, makes very difficult to attack and corrupt the system.

Partial trust. In a controlled environment, where many parties co-operate to get a common goal, such as an integrated supply chain (see Korpela et al., 2017), in principle each party trusts other parties a little bit. However, they do not fully trust each other, for several reasons: a centralized approach, where a central entity provides the IT support for everybody, could be prone to system faults, programming errors and external attacks. In contrast, having several nodes that provide consensus to transactions as well as that store multiple copies of the ledger significantly increases the reliability of the system.

Full trust. This scenario is the classical approach to the development of information systems to provide a service to many parties. A central authority is (or must be) fully trusted by other parties (they subscribe a service contract, or they are forced by laws). In this context, it is not exactly true that parties really and fully trust the central authority: they have to trust it, even if they do not want.

Clearly, the third scenario (and doubts concerning trust about the central authority) motivated the original design of BlockChain, which is inspired by the first scenario. However, the second scenario, being in the middle, has originated a different approach to BlockChain technology, which led to the definition and the development of two distinct families of BlockChain platforms:

Permissionless BlockChain platforms. This family encompasses classical BlockChain technology, devoted to support virtual currencies. A new node is free to enter the network, provided that its behaviour is compliant with general rules of the platform. In this case, the larger the number of nodes, the higher the warranty that transactions are correct and immutable. This type of BlockChain platforms is good for *No trust scenarios*.

Permissioned BlockChain platforms. This family encompasses platforms such that new nodes cannot freely enter the network; they must be authorized by an administrator. Furthermore, nodes' owners must agree with the business logic supported by the system: this means that only well-defined actions can be performed by transactions, i.e., only those allowed by the contract every party undersigned before entering the network. This type of BlockChain platforms is good for *Partial Trust scenarios*.

Let us explain the rationale behind the two families. When *nobody trusts anybody*, the consensus to transactions is reached by means of the *Proof of Work* mechanism, which we shortly described above. However, this mechanism is very expensive, because a very large number of miners is necessary, each one performing long and energy consuming computations. In practice, *no trust* means *a large (and expensive) effort to achieve trust*.

On the other side, *partial trust* asks for a different approach: it is not necessary to waste as many computational resources as those necessary in permissionless platforms. A very different consensus mechanism can be adopted. An example is the *Proof of Knowledge* approach (see Mazumdar & Ruj, 2018). In this approach, consensus is managed by building a total order among transactions, based on dependencies among *read sets*, i.e., data affected by a transaction, and *write sets*, i.e., new data produced by transactions. If it is not possible to build a total order among transactions on every node involved in the BlockChain, this means that a conflict has been detected and conflicting transactions are aborted. This consensus mechanism works with a small number of nodes.

Smart contracts

Originally, BlockChain technology was thought to support money exchange based on a virtual currency. However, a ledger can be used for many application contexts, not necessarily for money exchange. Consequently, the idea of using BlockChain for application contexts without a simple exchange of possibly virtual money is straightforward.

How to foster the adoption of BlockChain technology? If transactions are not totally free money transfers, but ruled operations that can be performed on the basis of an agreed contract, a new and immense scenario opens. This is the concept of *smart contract*; originally, it was introduced in Szabo (1997), "to describe agreements between two or more parties, which can be automatically enforced without a trusted intermediary" (from Atzei et al., 2018). The idea was ignored for a few years; then, the advent of BlockChain technology has made it actually applicable.

A smart contract can be seen as a contract state, i.e., the set of properties that characterize it, provided with some transformation methods, i.e., procedures that determine how the contract state can change. A transaction consists in asking to change the contract state by invoking transformation methods. When a transaction is issued, the contract state is changed, according to the invoked transformation method.

This concept has incredible potentialities: once two parties have agreed to start the contract, its behaviour can become automatic, there is no need for a third party that handles the contract.

This behaviour can be summarized by the following sentence taken from Clack et al. (2016): "A smart contract is an automatable and enforceable agreement. Automatable by computer, although some parts may require human input and control. Enforceable either by legal enforcement of rights and obligations or via tamper-proof execution of computer code."

Anyway, smart contracts are supported by different BlockChain platforms in different ways.

In-platform code. This approach to smart contracts is characterized by the fact that transformation methods are shared within the BlockChain platform, ready to be used when necessary. A transaction is a triple ⟨os, ns, r⟩, where os is the old state, ns is the new state and r is the request that generated the new state. As far as the possibility of using transformation methods by parties is concerned, three different scenarios are available. (1) ***Contract-Specific Code***: the code of transformation methods is associated to one specific contract, without any form of sharing. (2) ***Contract-family code***: the code of transformation methods is shared among contracts belonging to the same family. (3) ***Global Code***: transformation methods are global, in the sense they can affect many objects stored within the ledger.

External Code. This category encompasses smart contracts whose business logic is not within the platform. This is the case of *Bitcoin*: the first BlockChain platform in the world has not been designed to host smart contracts; nevertheless, it is used for many smart contract-based applications (see Atzei et al., 2018). This is made possible by implementing protocols based on cryptographic-message exchange: transactions are registrations of messages; involved parties receive messages, in such a way only involved parties can decipher them, and, consequently, act (see the description of *Bitcoin* in further sections).

It is clear that, in this scenario, the business logic of smart contracts is handled outside the BlockChain platform: each party must implement it, hoping to be conformant with specifications.

Results: Analysing principal BlockChain platforms

Based on the investigation methodology previously introduced, we now introduce and analyse the most popular BlockChain platforms.

(1) Bitcoin has been the first BlockChain platform. Born to support the *bitcoin* virtual currency, in fact, it validated the approach, proving the effectiveness of the idea. It is a typical permissionless platform: a new node (party) can freely enter the peer-to-peer network; remember that this approach is typical in the context of virtual-money transfer, that we characterize as the typical context where *nobody trusts anybody*.

As far as the support to smart contracts is concerned, its design strongly limits the possibility to add smart contracts to the platform in a native way; in fact, remember that only in a subsequent time the concept of smart contract has been associated with BlockChain platforms (consequently, *Bitcoin* has not been designed to natively support smart contracts). For this reason, smart contracts in *Bitcoin* must be necessarily based on external code: parties involved in the contract exchange ciphered messages that can be read only by involved parties; code for automatic execution of contracts is outside the platform, but this approach can create significant problems as far as trust in executing smart contracts is concerned. To address this intrinsic problem, Atzei et al. (2018) proposes an algebra for specifying semantics of contracts, to be executed by different remote systems connected to the platform.

(2) Ethereum (see Wood, 2014) is the BlockChain of the *Ether* virtual currency. Since it is designed to support virtual-money exchange, it is still a permissionless platform, thus it is based on the *Proof of Work* consensus mechanism, as *Bitcoin* is.

However, unlike *Bitcoin*, it natively supports the execution of smart contracts: they are designed to deal with exchange of money, even though contracts that do not exchange money could be developed as well. A contract is identified by an address and has a state, whose changes are stored within the ledger.

The contract is created with a creational transaction, which also registers the transformation code. Then, a party acts on the contract by sending a transaction request to the address that identifies the contract. Then, the transformation code is executed and the new contract state is stored in the ledger (see Luu et al., 2016 for a complete description).

Ethereum contracts are written in the *Solidity* programming language (introduced in Dannen, 2017), which is similar to *JavaScript*. Later, we will see an example of contract code.

Contract code can be introduced anytime by anybody; each contract has its own code. Due to the *Proof of Work* consensus mechanism, the transformation code is executed on a large number of nodes, causing an excessive use of computational power; however, this is necessary, because we are still in the *no trust* context.

(3) HyperLedger Fabric (see Sousa et al., 2018) is a *permissioned* platform that gives a different perspective to the adoption of BlockChain technology: a BlockChain is a database that immutably logs all changes (transactions) performed on the database; this approach ensures that the current state of the database can be rebuilt, by re-executing change requests stored within the ledger.

The first effect of this database view is that not everybody can enter the network: only authorized parties are admitted (in fact, it is a *permissioned* platform).

The second consequence is that smart contracts are global procedures, called *chain code*, which actually perform changes on data; a transaction is the invocation of a procedure by a party. Chain code can be written in three different programming languages: *Java*, *JavaScript* and *Go* (introduced in Pike, 2009).

Furthermore, chain code cannot be added freely by parties: it is uploaded by administrators of the chain, because its role is similar to stored procedures in relational database technology. Thus, admitted parties are not free to do anything they want: they are allowed to execute only predetermined procedures.

In terms of computational resources, a *Proof of Knowledge* consensus mechanism is adopted, that is called *Byzantine Fault Tolerant* consensus mechanism, explained by Sousa et al. (2018). This mechanism is able to limit the number of nodes involved both in the execution of chain code and in the validation of transactions, thus minimizing the necessary computational power, if compared to permissionless platforms.

(4) Corda is "a distributed ledger platform for recording and processing financial agreements" (from Brown et al., 2016, first sentence of Section 4). It is a permissioned platform, thus only authorized parties can enter the network.

Corda is designed to support legal aspects related to smart contracts: contracts are accompanied by a *legal-prose description* of the contract itself; furthermore, when a transaction is performed, a legal-prose version is generated.

A smart contract, or *smart agreement*, has a state, that is accessible only by involved parties, as well as it has transformation code and validity rules. *Java* and *Kotlin* (presented by Panchal & Patel, 2017) are supported as programming languages.

An interesting concept provided by *Corda* is the notion of *Contract Template* (see Clack et al., 2016): parties pre-load templates of contracts, where details (e.g., interest rate and duration) are not specified; when two or more parties agree, the actual contract is derived from the template, by specifying missing details; this way, all contracts derived from the same template share the same code.

Contract execution is performed only by parties involved in the contract. Then, a pool of *Observer* nodes guarantees the correct sequence of transactions (state changes) by validating timestamps. The effect is the limited amount of computational resources necessary to perform transactions and execute transformation code, because only few nodes are involved.

Anyway, the most distinctive feature provided by *Corda* is the legal-prose version of contracts: a correspondence mechanism ensures that legal prose has a code counterpart, in order to ensure legal validity to contracts.

The interested reader can find a detailed comparison of *Ethereum*, *HyperLedger Fabric* and *Corda* in Valenta & Sandner (2017).

Figure 3
Bitcoin Approach
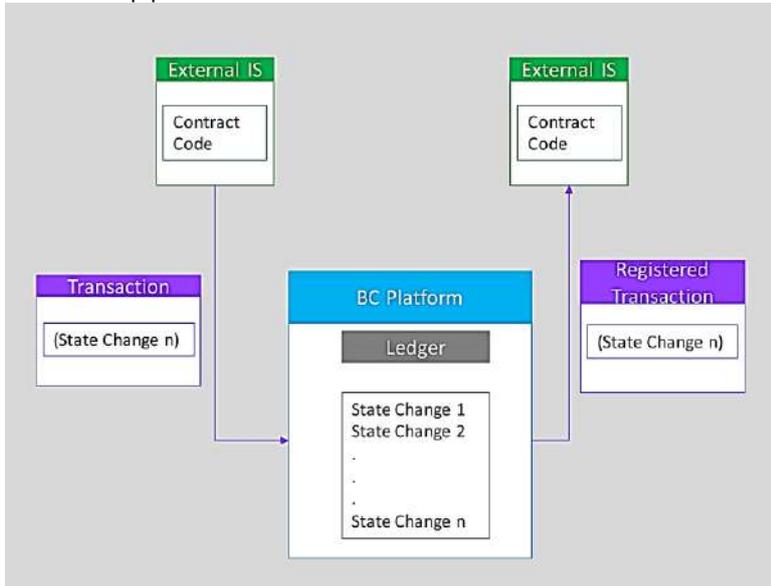
Source: Authors' work

Figure 4
Ethereum Approach
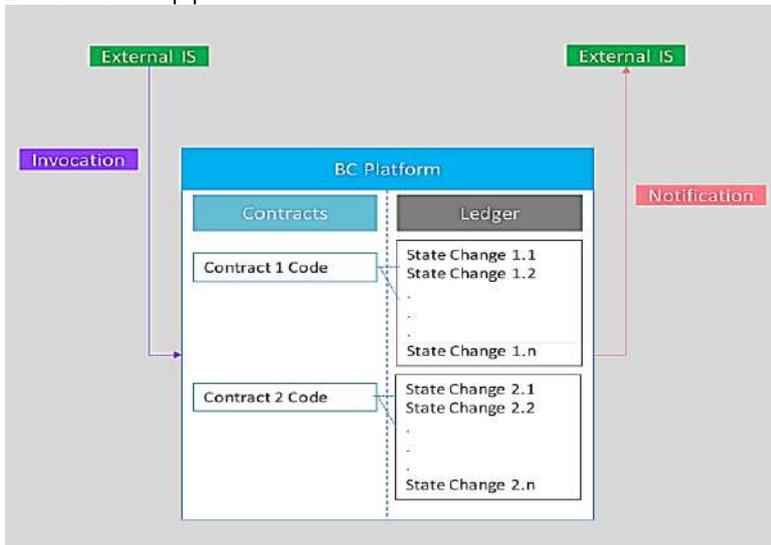
Source: Authors' work

Figure 5
Corda Approach
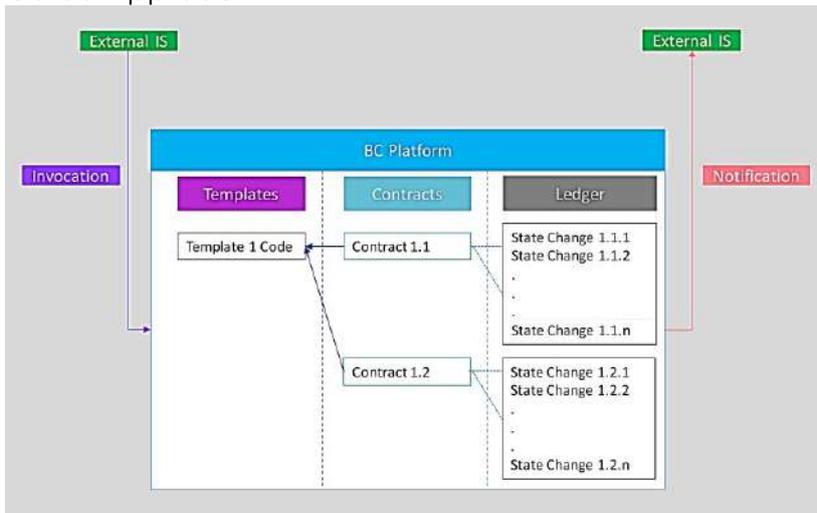
Source: Authors' work

Figure 6
HyperLedger Fabric Approach
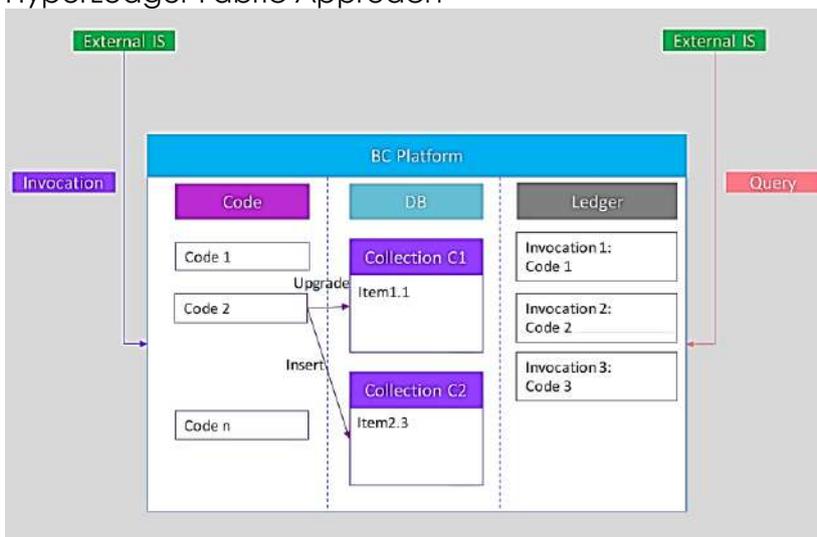
Source: Authors' work

To further clarify, consider Figures 3-6, that illustrate the different approaches adopted by the four discussed BlockChain platforms, as far as smart contracts are concerned.

(1) Figure 3 shows the *Bitcoin* approach. The code is not inside the platform; in contrast, it resides on external information systems (denoted as *External IS*). When the code is activated, it sends a transaction to the platform: its content is the description of the state change of the contract. Involved external ISs are notified by the change. The ledger stores all state changes.

(2) Figure 4 shows the approach adopted by *Ethereum*. The code is stored within the platform. When an external IS invokes the code, it is executed, and makes a change to the contract state. Other involved external ISs are notified; the ledger stores all state changes. Note that there is no code sharing: contracts that behave in the same way have their own copy of the code.

(3) Figure 5 illustrates the approach followed by *Corda*. The approach is similar to *Ethereum*, i.e., the code is within the platform. However, it is associated to templates.

When a contract is instantiated, it refers to a template; this way, contracts referring to the same template share the same code. When an external IS invokes the contract, the state change caused by the contract code is registered into the ledger; other involved external ISs are notified.

(4) Figure 6 shows the approach adopted by *Hyper- Ledger Fabric*. This platform creates a shared and distributed database among external ISs. A database contains data items. The code is global for the database: a transaction is an invocation of a procedure. The invoked procedure changes the state of data items in the database; the ledger stores all code invocations, in this way, the current database state can be rebuilt from scratch, if necessary. External ISs can query the database, as it were a traditional database.

Table 1
Features of popular BlockChain platforms and financial service type

	Bitcoin	Ethereum	HyperLedger F.	Corda
Features				
Permissionless	X	X		
Permissioned			X	X
Contract-specific code		X		
Contract-family code				X
Global code			X	
External code	X			
Financial Service types				
Virtual currency	X	X		
Asset property			X	
Fraud detection			X	
Contract between Financial Op.				X

Source: Authors' work

Smart Contracts in Ethereum

To help the reader understand how a smart contract looks like, we provide a simple example for *Ethereum*, written in the *Solidity* programming language. We report the code hereafter and, then, we will explain it.

```
pragma solidity >=0.4.21;

contract Wallets {
   address public owner;
   mapping (address => unit) public balances;

   function Wallets() public
  {     owner = msg.sender;  }

   function load(unit amount) public
  {   if (msg.sender != owner) return;
     balances[msg.sender] += amount;  }

   function transfer(address receiver, unit amount) public
  {   if (balances[msg.sender] < amount) return;
     balances[msg.sender] -= amount;
     balances[receiver] += amount;  }
}
```

Function *load* is exploited by the owner of the contract to load money to the pool of wallets, namely to the owner's wallet. Notice that, first, it is necessary to check if the issuer is the owner: if so, the owner's wallet is loaded with the amount of money received as parameter *amount*.

The last function is named *transfer*. It is called by any user that possibly has a wallet managed by the contract to transfer money to another user's wallet. Let us explain the function. The function receives two parameters, i.e., the identifier of the receiver and the transferred amount. First, it is necessary to verify if the sender user has enough money to transfer: if not, the function terminates with no effect. This check encompasses also the case in which a user previously unknown to the contract tries to transfer money: the user simply does not exist in the map and the 0 value is obtained as current balance of the wallet.

The second instruction of the function subtracts the transferred amount from the wallet of the sender, while the last instruction adds the transferred amount to the wallet of the receiver.

The reader can see that it is not hard to comprehend the contract and it is not hard to write it, being familiar with object-oriented programming.

Discussion

In the classical centralized scheme, parties performing transactions (have to) trust the intermediary. However, this starting hypothesis of unwavering confidence in central entities, and in their information systems, it is not always clear: can we really trust central entities?

This is the key point that has made BlockChain technology disruptive: it eliminates intermediaries, ensuring the maintenance of trust and even increasing it (see Brezo & Bringas, 2012), by making possible to build networks with a decentralized validation mechanism in untrusted contexts.

Having clarified this premise, in this section, we want to discuss potential applications of BlockChain platforms for financial services.

We begin with a question: *what is the best platform for financial services*? The answer is: it depends on the type of service. Hereafter, we discuss some possibilities, summarized in section *Financial Service Types* of *Table 1*.

1) Virtual Currency. If the service to provide is based on a virtual currency, like *bitcoin* or *Ether*, the choice is mandatory: a service based on *bitcoin* must be necessarily deployed on the *Bitcoin* platform; a service based on *Ether* must be necessarily deployed on the *Ethereum* platform.

However, although it is possible to guess that financial operators are attracted by the possibility to operate with virtual currencies, we expect that this will be a small part of all financial services that in the future will be deployed on BlockChain platforms, simply because national states have their own non-virtual currencies.

2) Asset Property. Financial institutions exchange assets of various types, such as equities, bonds, and so on. An important issue to regulate the financial market is transparency as far as ownership of financial assets is concerned.

In such an application context, a platform like *Hyper-Ledger Fabric* could be the right solution: activities to support are established by regulatory bodies, in this case, asset exchange recording.

3) Fraud Detection. Customers of financial operators could try to fraud them, trying to exploit the fact that, in some cases, operators do not exchange information. An example is given by a service offered by banks to account owners: if the account owner presents an invoice to be paid later by a customer, the bank anticipates the money. However, a typical minor fraud is the following: the account owner presents

the same invoice to more than one bank, in order to unduly receive the money more than once. A platform like *HyperLedger Fabric* could be, again, the right solution: once a bank receives an invoice from an account owner, the invoice is registered, in order to tell other banks that the money has been already anticipated.

4) Contract between Financial Operators. When two or more financial operators sign a contract, this could be managed as a smart contract. The goal is to ensure transparency and to avoid misinterpretation because several information systems must deal with the contract. The adoption of a smart contract executed within a BlockChain platform removes duplications and possible inconsistencies. Since the nature of contracts might be very specific and related to a small group of financial operators (two or three, for example), a global approach is not possible. In this case, *Corda* could be the best solution, because parties can agree on a template (shared implementation of the contract) that is instantiated when they sign the detailed agreement. In this context, legal value of contracts is a crucial issue. The legal-prose version of smart contracts and of transactions is essential for agreeing and documenting all state changes of contracts.

The reader can notice that permissioned platforms offer, in our opinion, the best support to traditional financial services. They provide transparency and trust among financial operators. Of course, since they are permissioned, financial operators must be admitted to the network. This ensures a kind of fairness among parties: a party that tries to fraud other parties can be easily blocked and, in the worst case, kicked out from the network; the damage for the fraudulent financial operator would be enormous; thus, this scenario further increases the level of trust.

However, it is not easy to set up a permissioned scenario, because parties must agree in advance: requirements are crucial and must be understood and shared by all parties. Typically, the financial market is global: this means that an international consortium is the only way to build and regulate a BlockChain platform for sharing financial services.

An aspect to consider that is under investigation by researchers is scalability. It is directly related to the speed of transaction processing within a specific BlockChain platform, as well as to the total volume of such transactions per unit of time. Different flavours of BlockChain have already suffered important moments of crisis, with strong bottlenecks that came not only to extremely slow down the service, but even to shoot the costs for users, who were in the position of paying extra fees to raise the priority level of their transactions. A congested BlockChain platform, which cannot process transactions at the rate at which they occur, is no longer interesting for all BlockChain parties. If the network does not work as expected, many users of different types look for other alternatives.

To respond to this crucial challenge of scalability, some variants of BlockChain technology are exploring different technical alternatives, such as working with smaller size signatures, incorporating secondary chains for specific types of transaction, or are experimenting with different block sizes. In particular, the maximum size of the block is a technically long-disputed conditioner, which even today can significantly limit the transaction capacity of the network.

To understand the potential impact of this issue, we refer to various works that made a performance analysis of BlockChain platforms, such as Pongnumkul et al. (2017) and Dinh et al. (2018). It appears that the latency of a transaction can be hundreds of seconds. Such a latency is too high for information systems that have to process a very large amount of transactions.

As far as the four BlockChain platforms we consider in this paper are concerned, *HyperLedger Fabric* manages several chains at the same time, one for each

application context: this way, it is able to serve many distributed information systems, each one with its own database and its own chain; as an effect in terms of scalability, the number of nodes involved in the computation is kept low, in order to reduce the latency of transactions.

Corda is able to execute contracts only on nodes of involved parties; a reduced number of observer nodes, that guarantees the correct order of timestamps, is still beneficial in terms of latency of transactions.

In general, the adoption of the *Proof of Work* consensus strategy is a significant obstacle as far as scalability and reduced execution times are concerned. In fact, the computational effort made by miners is quite high, so it can significantly slow down transaction processing. This is a crucial issue in *Ethereum*, where contracts are executed by a large number of nodes in the network. This is the main reason why *Hyper-Ledger Fabric* and *Corda* do not rely on the *Proof of Work* consensus strategy. This different behaviour is studied by Pongnumkul et al. (2017), where it is shown that *HyperLedger Fabric*'s throughput is significantly higher than *Ethereum*'s trough put. The same is for latency: transactions in *HyperLedger Fabric* have a highly reduced latency, if compared to transactions in *Ethereum*; however, 34 secs in the worst case are still too many, in many applications, such as, registering transactions performed by credit cards.

Furthermore, by considering the general philosophy of the *HyperLedger* project, it is clear that BlockChain platforms are going to replace or backup local databases in information systems; furthermore, they could become sources for NoSQL frameworks able to integrate many data sources for data science applications, like Bordogna et al. (2017, 2018).

As a final remark, we think that this paper is innovative in the scientific literature concerning the adoption of BlockChain technology for financial applications. Indeed, other surveys presenting BlockChain platforms in the financial market are available in literature, such as Bouri et al. (2018) and Corbet et al. (2018). Although it is true that these works consider the financial market, they are focused on studying the dynamics of transactions performed by means of virtual currencies. In contrast, our perspective is quite different: this paper presents basic technological aspects, as well as it classifies application contexts; the goal is to provide readers with the basis to understand, for each single type of financial service to support that are not relying on virtual currencies, which is the best platform to potentially adopt.

Conclusion

This paper has presented a brief overview of most popular BlockChain platforms, by introducing their main features. We relied on an investigation methodology that highlights the different ways platforms support the concept of smart contract. Then, we focused on financial services, i.e., we investigated the best platform for supporting different types of financial service, by motivating our choices.

We can summarize the main outcomes of our analysis. (1) The most recent platforms, such as *HyperLedger Fabric* and *Corda*, definitely divide BlockChain technology from virtual currencies. (2) *Corda* addresses the problem of giving a legal description of smart contrasts, thus giving them the same legal validity as traditional contracts; this was a critical issue in the financial market. (3) *HyperLedger Fabric* opens the way to effectively integrate information systems of financial institutions, as an effective form of fraud prevention.

We can now make hypothesis about the future work on this topic. This survey has suggested us to investigate the problem of designing complex services and complex data models for permissioned platforms: we will investigate this in the near future.

Finally, to conclude our vision of the future, we could think about hybrid approaches, in which a BlockChain platform and a NoSQL data store system able to store large volumes of data in cloud environments (usually called Big Data) could cooperate to provide a service able to deal with large volumes of data ensuring, at the same time, their temporal integrity; as far as financial services are concerned, this approach could open the way to support a plethora of financial services by means of BlochChain technology, that now are considered not feasible.

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About the authors

Pablo García Bringas is actually working as Vice-Dean of Deusto Engineering, at University of Deusto. He has been dedicated to Research, Technology and Innovation for 20 years, from positions as Head Researcher of DeustoTech Computing - S3Lab, and as General Director of DeustoTech - Deusto Institute of Technology. García-Bringas has combined teaching (in several BSc, MSc, PhD, and in-company courses) with research since 1998, mainly focused in Data Mining applied to the fields of (a) Information Security, (b) Industrial Processes, and (c) Genomics and Proteomics. He has over 15 years of experience in R&D management, with many projects, journal papers, and PhD supervised dissertations. The author can be contacted at **pablo.garcia.bringas@deusto.es.**

Iker Pastor-Lopez holds a PhD in Computer Science with the highest qualification and with Cum Laude Mention, since 2013. Master in Information Security, since 2010. Computer Engineer, since 2007. Program in Big Data and Business Intelligence, since 2016. He works in the Faculty of Engineering of the University of Deusto, and focuses him scientific interests in the areas of Big Data Analytics, Opinion Mining and Computer Vision. He is the author of several scientific articles in conferences and indexed journals. In addition, he is a member of the scientific committee of several congresses and reviewer of JCR journals. The author can be contacted at **iker.pastor@deusto.es.**

Giuseppe Psaila received his PhD at Politecnico di Torino (Italy). He is associate professor at University of Bergamo (Italy). He works on many topics concerning data management, such as data mining, XML processing, query languages and soft computing, information retrieval, Big Data and Open Data. The author can be contacted at **giuseppe.psaila@unibg.it.**

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Data Mining Applications in SMEs: An Italian Perspective

Amir Topalović, Antonia Azzini
Consortium for the Technology Transfer, C2T

Abstract

Background: From the last decade, data mining techniques, employed in particular in customer relationship management, have assumed a key role in the profitability and operations of companies. To support small and medium companies (SMEs), several innovative and continuously improving tools have been developed that allow SMEs to utilize the internal and external data sources to increase their competitiveness. **Objectives:** In this paper, an analysis of the impact of digitalization, and in particular data mining techniques, in the context of SMEs development is presented. **Methods/Approach:** A review of various sources has been conducted, with the focus on open source tools, since in the context of the Italian economy they are used by SMEs the most. **Results:** First, the analysis presents a brief review of the data mining techniques available and shows how they are practically employed in small companies. Second, an economical review of investments in data mining projects in Italy is presented. **Conclusions:** The review indicates that data mining techniques can boost a company in the market. However, the awareness of data mining as a company asset is still not strong in Italian SMEs and most investments in Italy are still carried out by large companies.

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Introduction

From the last decades until today, customer relationship management has increasingly assumed a key role in the profitability and operations of companies, thanks to the management of the relationships with the market to which they are addressed (Ghaderi & Fei, 2013). As widely reported in the literature (Ngai et al, 2009), the objective of Customer Relationship Management (CRM) has been based on the study and identification of the needs of the market to which a company turns. The aim is leveraging these aspects to increase the company's profitability in the long term

(Stringfellow et al., 2004), clearly taking into account several environmental, social, economic, and financial factors that surround a company, but which are constantly evolving. Companies are required to implement solutions to be able to deal with these changes (Rygielski et al., 2002). In this context, the advent of information technology and in particular the introduction of innovative Knowledge Management techniques, and data mining more specifically, has transformed customer relationship management, as well as the way companies, manage information about their customers (Shaw et al., 2001).

Moreover, digital innovation increasingly present in recent years has strongly influenced and is still bringing, a continuous change in the social and economic logic (Pejić Bach, 2014, Ministry of Economic Development, 2017). This innovation also calls for a definition of new personal attitudes, as well as continuous updates visible in the business processes, in the individual company or enterprise, and increasingly greater contexts and territorial aggregations. It is possible to observe how these changes are directly affecting the dynamics of the information and communication technology market, which continues its rapid transformation into the direction already taken, highlighting at the same time the slowdown of more traditional technologies on the one hand and the dragging effect of new ones on the other. New strategies implemented in various contexts force companies to renew continually, with particular attention to all the new information and communication technology investments that the company must continuously employ.

The concept of a data-centric business model, which has been subject to discussion in the literature and the market for several years (Blagojevic & Micić, 2013; Calvello et al., 2020), is becoming increasingly interesting and is therefore applied by SMEs, particularly in all economic sectors where new competitive scenarios arise. All this happens with particular attention to investments in information technology. Indeed, technologies and solutions involving processes such as data and information management and exploitation are among the most dynamic sectors in today's market.

Nowadays, popular technologies include machine learning, big data, and Analytic technologies, along with architectural and cloud-ready infrastructure technologies. These approaches have as a point of innovation the ability to reorganize completely how data is acquired and managed by end-users. One example is represented by machine learning and big data technologies, actually widely used to make real-time decisions and learn old and new processes. The combination of these new analytical and cognitive technologies is increasingly becoming what differentiates market leaders. In fact, in such a scenario what no company can avoid is finding new ways to achieve the goal to effectively predict and design new solutions to improve industrial processes, to assist people in the triple role of customers, citizens, patients, and finally, to make decisions in different market environments, currently dominated by systemic uncertainty and recurring turbulence.

According to the work carried out by Almeida and Bernardino (2016), it is difficult for SMEs to obtain important positions, with good profits, in the market, especially the global market. The growth of the global market causes new problems for companies. Extracting knowledge from the huge amount of data available to a company (whether it is data generated inside or outside) has been recognized as one of the most valuable ways to obtain a competitive advantage. In this sense, the recognition of the importance of data mining allowed this research area to be among the fields of computer science that has produced the biggest amount of research and development in recent years. The authors show how there are many use cases for data mining Tools, even though the most common consists of extracting patterns and

trends stored in data and use these patterns to discover previously unknown information to be used in strategic management decisions (Shaw et al., 2001). This information comes in many forms and has a lot of characteristics that differentiate it from one another. To support SMEs to cope with the continuous evolution of the data mining tools used in a data management cycle, several innovative and continuously improving tools have been developed.

The goal of this paper is to present an analysis of the impact of digitalization, and in particular, data mining techniques in the context of customer relationship management applied to boost SMEs development. In detail, we aim to analyse only open source tools because they are the most used by SMEs. The analysis also presents a brief review of the data mining techniques available and shows how they are practically employed in small companies, with particular attention to the Italian situation.

We choose to analyse only open source tools because they require no acquisition costs, have bigger flexibility and a faster renovation due to their extensive development community, and are robust enough for SME's needs. The analysis presents a brief review of the data mining techniques available and shows how they are practically employed in small companies. Then we also present an economical review of investments in data mining projects in Italy, which on one side outlines that, once used, data mining techniques can boost a company in the market, on the other side the awareness of data mining as a company asset is still not strong in Italian SMEs and most investments in Italy are still carried out by biggest companies (Cedrola et al., 2009).

The remainder of this paper is structured as follows: after a background of the techniques already presented in the literature regarding the information and communication technology market, the basic concepts of the data mining approaches are summarized into Section 3. Section 4 reports the applications of such data mining solutions into SME applications, by introducing the advantages coming from the use of Customer Relationship Management Services in improving these applications. This Section also provides a detailed discussion of the Italian market. The next Section 5 focuses the attention on a set of techniques that are used, alone, or combined with the Data Mining, in the information and communication technology area for the SMEs. A snapshot of the Italian situation is summarized in Section 6, while Section 7 concludes with some final remarks.

Literature Review

Data mining as a support to competitive advantage

Digital innovation is bringing a continuous change in the socio-economic logics that affect the processes of both SMEs and large companies (Sali, 2020), in contexts ranging from territorial realities to the international situation.

In this context, the information and communication technology market is a good marker of the economic trend, both national and international, highlighting in general a slowdown in traditional technologies on the one hand, and a continuous increase in new paradigms on the other, primarily the so-called innovation accelerators. Innovative technologies and services, of primary interest to businesses, embrace different processes and technological solutions ranging from data and information management and exploitation, including machine learning, big data, and Analytics solutions, to processes based on new architectures and cloud infrastructures, as well as processes related to the Internet of Things and the management of e-commerce services. The different contributions reported by the literature (Assintel, 2019; Ministry of

Economic Development, 2017; Rojas-Torre & Kshetri, 2019) highlight the main aspects considered in the definition and application of innovative solutions to different markets, according to specific situations and contexts.

Iqbal et al. (2018) present a qualitative research work regarding the use of big data to improve the overall management in SMEs, while an interesting comparative work related to the main data mining techniques applied for SME manufacturing is presented in (Packianather et al., 2017), and a survey on open-source data mining tools is reported by Almeida and Bernardino (2016).

A contribution showing the impact of the transformation from the more traditional use of information and communication technology to internet of things solutions is presented in (Abazi, 2016), where the authors explain in detail the influence of smart solutions to SMEs, while Jun et al. (2017) present a platform definition and integration to support smart solutions for SMEs. Moreover, another interesting approach highlights the versatility of the internet of things techniques, by describing a combined application of them with big data solutions for manufacturing industries (Mourtzis et al., 2016). In this topic, another interesting overview of big data for growth in SMEs is reported by Sen et al. (2016).

Another detailed work discussing the evolution of knowledge management into SMEs is reported by Alavi and Leidner (2001), in which three research questions have been identified, concerning the barriers hindering the spread of knowledge management practices in SMEs, the main Knowledge Management Systems (kMSs) adopted by SMEs, and the impact of the use of knowledge management practices on SME performance. In another work (Ghaderi & Fei, 2013), the proposed knowledge management application highlights two groups of SMEs: in the first one the business is for the most part capital-based, and it belongs to the capital intensive organizations; in the second one the business is, for the most part, knowledge-based, then belonging to knowledge-intensive organizations. Finally, a recent comparative analysis is available (Alavi & Leidner, 2001), here an empirical study has been carried out by comparing the international economical situation w.r.t. the improvement carried out by knowledge management activities. The qualitative side of this research is focused on observing existing SMEs and considering the big data literature (Landset et al., 2015; Sen et al., 2016) to offer in future research a new management system and innovative techniques.

As previously introduced and reported in the literature (Ngai et al., 2009), the information available to clients together with the information technology tools suitable for their management represents the basis on which the company's success strategies are mainly defined. With this trend, technologies such as data mining have opened a new era for customer relationship management, through which companies can gain competitive advantages. Data mining techniques are considered a leading customer relationship management tool that has been deeply influenced by advancements, more general in information technology applications, and in particular in the Digital Innovation area.

Until the last decade, much research has been carried out in the context of data mining in large companies (Hsu, 2009), while similar literature in SMEs has been very limited (Almeida & Berbardino, 2016; Linoff et al., 2004). The reason was mainly due to the lack of investments by the companies themselves, as well as the limited availability of information to access.

The ever-increasing growth of Digital Innovation technologies for companies has led them to move from product-oriented business strategies to those oriented towards customer relations (Marzo & Scarpino, 2016), with particular attention paid to service

improvement activities that lead to customer loyalty in different segments (Yang et al., 2011).

In recent years, not only large companies and multinationals but also SMEs have been exploiting customer relationship management technologies to increase long-term profitability. Several authors claim that customer retention is important for SMEs to cope with the limited availability of resources, such as (Chen & Popovich, 2003). On the other hand, Skaates and Seppänen (2002) also stress the importance of the role that customer relationship management activities acquire by contributing to the development of SMEs' competencies, while other authors stress precise customer segmentation and customer profiling and targeting (Gurău et al., 2003).

Despite the importance of data mining techniques to CRM, there is a dearth of literature in this area. According to the literature (Chen & Popovich, 2003; Ghaderi & Fei, 2013,), the implementation of data mining applications in customer relationship management follows an emerging trend among business organizations. Appropriate data mining tools, which are good at extracting and identifying useful information and knowledge from enormous customer databases, are one of the best supporting tools for making customer relationship management decisions (Berson et al., 1999). Consequently, the application of data mining techniques in CRM is worth pursuing in a customer-centric economy (Ngai et al., 2009).

The choice of the use of data mining Techniques in the definition and management of significant relationships and rules for the management of large amounts of data in a DB is supported in the literature by the increasing need of companies to define solutions able to extract and manage hidden knowledge within such data (Hui & Jha, 2000; Marbán et al., 2008; Witten et al., 1999).

The implementation of data mining applications to CRM follows an emerging trend among corporate organizations. In particular, appropriate data mining tools, able to extract and identify useful information and knowledge from huge customer databases, have become one of the best decision support tools in CRM techniques (Berson et al., 1999). Increasingly, national and global economies are paying more and more attention to the customers to whom they are addressed, putting in the foreground the desires and needs of the various customers. Ngai et al. (2009) present an interesting discussion on the application of data mining techniques in CRM.

An overview of data mining techniques

Starting from a general definition, data mining is the discovery process of relationships, patterns, and previously unknown and potentially useful information within large databases (Ali & Wasimi, 2009). A pattern indicates a structure, or, in general, a synthetic representation of data. Data mining can be defined as an analytical process, aimed at selecting and exploring models based on large quantities of data in the search for reports and information, in some cases unknown beforehand. This information can also be converted into commercial actions to obtain a business advantage.

In companies, data mining is often used to develop applications integrated into business decision-making processes, rather than studies of a single event or aspect, economic or business. Moreover, it allows for the integration of quantitative analysis and business knowledge. The schema reported in Figure 1 shows the rule assumed by data mining into a knowledge discovery from data process, together with the well known related functionalities (Fayyad et al., 1996; Luo, 2008).

Figure 1
Functionalities of a knowledge discovery from data process
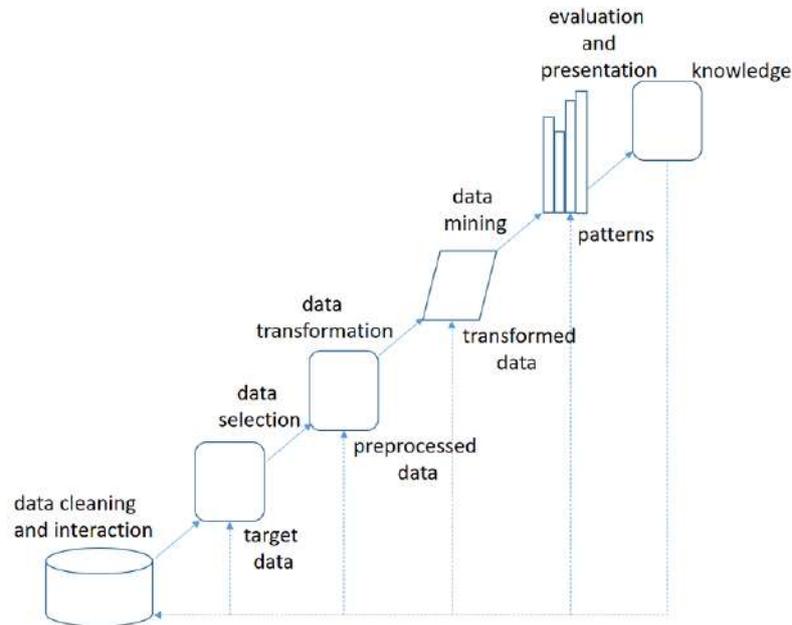
Source: Author's work (2020).

The multidisciplinary nature of data mining also allows the interaction between different technological solutions, including knowledge discovery techniques, extraction of information from Databases, statistical analysis techniques, as well as knowledge-based or self-learning systems. Indeed, statistical techniques help to check hypotheses using small random samples and sample sizes, whereas data mining automatically generates new hypotheses using an endless quantity of data. Artificial intelligence and machine learning are also used to analyse data.

Data mining presents several advantages, which can be summarized as follows: the processing of quantitative, qualitative, textual, image and sound data; a priori assumptions are not required; assumptions about the distributive form of the variables are not required; the processing of a large number of observations and variables; the implementation of optimized algorithms to minimize processing time; the simplicity of interpretation of the result; and the easy visualization of results.

The novelty offered by data mining tools is therefore based on the possibility of integrating (in companies where it is possible) decision-making processes with constructed rules, synthesizing high information assets (Ali & Wasimi, 2009). The results obtained with data mining tools must, therefore, be presented, communicated, and shared with the company areas to obtain high benefits, thus defining reticular collaborative models.

The main methodologies that can be implemented through data mining techniques (Calvello, 2020) are summarized in the following points: (i) exploration through multidimensional visualization (multidimensional scaling, logistic regression analysis, stepwise, match analysis); (ii) association & sequences (usually used in market basket analysis to measure product affinity); (iii) clustering activities (segmentation of customers into homogeneous groups); (iv) factorial analysis (to determine the number of factors to be extracted and for main components); (v) prediction models based on classification algorithms (e.g. decision trees and neural networks); (vi) learning

methods (e.g. kohonen maps and other unsupervised neural networks); and (vii) genetic algorithms.

Data mining techniques are oriented to business needs. Nowadays many processes in business are based on data. In such a context, Data mining helps to recognize trends and patterns to improve processes, develop business, and enjoy more success (Wanghualin, 2010). Examples of data mining applications are also represented in Figure 2.

Figure 2
Examples of data mining applications
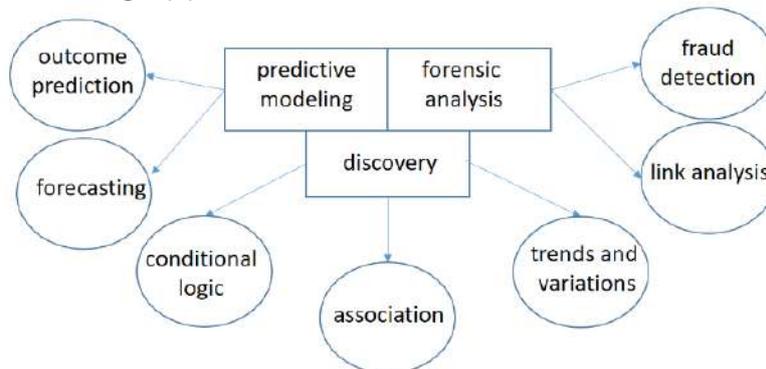
Source: Author's work (2020).

Enhancing the management of business information residing in large databases is one of the best-known objectives of data mining. However, the potential of the techniques, methodologies, and examples that are part of these methodologies go beyond simple data enhancement. Examples can be identified in:
- Clustering analysis, to identify target groups: in companies and in particular in business and marketing activities it is useful to segment (to the cluster) the database and provides a specific product or service to a given customers' selection. The different combinations of variables make the cluster analysis more or less selective according to the needs.
- Regression analysis is used for example in predictive marketing, where studies are conducted on changes, habits, customer satisfaction level, and other factors related to economic and financial parameters, such as the available budget, and so on.
- Classification analysis is often used by companies to detect spam, identify possible correlations between potential customers, as well as manage user classifications before and after certain senior events (e.g. advertising campaigns).
- Anomaly detection, to detect inconsistencies or anomalies, this methodology is widely used in both large companies and SMEs. It allows identifying anomalies, malfunctions, or inconsistencies concerning the database management and the data itself. They are often translated into machine learning and knowledge discovery algorithms.
- Intrusion detection, a methodology widely used for the management of intrusion detection problems, with particular attention to the problems of contamination of networks and companies databases.
- Association rule learning is widely used in the sales activities managed by the various companies to identify and manage the relationships between data,

particularly interesting for the marketing campaigns. Association rules techniques and association mining are examples of these methodologies.

- Decision trees are methodologies used for the optimization of project risk management; they are often used in cost/benefit analysis activities, widely used in risk analysis activities, and in the analysis of activities to be undertaken, schematized through tree graphs.
- Neural networks to automate learning, these methodologies allow to define learning algorithms, mainly related to the management of company data, and activities to be performed under certain conditions (pattern learning), to achieve certain objectives both within the company and aimed at the market and business activities.
- Rule induction includes methodologies developed to perform analysis on data of a company databases and to perform forecasting activities that will be carried out according to defined conditions. Examples of these situations are represented by all the activities related to the management of material purchases or product sales according to the markets to which a specific company is addressed.
- Finally, data warehousing for the big data section is a methodology that particularly concerns the profiling of customers, through the structured aggregation of their information, for the management of information extraction activities, consequent analysis, and decision-making activities in a given economic sector.

It is important to underline that data mining models do not use solutions that are defined better than others are, but each technique refers to certain objectives and data types to be analysed. Moreover, often the best results to transform data into information are obtained through a combination of different analysis techniques. From a general point of view, a data mining process can be summarized by a series of sequential steps, as shown in Figure 3.

Figure 3
Main Steps of a General data mining Process
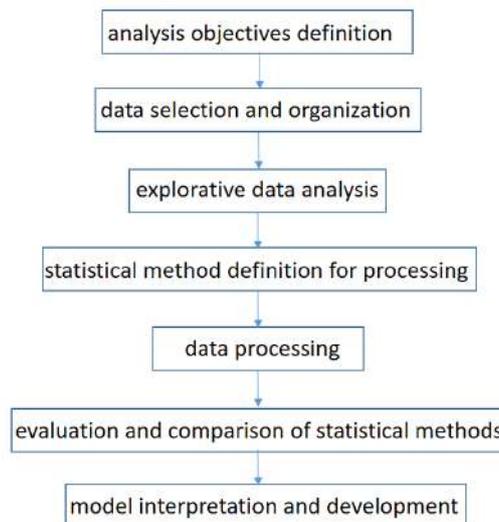
Source: Author's work (2020)

Data mining and SMEs

Data mining, considered as a component of the wider knowledge discovery process, allows identifying, in the information stored in a database, models, and relationships hidden in the data (Witten et al., 1999). However, the need to know the activities, to understand the data, or to be aware of general information as well as the statistical methods used remains unchanged.

Nevertheless, as presented in the literature by Rygielski et al. (2002), data mining tools make it possible to answer business questions that in the past took too long to pursue. Literature studies in this field have shown that the answer to these problems that companies still face today is the pivot on which CRM is still based (Thomsen & Pedersen, 2009; Wanghualin, 2010).

There are different techniques among data mining solutions, each with its advantages and challenges for different types of applications and for different types of companies and markets to which they refer.

Customer relationship management services

Rygielski et al. (2002) explain how customer relationship management represents a new application area where companies can gain a competitive advantage. Particularly, the application of data mining techniques allows the extraction of hidden predictive information from large databases, as well as the organizations, to identify valuable customers, predict future behaviours, and enable companies to make proactive knowledge-driven decisions.

As specified in the literature, CRM is defined by four main concepts: knowing, destining, selling, and serving (Coomar, 2020; Gurău et al., 2003). The focus then shifts from the product to the customer and the services it can benefit from, shifting market strategies from the outside to the inside. As the authors point out, CRM is based on the analysis conducted by the company towards its customers and the market to which it addresses, to define personalized offers, mainly aimed at customer loyalty, always through a series of services (customer care). Figure 4 reports the main services blocks adopted by a CRM system (as also reported by the literature (Stringfellow et al., 2004, Wanghualin, 2010), by showing the main activities carried out and their correlations.

Figure 4
Customer relationship management main services blocks

Source: Author's work (2020)

In this regard, companies mostly push their development of customer orientation by integrating CRM across the entire customer experience chain, leveraging technology to achieve real-time customer management, and constantly innovating their customer value proposition (Linoff & Berry, 2004). In this sense, data mining techniques are widely used in data analysis, knowledge extraction, and subsequent decision-making activities, based on the most attractive segmentations of the market.

Data mining and customer relationship management solutions in marketing

Data mining represents, in this field, a tool, widely used by companies, especially SMEs, in the definition and management of customer relations, to adopt increasingly a "customer-oriented" approach. This activity is fundamental for understanding the customer life cycle, because it relates directly to customer revenues and their profitability and because it allows highlighting the weak points of the customer-company relationship, to resolve where possible or reduce critical aspects.

Moreover, the customer's life cycle provides a good framework for the application of data mining, often by giving useful input information related to a specific customer (e.g. on habits), and at the same time by providing useful information on potential customer interests.

Companies report different examples of applications of data mining technologies. The most common in CRM are discovery and predictive modelling activities (Skaates & Seppänen, 2002). Examples are represented by:

- Retail, including activities of client segmentation through data acquired from store-branded credit cards. Examples of such analysis activities concern performing basket analysis, sales forecasting, handling of the behavioural marketing databases (e.g. cost-effective promotions), merchandise planning.
- Banking, including card marketing analysis, fraud detection applications, and predictive life-cycle management (examples consider data mining solutions that support banks by predicting customer's lifetime value).
- Telecommunication, comprising call detail record analysis, and customer loyalty, where the companies can use data mining to identify the characteristics of customers who are likely to remain loyal once they switch, thus enabling the companies to target their spending on customers who will produce the most profit.
- Different knowledge discovery applications.

Data mining techniques can support high amounts of data, of different nature, such as textual, numerical values, images, audio recordings, etc., by allowing analysis based on a high number of observations and by considering different and numerous variables, that comes from the continuous evolution of the market. These techniques can also be defined through algorithms, developed to address the critical aspects emerging from more traditional solutions, able to minimize, where possible, the computational effort, while ensuring results, even though locally optimal, and simple interpretations by customers. The graphical representation of these advantages is explained in Figure 5.

Figure 5
Advantages of data mining solutions in the context of SMEs
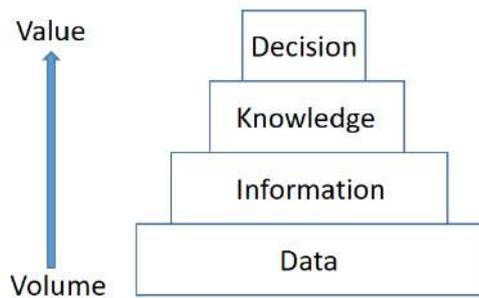
Source: Author's work (2020)

Information technologies and SMEs in Italy

Background

In the italian scenario, several companies associations have tried to capture and analyze how information and communication technology is changing the way companies organize their work. Among them the most important and widest survey has been provided by the Italian Association of information and communication technology companies (Assintel), handled by the International Data Corporation (IDC) (IDC, 2020). Their 2019 Report (Assintel, 2019) describes a wide and rich analysis of the actual Italian situation and it has been taken as a source of most of the numbers and concepts described.

A picture of the recent Italian situation highlighted by the Assintel report (Assintel, 2019) shows, on the one hand, a growth of the information technology market, with particular attention to the software and information technology services area, while on the other hand a decrease in investments in the telecommunications services market. According to experts, compared to the hardware market, software confirms that it is the main driver of growth in information technology spending in Italy, with an increase of +4.7% in 2018 and +5% in 2019 (Assintel, 2019).

The increase is mainly observed in application software, thanks in particular to the growth of investments in the company resource management and relationship management, collaboration, and content management applications (customer relationship management, collaborative, and content applications) markets. These markets have seen an increase in turnover by companies of +6.5% and +8% respectively over the last two years (Giornale delle PMI, 2019).

An increase in investments was also highlighted by the same report in the context of application development & deployment. In the latter case, it is above all the applications more closely linked to data management, analysis, and access (data access, analysis & delivery, and data mining software) that have enabled significant growth to be recorded. This trend, therefore, underlines the importance of data and its management for business success.

Moreover, regarding the objectives that Italian companies are pursuing through the digital transformation initiatives, another interesting focus concerning the CRM emerges in two areas: the improvement of the relationship with customers, in terms of increased customer experience and loyalty, and the improvement of automation levels and internal efficiency. While larger companies primarily pursue automation and internal efficiency objectives, micro companies are aiming in a way priority to improve the relationship with the client, which once again emerges as an area of strong focus by Italian companies. Impacts in the pursuit of this objective are evident in the strategies, processes, and services provided: the digitization initiatives aim,

indeed, to attract and retain customers, transforming in some cases the way products and services are created and presented, to renew interactions, through the adoption of an increasingly omni-channel approach, and in some cases to enable advanced analysis of customers and their behaviour (customer intelligence, behavioural analysis).

Critical outlook to the digital transformation in Italian SMEs

In agreement with the international trend, also in Italy, we can observe a growth towards a technological evolution that goes in the direction of the so-called "Digital Transformation" phase. There are scenarios in which investments are devoted to implementing solutions more aimed to define and improve knowledge management, such as cloud computing, social business, big data as well as machine learning solutions. This is demonstrated by examples of solutions recently considered in the investment plans of Italian companies, both large and SME, such as the so-called virtual reality augmented reality, robotics, 3D printing, internet of things, currently classified as innovation accelerators, since they represent technologies capable of innovating different processes, knowledge management, data management, and the market in general, showing themselves in a new and efficient way in the economies considered. This shifts the focus of Italian companies' investments from an approach oriented to the maintenance of existing infrastructure to solutions that concretely allow innovation and a more competitive market positioning. Activities such as archiving, knowledge management, and data analysis are the main challenges that also Italian companies have to face today and even more so in the coming years, mainly taking into account the global growth in data volume. It is therefore essential to have solutions capable of dynamically managing data and business knowledge (Corso et al., 2003). Italian companies are also increasingly moving towards the adoption of big data analytics and machine learning solutions, which registered a growth of 17% in 2019 (Assintel, 2019).

Nevertheless, despite the opportunities of internet of things, there are still few companies in Italy that are developing concrete projects. In fact, according to IDC (International Data Corporation) survey data, only a small percentage of companies are experimenting with internet of things, mainly through feasibility studies and pilot projects. Not surprisingly, micro and small enterprises are still in a phase of study and evaluation of the topic. Large enterprises are the most dynamic in this area and are positioned as those that seem to have a better understanding of the strategic impact of internet of things and are therefore carrying out pilot projects or real concrete activities. Another 14% of large enterprises are undertaking feasibility studies, followed by 7% of companies that are carrying out trials and pilot projects. On the other hand, 14% of large enterprises are in a phase of industrialization of the experiments carried out or are developing a concrete project (Corso et al., 2003). The main driving forces behind the implementation of internet of things projects are the possibility of improved productivity and competitiveness: Italian companies are beginning to become aware that internet of things technologies can help them to compete more effectively, reduce operating costs, increase productivity, innovate the offer and generate new sources of revenue, also reaching new customers and increasing the customer experience.

The sectors that more than others are working on concrete projects in internet of things are retail, mainly in the field of product testing and quality control, and public exercises, tourism, and reception, more oriented to behavioural analysis and projects in the field of customer interaction. Wholesale trade is mainly characterized by being in a phase of industrialization of experimentation and companies in the sector are

working on the management of the physical security of buildings, plants, and other assets. The Industry sector is in a phase of experimentation and pilot projects and this case, the areas explored are different: security of buildings, plants, and assets, efficient energy management and consumption monitoring, as well as logistics and fleet management, behavioural analysis, and customer interaction. The impacts of the internet of things in the industry sector are perhaps the most evident today and the National Enterprise Plan 4.0, is helping to encourage companies to invest in this type of solutions, which allow a renewal of production facilities, the convergence between physical and virtual production spaces, real-time monitoring of activities and the collection of strategic data directly from the field, for advanced analysis of strategic support to decision-making processes. In many cases, companies in the Industry sector are beginning to give internet of things strategic importance that can help them to compete more effectively in markets undergoing a profound transformation, through the launch of innovative products and services, and to reduce operating costs in some cases. Other sectors, such as public administration, health and education, and finance, are still in a feasibility study phase or have started some internet of things pilot projects. In these cases, we are mainly exploring the opportunities offered by the Internet of Things in the areas of building and plant security, energy management and consumption monitoring, and identification of staff and company staff.

Despite the experiments, pilot projects and some examples of concrete applications, there are still several obstacles to the full explosion of internet of things within the digitization strategies of Italian companies and among these, there are concerns about data security, privacy, and problems related to their management and analysis: in fact, it seems not yet clear how to extract real value from the amount of data collected through internet of things systems and applications to generate new business opportunities and enrich the products and services offered to customers. The other obstacles relate to a general lack of adequate economic resources to be allocated to investments in this area, in addition to security concerns: in this case, there are still several uncertainties regarding the most appropriate measures and technologies that companies should implement for the protection of hardware, software, and networks that underpin internet of things projects.

The perception of the role of information technology security has always been particularly problematic in Italy. The development of a specific culture requires a radical evolution in the understanding of the information technology risk that companies of all levels and levels face when they connect to a network. Only 19% of Italian companies consider information technology Security as a strategic investment to enable digital transformation models: there is some progression in the perception of information technology Security compared to the more recent past, but it is still a rather slow evolution, which mainly concerns medium and large enterprises (where the figure is over 45%). In fact, 35% of Italian companies consider security only as an additional cost item, like many others, within the budget, more and more articulated and complex, necessary for the management of the company information technology, and 32% consider it as a contingent and occasional cost, an expense to be faced once in a while, and then completely forget about the problem (especially among micro and small enterprises) (Sali, 2020).

The perception of security also characterizes the industrial sectors in distinct polarities: finance is the sector that believes more in the role of information technology security as an enabling technology to progress in the digital transformation field (almost 33% of the companies), while at the opposite extreme is the public administration, where almost 70% of the companies believe that security is only a contingent and entirely occasional expense (Assintel, 2019). It should be noted that

an evolved culture of security is particularly highlighted in the South and Islands despite other geographies (which are very often dominated by an entrepreneurial fabric characterized by small manufacturing companies, not always inclined to this type of expenditure). Consistent with the basic assumption that information technology security does not assume any strategic investment value, not even in a context now widely regulated by new laws and regulations such as the GDPR, the survey conducted by IDC (IDC, 2020) shows that Italian companies allocate only an extremely limited portion of the company's information technology budget to Security technologies: over 42% of companies dedicate up to 3%, 13% between 3 and 10%, only 2% above 10%.

Digital transformation in Italian SMEs supported by data mining

The progressive diffusion of digital transformation initiatives and projects in Italian companies is helping to outline an evolutionary framework in which both organizational structures and working methods change, as well as the physical environments and spaces within the companies themselves. The issue of Enterprise 4.0, supported also at government level with incentives of various kinds, from funding facilitations to tax relief measures, will contribute shortly to support the growth of companies that innovate their processes and supply system, thus promoting the development and use of digital technologies in a pervasive way. In this context, it will, be necessary to embrace a culture of innovation, providing for diversified research and development and training activities, but also to adopt advanced security policies and tools, capable of protecting systems, data, and information. These, in fact, already today must necessarily be accessible even outside the company perimeter to enable agile work policies and automation and innovation of processes, not only operational but also decision-making and strategic. Digitization is helping to change the way we work and redesign the physical and logical spaces of companies: in the era of Digital Transformation work activities are starting to be less tied to a physical location and rigid hours, but thanks to the possibility of accessing company resources and information from anywhere, the prospects of "agile" work are opening up for employees. In this context, for several years now, some companies and public bodies have been adopting policies that provide for the introduction of new and flexible measures to better reconcile work and private life; these initiatives are also promoted and regulated in many cases at the legislative level.

According to the research conducted by the International Data Corporation (IDC), more than half of the companies surveyed have launched at least one Smart Working initiative (IDC, 2020). The main activities implemented by companies are so far geared towards ensuring the possibility of working remotely (26% of companies) and enabling employees to work with mobile devices (22%). The sectors that stand out more than others for having adopted policies of this type are finance, wholesale, industry, transport, communications and utilities, and other services. The objectives of the projects and initiatives undertaken so far are aimed at ensuring greater flexibility and efficiency in work activities, with a greater emphasis on objective-based assessment and the possibility of a better balance between work and personal time. Thanks to initiatives of this kind, it is often necessary for companies to redesign physical spaces as well, for example by reducing fixed workstations and expanding shared workspaces, in addition to promoting the use of digital technologies by employees and strengthening systems for measuring and evaluating individual and collective performance. In this way, in addition to making staff more responsible, as the assessment is based more on professional objectives and is not limited to physical

presence in the office and rigid working hours, greater collaboration and sharing of activities among employees is enabled.

Moreover, following the research team of the Digital Innovation Observatory of the Politecnico of Milan, the Smart Working is defined as "a new management philosophy founded on a return to people being given flexibility and autonomy in choosing their spaces, their working times and the tools they use, against a backdrop of taking more of innovation in work models within a smart working perspective and for developing methodologies based upon a multi-disciplinary approach that can support decision-makers (information technology managers, CIOs, human resource managers, and facility managers) in public and private companies" (Smart Working Observatory, 2020).

Also by what reported by the same Italian Observatory, Smart Working represents an organizational phenomenon of growing interest in Italy, which is increasingly becoming an object of planning by organizations. The authors also refer that the number of smart workers, workers who enjoy flexibility and autonomy in the choice of time and place of work and who are equipped with digital tools suitable for working on the move, is constantly growing and today there are about 570 thousand. Currently, 24% of SMEs refer to this mode of work (Smart Working Observatory, 2020).

The Italian Observatory also shows that it is mainly medium-sized and large companies that adopt smart working policies, allowing remote working, and providing employees with the ability to work using mobile devices. Large enterprises - more than others - seem to understand the benefits of such policies (53% allow remote working) and are oriented towards the creation of digital workspace that tends to converge and integrate all the services that support business operations and processes, including communication and collaboration, as part of the digital evolution of physical work environments.

Soon, the digital workspace paradigm is expected to become more and more widespread, progressively replacing the traditional physical workstation paradigm:, thanks to the increasing use of digital communication platforms based on data mining technologies, as well as sharing tools and mobile terminals and applications, the possibility to work from anywhere, to be recognized and measured by systems by objectives, will be extended, by also promoting dialogue and collaboration between people, innovating processes and operating environments. Examples of these solutions are, even if partially, collected by the literature shows, in a wider context, interesting applications of data mining in for learning systems (Blagojević & Micić, 2013), internet of things systems (Alam et al., 2016; Lee & Lee, 2015) and Knowledge Management Systems (Alavi & Leidner, 2001; Kovalev et al., 2018; Luo, 2008), and more general open-source approaches in (Hsu, 2009; Landset et al., 2015; Thomsen & Pedersen, 2009).

The above-reported evolutions will also offer companies the opportunity to focus more on the company's activities and business, while also improving employee satisfaction, thanks to greater flexibility to reconcile work and private life. In a context in which the digital revolution will continue to impact the company's organization and markets, transforming them profoundly, collaboration platforms will become an important vehicle to build and spread knowledge among people and to stimulate and govern the circulation of ideas resulting from shared work.

Among the major innovations in the working environment, technologies that allow the automation of tasks and processes, which allow us to perform more or less complex tasks without the support of human beings, stand out: artificial intelligence and cognitive computing systems will represent the major evolution in this area. The topic is still emerging for Italian companies: according to the survey data, about 70%

do not foresee any impact on work or, in any case, a rather limited impact, due to the lack of skills and knowledge on the topic, but also for unclear "business cases" and legal issues related to data management. Despite this main orientation, a small percentage of companies (16%) already foresee positive and extended impacts for automation technologies on their processes to ensure greater efficiency and productivity of work activities. In the short term, the most significant developments in artificial intelligence and cognitive systems will be recorded in the field of customer service automation and conversational platforms, which are based on the analysis and understanding of natural language: these will allow the development of applications and systems capable of interacting, dialoguing and supporting both employees and customers of the company on certain support services, automating repetitive activities of varying complexity.

The evolution of this type of system will be characterized by a greater capacity to adapt to different processes, able to adapt through the formulation of hypotheses, and to improve through continuous interaction with users. Artificial intelligence and cognitive computing systems are also beginning to be used for the automation of security activities (for example, in the threat intelligence and prevention system field) and in production and distribution processes, thanks to applications in predictive maintenance and intelligent automation field. The drivers that will guide the progressive expansion of this type of systems and technologies are the possibility to receive accurate forecasts, based on advanced analytical models and algorithms, strategic recommendations on decisions and actions to be taken to optimize and improve processes and operations, and a better knowledge of customers and new ways of interaction. Despite the positive impacts that artificial intelligence and cognitive computing systems can have in companies, there is a small share of reality that highlights how there are also resistance and critical issues related to these technologies: 13% of companies that participated in the survey say they perceive negative impacts related to work automation technologies, mainly due to resistance from employees. In this case, we refer to concerns about the possible replacement of human beings in the performance of activities, especially the simplest and most repetitive ones. Another area that is experiencing significant growth among Italian companies is that of connected objects, i.e. the Internet of Things: through the implementation of connected devices and platforms and thanks to the growing development of support applications companies are experimenting with the opportunities that this type of technology can offer, both in the field of innovation and process efficiency and in the innovation of products and services.

Moreover, digital innovation and data mining can become key drivers for the productivity and performance of SMEs, helping them to compete in a market that will be increasingly interconnected and digitally driven. According to the work carried out by researchers of the Digital Innovation Observatory in SMEs of Politecnico di Milan (Sali, 2020), today, there are about 200 thousand SMEs in the Italian market, and although numerically they represent only 5% of the entrepreneurial fabric, they represent an important slice of the Italian market: they alone generate 41% of the entire turnover and 38% of the added value.

In this context, the analysis of the data is also of particular interest to SMEs, which, according to a published contribution of the editorial staff of the Italian SMEs Journal (Giornale delle PMI, 2019) in 62% of cases have made investments in 2019, mainly focused on the definition and implementation of technological solutions in the integration of internal data (80%), basic training on data analysis for resources already present in the company (66%), integration of data from external sources (57%) and the development of predictive analysis projects (four out of ten, +10%). The main

objectives of the investments appear, according to the authors, to be the integration of data mining with digital innovation solutions for the optimization of the supply chain, particularly in manufacturing, the analysis of the competitive environment, and the need to increase the effectiveness of marketing campaigns. Among the companies that have implemented such projects, the results are perceived as highly innovative in 29% of cases. 40% of the sample developed advanced analysis projects, at least predictive, usually relying on external expertise. 18% show good maturity in the development of descriptive analysis and integration of internal data and are also working on the integration of external data, as well as showing interest in employee training (six out of ten have implemented data analysis training plans). 4% is only focusing on investments in internal data integration, while 38% have not initiated any initiatives or investments and do not perceive the benefits of Analytics projects.

Moving the analysis to skills, the distance from large enterprises is widening: only 16% of SMEs have at least one Data Scientist and just over one in five (23%) at least one Data Analyst. Not far away are the numbers of medium-sized enterprises alone, where the Data Analyst is present in one in three companies. In companies that have taken on Data Science profiles, the results of the projects are perceived as very innovative in 40% of the cases, compared to 21% of companies that use only external collaborators.

Conclusion

In this paper an analysis of the impact of digitalization, and in particular, data mining techniques in the context of CRM applied to boost SMEs development is presented. We analyse only open source tools because they are the most used by SMEs. The analysis presents a brief review of the data mining techniques available and shows how they are practically employed in small companies. Then we also present an economical review of investments in data mining projects in Italy, which on one side outlines that, once used, data mining techniques can boost a company in the market, on the other side the awareness of data mining as a company asset is still not strong in Italian SMEs and most investments in Italy are still carried out by biggest companies.

This aspect is underlined by the fact that, basically, Italian companies see data mining and, more generally, machine learning, as a carrier of innovation and optimization inside the organization and outside, to provide new services and products, but they are still very "prudent" in the investments, due to a difficulty to find personnel with the right skills both internally and in the recruitment market. Moreover, the perception of the role of information technology Security has always been particularly problematic in Italy. The development of a specific culture requires a radical evolution in the understanding of the information technology risk that companies of all levels face when they connect to a network. Only 19% of Italian companies consider information technology Security as a strategic investment to enable Digital Transformation models, and this slows down the rate of Italy changes.

The presented snapshot of the Italian market shows how digital innovation is pushing socio-economic logics to an unstoppable change in Italy, with a transformative approach that requires new personal attitudes, inside processes, inside every single enterprise, in territorial and regional contexts and aggregations, and so on up to the Country System.

Differently, from previous research, this paper aims to outline the contribution, both technological and economical, that data mining provides to the development of the Italian small and medium companies, which are still the core of the Italian market.

This contribution highlights how one of the most important advantages, coming from the application of data mining tools, is based on the possibility of integrating (in

companies where it is possible) decision-making processes with constructed rules, synthesizing high information assets. This information can be further converted into commercial actions to obtain a business advantage. In this field, data mining represents, then, a tool, widely used by companies, especially SMEs, in the definition and management of customer relations, to adopt increasingly a customer-oriented approach. Consequently, the application of data mining techniques in customer relationship management is worth pursuing in a customer-centric economy.

Interesting possible future works in this direction could concern the analysis of the development of technologies based on data mining in Italian SMEs, with a comparison with the previous situation they occupied in the Italian and international market. Further studies could also interest the new emerging technological solutions in the economic market, which increasingly play a valuable role in the business.

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About the authors

Amir Topalović received his Master Degree in Finance and Risk Management at the University of Parma and he is actually a PhD student in Business and Administration at the University of Sarajevo under the supervision of Prof. Nijaz Bajgoric. His thesis title is "A TOE based Study on Data Mining employment in Italian Small and Medium Enterprises". Currently, he is CEO at C2T, Consortium for the Technology Transfer, and his research interests are related to data mining in corporate and banking data. The author can be contacted at **amir.topalovic@consorzioc2t.it**

Antonia Azzini is an ICT researcher and innovation manager at Consortium for Tehcnolgy Transfer C2T. With a PhD in Computer Science at the University of Milan, and a long experience as PostDoc at the Computer Science Department of the University of Milan, she is responsible of the cooperation with universities and other research centres. She is member of the Editorial Board of IJKL Journal, and she is a member of the IFIP 2.6 Working Group on Databases. The author can be contacted at **antonia.azzini@consorzioc2t.it.**

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Intelligent Personal Assistant in Business-Context: Key-feature Evaluation for User Acceptance

Daniel Hüsson
UCAM - Catholic University of Murcia, Spain
Alexander Holland
FOM University of Applied Sciences Essen, Germany
Rocío Arteaga Sánchez
UCAM - Catholic University of Murcia, Spain

Abstract

Background: The usage of intelligent personal assistants (IPA), such as Amazon Alexa or Google Assistant is increasing significantly, and voice-interaction is relevant for workflows in a business context. **Objectives:** This research aims to determine IPA characteristics to evaluate the usefulness of specific functions in a simulated production system of an Enterprise Resource Planning (ERP) software. A new function called explanation-mode is introduced to the scientific community and business world. **Methods/Approach:** As part of a design science research, an artefact, i.e. an add-on for speech-interaction in business software, was developed and evaluated using a survey among ERP users and researchers. **Results:** In the area of IPA-features, the search-function and speech input for textual fields were recognised as most useful. The newly introduced feature, the explanation mode, was positively received too. There is no significant correlation between the usefulness of features and participant-characteristics, affinity to technology or previous experience with IPAs in a private context, which is in line with previous studies in the private environment leading to the conclusion that the task attraction is the most important element for usefulness. **Conclusions:** Most of the participants agreed that the speech-input is not able to fully substitute standard input devices, such as a keyboard or a mouse, so the IPA is recognised as an addition to traditional input methods. The usefulness is rated high especially for speech-input for long text fields, calling up masks and search-functions.

Keywords: intelligent personal assistant, human-computer-interface, enterprise-resource-planning, machine learning, business process, natural language processing
JEL classification: O3, O31, O32, O33

Introduction

With intelligent personal assistants (IPA) like Amazon Alexa or Google Assistant, a new area of user-interaction has approached, superseding the user-input by keyboard, mouse and touchscreen with control systems by voice commands, starting workflows and guide the user through complex processes and decision making via speech synthesis (Doss et al., 2018). Influenced by the experience in the private use of IPA functions, users are looking for equivalent comfort in business applications to control processes, resulting in an increasing number of IPA users in the business environment (Budzinski et al., 2018; Saran, 2018). For instance, Amazon initiates Alexa for business issues by integrating Microsoft Office 365 to access and control the scheduler via voice control (Amazon, 2019). Enabled by improvements in artificial intelligence, tools are able to foster better interaction between human and machine, but the main indicators for continued use and satisfying user experience are not discovered well enough (Yang & Lee, 2019).

Previous researches set the focus on private (Cowan et al., 2017) or educational (Babicet al., 2018) use of IPAs, also the specific use of certain IPA features and the satisfaction rate have been examined (Lopatovska et al., 2019), but there is no research investigation concerning the usage and recommendation of IPA-features in a business context, leading to a need to identify relevant features in the context mentioned above. From this the main research question of this article is derived: "Which specific AI-features in the field of IPA are being recognised as applicable in a business context?"

In order to contribute to this question and underlying research gap, the purpose of the paper is to analyse specific use-cases and work out which features can benefit from an IPA-Implementation to cover existing weak points in process flows in terms of usability, especially in navigation, information overload and lack of system communicativeness derived from the literature (Lambeck et al., 2014a, 2014b; Wong et al. 2016). This article also addresses the findings from previous researches regarding challenges of ERP-implementation in terms of general usability, resulting in a high need of user training to enable users to manage the system (ElFarmawi, 2019) and the impact of data on decision making (Potančok, 2019).

To analyse the specific user-requirements and the acceptance of speech-workflows in business context a prototype for an IPA was developed and implemented in a state of the art web-based ERP system as an additional module (Hüsson & Holland, 2019a). The prototype was named V-IP-A and is fully web-based, for easy distribution and evaluation, with less installation complexity. The only necessary precondition is the usage of the browser chrome, due to the ready-to-use speech-framework web speech API (WSA) introduced by the W3C Community in 2012 (Shires & Jägenstedt, 2018; Wedekind, 2018).

As part of a design science research approach, the artifact was introduced, applied and discussed with the academic community in different national and international conferences (Hüsson, 2019a; Hüsson & Holland, 2019a, 2019b). Feedback from the conferences helped to narrow the scope of the research project and working out key indicators for user acceptance and relevant features. In order to close the gap to the business context, the artifact was also introduced to a professional audience during a business summit in September 2019 in Krefeld, Germany (Hüsson, 2019b). Based on the artifact an evaluation method for features and user-acceptance was derived and discussed (Hüsson & Holland, 2019b).

Due to the feedback from the academic and business fields, a new version 1.1 of the artifact was developed including the functionality to enter notes by voice input – which was requested as the most useful feature by business users (Hüsson, 2019b, 24),

and a corresponding version of the questionnaire was created and provided to experienced ERP system-users. The participants got access to the IPA-artifact and were enabled to work with the IPA in an ERP-environment to gather insights into the usage in a simulated productive system. The questionnaire was sent to 500 ERP system-users and researchers in different user-levels and departments.

This article contains novel theoretical and practical contributions. On one hand, the authors adapt and develop IPA-features in a business context based on existing research gaps. This paper contributes new insights to the existing literature by introducing a new user-experience-item called explanation-mode to IPAs in a business context extending the level of interaction between the user and the ERP system. In addition, the authors are verifying findings from studies in the private environment regarding main drivers for usefulness of IPA according to the task attraction. On the other hand, this article provides an empirical analysis of the usefulness and user-acceptance of the implemented features of IPAs in the business context based on a fully functional prototype.

In the next section, the authors presents the theoretical framework. The third section describes the research method and presents the data analysis as well as the results. Then, the paper discusses the results and, finally, conclusions are presented.

Literature review

Based on fundament literature research speech recognition is the result of almost 70 years of research starting in the early 1950s by understanding digits of the ten-digit series (Davis et al., 1952) paving the way for conversational agent, that started in the 2010s, when the first IPAs like Cortana or Alexa were introduced to the market (Yang & Lee, 2019). Due to the complexity of languages and individual pronunciation, much research was needed to leverage speech recognition from the recognition of single numbers to whole sentences and to interact with users via speech synthesis, which in turn enabled intelligent dialogue systems such as Siri or Alexa (Juang & Rabiner, 2004; Knote et al., 2019). Automatic speech recognition in combination with speech synthesis enables a wide range of opportunities in interacting with the user, but actually, the main tasks fulfilled by IPAs are simple information retrievals or service executions in a private context, such as setting a timer, playing songs, readings news or controlling smart devices (Gnewuch et al., 2017; Knote et al., 2019; Yang & Lee, 2019). As stated in the introduction the personal use of IPAs is already affecting the demands in business contexts, leading to a necessity to understand what type of tasks can be supported by IPAs and what are the key indicators for valuable features and high user acceptance. The literature usually addresses two groups of challenges to determine the acceptance of an IPA (Sarikaya, 2017):

1. User experience challenges such as operational errors, lack of competence and privacy and security concerns
2. Technical challenges like experience scaling, speech-recognition challenges, language understanding and different devices.

In related studies, five fundamental objectives for maximizing the value of IPAs were discovered: efficiency, convenience, ease of use, enjoyment and reduced cognitive effort (Rzepka, 2019). Other researches in the field of para-social relationships found that the most important construct for user satisfaction is task attraction, indicating the user's perception of an IPA to complete given tasks as a reliable work partner (Han & Yang, 2018). On the other hand, researches in the field of user acceptance in ERP systems are pointing out significant issues in terms of usability, especially in navigation, information overload and lack of system communicativeness (Lambeck et al., 2014a, 2014b; Wong et al., 2016). Since most of the IPA studies are working on theoretical

background and focusing on the private use of IPAs it is important to investigate the user interaction and impact on usability in real-world business scenarios to get a full picture of the IPAs potential to solve user interface issues in ERP systems.

Methodology

As mentioned in the introduction, this study is part of a design science research project investigating the impact of artificial intelligence on business processes in SMEs. The prototype is designed as an artifact in the field of action design research (Sein et al., 2011) connecting the business requirements regarding the usability of an ERP system with the academic requirements of an output of design ensembles that contribute to the know-how for developing specific artifacts (Peffers et al., 2018). Previous studies discovered that perceived usefulness is one of the most important extrinsic and utilitarian values (Hsu et al., 2014; Kalinic & Marinkovic, 2016). Especially when it comes to modern technologies such as smartphones or mobile applications, the perceived usefulness and necessity is strongly influencing the usage intention (Park & Chen, 2007; Mohd Suki & Mohd Suki, 2017). Beside usefulness, the perceived enjoyment is also recognized as an intrinsic motivation for adopting technology products (Venkatesh, 2000; Yang et al., 2016). Since the focus of this study is the business use of IPAs and prior research in the area of personal assistants underpins the importance of usefulness over enjoyment (Yang & Lee, 2019), the main emphasis was set to evaluate the most useful features of the IPA and to get suggestions for not yet implemented features with a high level of usefulness.

Artifact development

For the purpose of evaluation, the prototype of an IPA was fully integrated into a web-based ERP-system and can be activated with a button, as presented in Figure 1. By using a button instead of a hot-word-detection like "Alexa" or "OK Google" the security concerns regarding privacy (Manikonda et al., 2017) can be reduced because the IPA does not have to listen continuously for a hot word detection.

Figure 2 illustrates the system architecture focussed on the interaction between users, WSA and ERP-components (Vemas.NextGen), working out the different elements to transfer information and respond to the user command.

By combining voice input and output with a display, the full range of audio- and visual interaction can be provided, levelling up the user experience and the way ERP systems can interact with users (Nishimura et al., 2018; Saran, 2018). Contributing to the usage-pattern in private context as worked out in the previous chapter, the IPA supports short commands for information retrieval and task execution. During the development of the voice assistant, guidelines (Murad et al., 2018, 2019) were taken into account, to create a state-of-the-art user experience to reduce the risks and training cost for ERP-implementations (ElFarmawi, 2019). Table 1 gives a brief summary of the IPAs functions for user-interaction, derived from the research based on detailed and previously mentioned literature research, feedback of conferences and business-summit participants as explained later in this chapter.

Figure 1
Start screen intelligent personal assistant
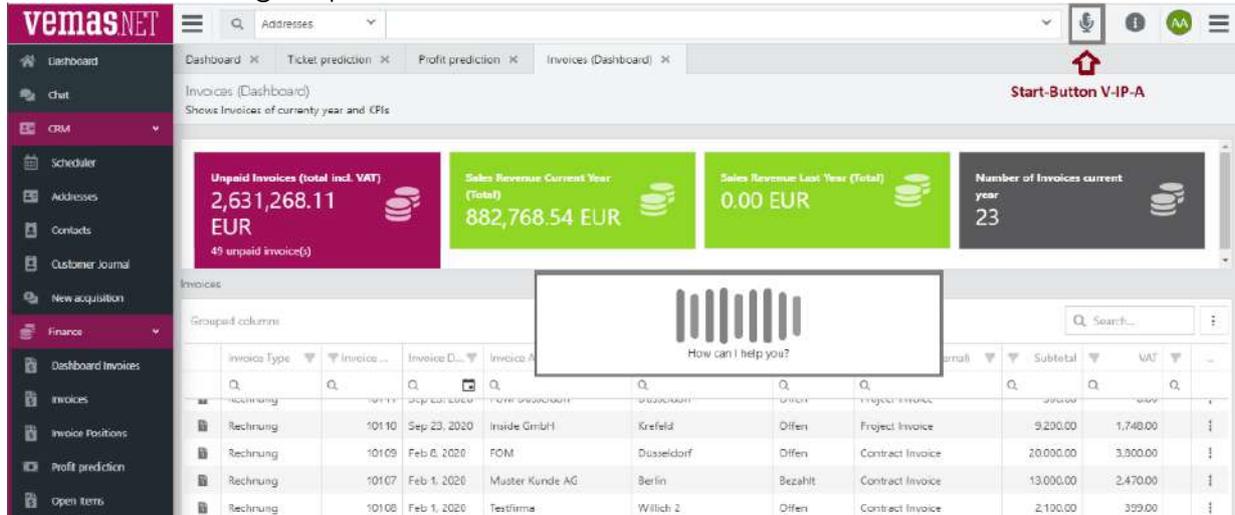
Source: Authors' work

Figure 2
System architecture of V-IP-A and interaction flow
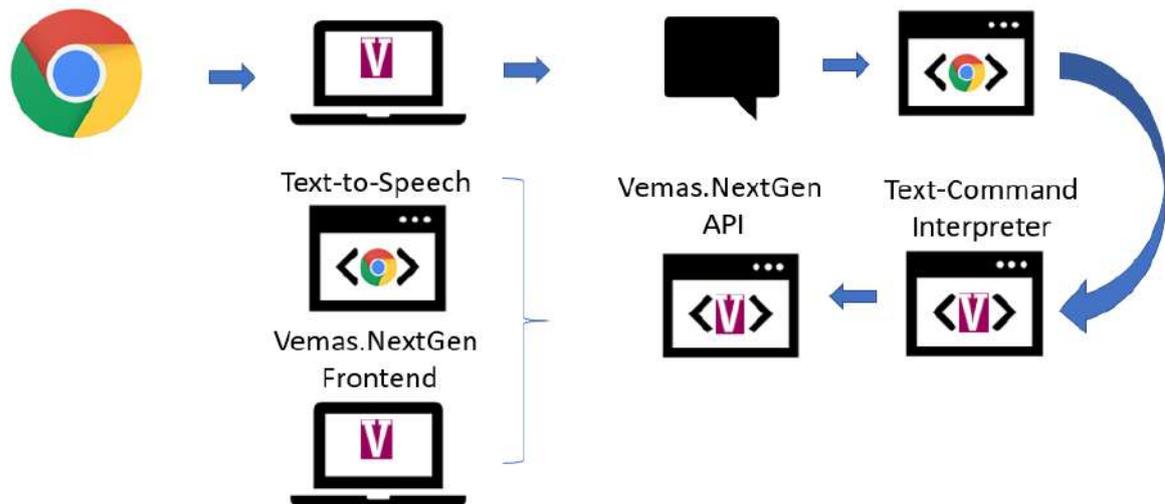
Source: Authors' work

Based on these functions, a set of commands was implemented to fulfil tasks within the ERP system. The chosen and implemented features were suggested by ERP-experts and ERP system-users and discussed with researchers and key-users during conferences (FOM Data Science February 2019 Düsseldorf Germany, 10th Conference Professional Knowledge Management March 2019 Potsdam Germany and 32nd Bled eConference – Humanizing Technology for a Sustainable Society June 2019 Bled Slovenia) and a business summit (Vemas.Inside September 2019 Krefeld, Germany). Based on this feedback the prototype has been developed until a final draft for the evaluation was deployed.

Table 1
Functional overview IPA

No.	Function	Description
1	Speech-Commands	Analysing speech for keywords to trigger actions like opening a specific form or report. The speech must be divided into commands and parameter for the command. **Limitation**: Only one command at a time, the commands are predefined and addressable by keywords, but extendable by add-ons. Recognizing the personal name, e.g. for searching for a company or contact person are not in focus for this stage of the prototype.
2	Speech-User-Interaction	The IPA should give a voice-feedback in the context of the triggered command and request missing parameters to fulfil the command.
3	Explanation-Mode	The IPA should be able to cluster data, label and rate KPIs and give a brief summary of the data, which are displayed as a chart and explain the main points to the user via speech synthesis. **Limitation**: The type of report is already known, and the data-content is classified by a configuration. Query Detail-Information for a specific cluster is not supported.

Source: Authors' work

Artifact features

For information retrieval, the user can ask the system for a brief summary (Feature set F1), triggered by one of the defined keywords *"briefing"* or *"summary"* the system matches the briefing-command and starts gathering information, such as notes to customers written by other ERP system-users. For example, a note created by the fictitious user Melanie Becker on 8th February 2020 at a fictitious customer FOM Düsseldorf will be read out like that:

"Note by Melanie Becker on February 8, 2020, 01:42 p.m. at FOM Düsseldorf.
Contact person: Mr Rüdiger Buchkremer.
Subject: Interest in ERP-system.
Content: The director of the Institute for IT Management and Digitization Prof. Dr Buchkremer called and requested information on the ERP system."

Important details are submitted via speech-synthesis, to get a brief summary about relevant information about interests and customers. As an example for task execution, a command for creating notes was implemented (Feature set F2). Triggered by the keyword "create note", followed by a company name, the ERP system starts to search for the company, opens the note-formula and listens to the user's voice to gather the content of the note via speech-to-text. In addition to simple workflows, a complex command-setup was implemented for information retrieval and user-interaction using the explanation mode of the IPA. Triggered by the keywords "current situation" the IPA presents a graphic report (see Figure 3), showing the profit margin of the company and starts to explain the figures including a preconfigured interpretation of the value ranges for relevant key performance indicators (Feature set F3).

Figure 3
Report contribution margin
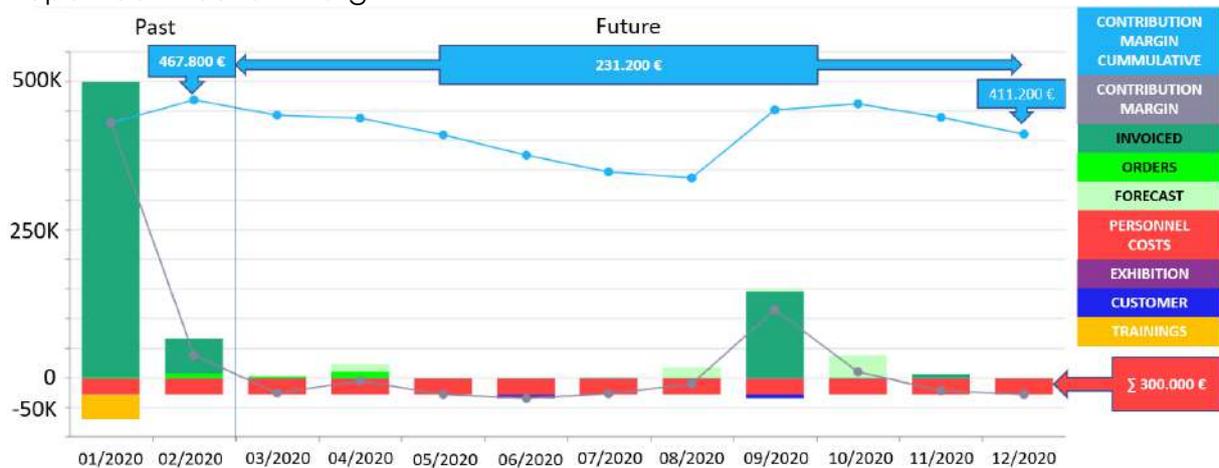
Source: Authors' work

Via speech synthesis, the system will read out the following information and highlight important coordinate points in the chart to attract the user's attention.

"The current situation of the company is as follows: In the past, January until February 2020 approx. 467.800 € as contribution margin. For the future March to December 2020, about 231.200 € are expected as contribution margin. For the entire period, January to December 2020 is the expected contribution margin approx. 411,200 €. The contribution margin is higher than the shareholder expectations. The highest costs are caused by personnel costs: 300.000 €. Personnel costs are below the planned budget."

The user is also able to comprehend the summary with a drill-down triggered by the command "show me details for", followed by the name of the month, e.g. January. The IPA shows a grid with detailed information about the costs and revenues in the requested date span as presented in Figure 4 and retrieves more details about the background of the displayed report. With these details, the user can gain deep insights of the revenue- and cost structure of the company, for example, the level of personnel costs (highlighted red) or very profitable projects (highlighted green).

This feature enables the user for data-driven decisions in combination with their own intuition leading to data-informed decision making (Potančok, 2019). Since this research direction is still new, it is necessary to be noted that business intelligence (BI) on its own is not able to increase the organisation's performance, but the combination of BI and business process management - when both are aligned - are giving a business value (Suša Vugec et al., 2020).

Figure 4
Drill-Down function for details on period January 2020

PERIOD	TYPE	REFERENCE	PROCEEDS	COSTS	CONTRIBUTION MARING
01/2020	INVOICED	PO#: 10000	435.000 €	5.000 €	430.00 €
01/2020	INVOICED	PO#: 20000	15.000 €	5.000 €	10.000 €
01/2020	INVOICED	PO#: 30000	50.000 €	10.000 €	40.000 €
01/2020	PERSONELL COSTS	TEAM 1		15.000 €	- 15.000 €
01/2020	PERSONELL COSTS	TEAM 2		10.000 €	- 10.000 €
01/2020	TRAININGS	TEAM 2		30.000 €	- 30.000 €
Σ			500.000 €	175.000 €	425.00 €

Source: Authors' work

Artifact evaluation

The main research design has been discussed in the course of a scientific conference (Hüsson & Holland, 2019b). To evaluate the IPA-artifact a questionnaire is derived from the implemented features enabling the participant to rate the usefulness of single features according to a four-point Likert scale ranged from strongly agree to strongly disagree (Lozano et al., 2008). Since there is no neutral answer-option the participants have to decide whether they agree or disagree with the usefulness of a feature (Nowlis et al., 2002). The authors choose this option to get a clear positive or negative rating of the specific feature regarding the usefulness. For each feature-set, the participant was able to give a separate free text written feedback in a comment-section.

The questionnaire for feature evaluation was online available from 15.11.2019 till 31.01.2020. The link was sent to 400 ERP system-users from an internal mailing list and 100 users with research-background. The questionnaire provided a link to a video with a brief description of the IPAs-features and a link for direct access to the demo-environment for an individual experience of the IPA in a simulated production system.

The survey was structured in three parts:
1. Demographic characteristics like gender and job information
2. Characteristics in experience with technology (IPA and ERP)
3. feature-rating and comments

The independent variables have to be derived from researches in the field of private use of IPAs (Jiang et al., 2015; Kiseleva et al., 2016; Han & Yang, 2018; Yang & Lee, 2019) based on missing comparable business studies of IPA the existing findings have to extend the business perspective. The supposed dependent variables must be derived based on technical framework recommendations (Zhou, 2016) in combination with feature-ratings in a private context and business needs (Saad et al., 2017). On the other hand, the main goal of the survey is to identify the most useful features to get a solid foundation for further improvements of the artifact in order to contribute to the rigour cycle of the design science research. Since previous studies identified the task attraction as the main driver for usefulness and continues intention in private use (Han & Yang, 2018; Lopatovska et al., 2019), the expectation for the outcome is a not significant correlation in a business context too. To approve the

expected outcome the correlations will be analysed in the result chapter with the aid of a correlation matrix.

Table 2
Characteristics and theoretical foundation

Characteristics	theoretical foundation
Gender (GQ1), Age (GQ2)	*Comparable study (Han & Yang, 2018)*
Personnel responsibility (GQ3)	*Derived from occupation (Han & Yang, 2018)*
Job position (GQ4)	*Comparable study (Luger & Sellen, 2016)*
Industry (GQ5)	*Comparable study (Lambeck et al., 2014b)*
Experience with Voice-Assistants (GQ6)	*Derived from technology expertise (McLean & Osei-Frimpong, 2019) and Experience (Brill et al., 2019)*
Open for new technology (GQ7)	*Derived from study of attitudes towards technology (Edison & Geissler, 2003) and technology optimism from comparable study (Kowalczuk, 2018)*
Participant type (GQ8)	*Comparable study (Kiseleva et al., 2016)*
Experience with ERP systems (GQ9)	*Derived from technology expertise (McLean & Osei-Frimpong, 2019)*
ERP system (GQ10)	*Comparable study (Lambeck, et al., 2014b)*
Current tasks will change in future due to new technology (GQ11)	*Derived from studies about the impact of technology on the future of work (Betz et al., 2019; Kaplan & Haenlein, 2019)*
Percentage of repetitive activities (GQ12)	*Derived from GQ11 as an indicator for automation potential and a mediator for impact on current tasks, since repetitive activities have a higher risk of automation (Grace et al., 2018).*

Source: Authors' work

Table 3
Feature sets and theoretical foundation

Feature set	theoretical foundation
Summary-Function (Feature set F1) *Gives a short summary of the information of the day recorded in the system*	*Information retrieval derived from comparable studies (Iannizzotto et al., 2018; Ammari et al., 2019)*
Entry-Function (Feature set F2) *Open masks and enter content via voice input*	*Derived from functions like calendar entries and chatbots (Jain et al., 2018; Lang et al., 2018; Kaplan & Haenlein, 2019)*
Explanation-Function for reports (Feature set 3) *Explains components of reports and evaluates key figures via voice output*	*Derived from a study in the field of data analysis (Collins et al., 2018)*
Other Features (Feature set 4) *Additional not yet fully implemented features: worktime recording, search and prediction*	*Derived from function suggestions (Zhou, 2016)*

Source: Authors' work

To avoid missing values the structure of the questionnaire does not allow empty answers for important items. Out of the 500 possible participants, more than 10% of respondents successfully completed the survey, resulting in a total of 66 respondents. Due to the complexity of the survey and the required ERP-knowledge in combination with IPA experience to judge the usefulness of the features a respondent rate of 13,2

% can be regarded as sufficient for a meaningful analysis (Delİce, 2010; Fosnacht et al., 2017).

Results

The sample characteristics as worked out in Table 2 and 3 are now displayed in relation to the sample in Table 4 and 5. The evaluation shows that more than 90% of the participants have experiences with ERP systems and approximately 80% have experience with voice-assistants. More than 74% watched the tutorial video and roughly 35% tried out the artifact in a simulated production system. More than 92% of all participants expect, that new technologies (Compare Sum of percentage in GQ11 in Table 5) will have an impact on their work tasks. This result aligns with other research results (Baccala et al., 2018; Betz et al., 2019), but surprisingly even participants with a low proportion of repetitive activities (23 participants with less than 20%), agree or partially agree, that their work will be affected, only one participant in this characteristic answered with rather not true.

Table 4
Demographic characteristics

Characteristics	Respondents (n=66)	
	Number	Percentage
Gender (GQ1)		
Male	46	69,70
Female	20	30,30
Age (GQ2)		
18-25	6	9,09
26-35	26	39,39
36-45	12	18,18
46-55	15	22,73
>55	7	10,61
Personnel responsibility (GQ3)		
Yes	31	46,97
No	35	53,03
Job position (GQ4)		
Assistance	1	1,52
Clerk / Employee	25	37,88
Executive employee / team leader	10	15,15
Head of department	8	12,12
Management	4	6,06
No Answer	18	27,27
Industry (GQ5)		
IT	30	45,45
Service	16	24,24
Others	20	30,30

Source: Authors' work

The demographic characteristics presented in Table 4 are in line with previous researches, stating that the IPA market is in an early stage (Han & Yang, 2018) and attracting early adopters which are usually younger (Everett, 1995) and new technology attracts more male than female participants (Dobscha, 2003; Kotzé et al., 2016). The importance of the attitude towards technology is also underpinned by the result of the survey, all participants agreed or partially agreed, that they are open for new technologies (GQ7).

Table 5
IT experience of respondents

Characteristics	Respondents (n=66)	
	Number	Percentage
Experience with Voice-Assistants (GQ6)		
Yes	54	81,82
No	12	18,18
Open for new technology (GQ7)		
I agree	53	80,30
I partially agree	13	19,70
Participant type (GQ8)		
Watched the video and tried the IPA	17	25,76
Tried the IPA only	7	10,61
Watched the video only	32	48,48
Either watched or tried the IPA	10	15,15
Experience with ERP systems (GQ9)		
User	12	18,18
User with advanced knowledge	11	16,67
Key-User (expert for process areas)	7	10,61
Administrator (expert for configuration)	7	10,61
Key-User and Administrator	15	22,73
No Experience	6	9,09
ERP system (GQ10)		
Vemas.NET	39	59,09
SAP	10	15,15
None	10	15,15
Microsoft Dynamics	3	4,55
Others	16	24,24
Current tasks will change in future due to new technology (GQ11)		
I agree	39	59,09
I partially agree	22	33,33
Rather not true	4	6,06
I disagree	1	1,52
Percentage of repetitive activities (GQ12)		
< 20 %	23	34,84
…between 20 %and 50 %	37	56,06
>50 %	6	9,09

Source: Authors' work

Based on their personal impression of the IPA the participants rated the features regarding the usefulness and had the opportunity to vote for further features. The results are presented in Table 6.

With 87,9% positive votes (I agree or I partially agree) F4.4 – speech-search is the best-rated feature, followed by F2.2 -speech-input at 84,9% and F2.1 – speech navigation at 84,8%. After a top-down analysis leading to the descriptive results presented, the survey results are analysed to investigate the quality dimensions in the area of usability.

Table 6
IPA-feature rating (n=66)

Summary-Function (Feature set F1)	I agree	I partially agree	I partially disagree	I disagree
The daily summary of the processes informs me specifically for my tasks (Feature **F1.1 – daily summary**)	36,36 %	33,33 %	22,73 %	7,58 %
The IPA should compress the notes of the users again and output only keywords (Feature **F1.2- daily summary compressed**)	19,7 %	36,36 %	27,27 %	16,67 %
It should be possible to output more information, such as the number of open and completed hotline tickets, number of documents created (Feature **F1.3 – daily summary extended**)	40,91 %	31,82 %	15,15 %	12,12 %
Entry-Function (Feature set F2)				
Calling up the mask via voice command enables faster acquisition (Feature **F2.1 – speech navigation**)	39,39 %	45,45 %	4,55 %	10,61 %
The possibility to enter the textual content via speech simplifies the input (Feature **F2.2 -speech-input**)	57,58 %	27,27 %	3,03 %	12,12 %
Speech recording in all masks with input fields for longer texts is helpful (Feature **F2.3 – Speech-Input long text**)	51,52 %	28,79 %	4,55 %	15,15 %
Explanation-Function for reports (Feature set 3)				
The combination of language interaction in graphical and tabular overviews promotes the understanding of the displayed content (Feature **F3.1 - explanation**)	57,58 %	21,21 %	15,15 %	6,06 %
The pre-evaluation of the key figures via voice output influences my own decision making (Feature **F3.2 – explanation influence**)	15,15 %	40,91 %	33,33 %	10,61 %
The graphical and tabular views are sufficient for me, I do not need any linguistic preparation (Feature **F3.3 – no explanation**)	30,3 %	42,42 %	16,67 %	10,61 %
Other Features (Feature set 4)				
The recording of working hours via voice input would make my work easier (Feature **F4.1 – worktime recording**)	31,82 %	24,24 %	21,21 %	22,73 %
Voice commands can completely replace navigation via keyboard, mouse or touch screen (Feature **F4.2 – replace keyboard**)	9,1 %	22,7 %	37,9 %	30,3 %
Forecasts and predictions e.g. of expected sales figures (predictive analytics) can be better understood through the combination of graphical representation and speech interaction (Feature **F4.3 - prediction**)	37,88 %	37, 88 %	10,61 %	13,64 %
A search function to open customers, prospects or contacts directly by voice speeds up the process of finding information (Feature **F4.4 – speech-search**)	56,06 %	31,82 %	4,55 %	7,58 %

Source: Authors' work

Table 7
Correlation Matrix nominal characteristics and ordinal features

	M	SD	GQ2	GQ3	GQ4	GQ6	GQ7	GQ8	GQ9	GQ11	GQ12
Age (GQ2) - Clustered	2.86	1.19									
Personnel responsibility (GQ3)	0.47	0.50	.17								
Job position (GQ4)	2.02	1.52	-.02	.28*							
IPA experience (GQ6)	0.82	0.39	-.05	.13	-.14						
New technology (GQ7)	1.20	0.40	-.04	-.08	.03	-.06					
Participant type (GQ8)	1.47	1.04	.03	-.13	.15	-.11	-.20				
ERP experience (GQ9)	2.42	1.85	.34**	.14	.31*	-.22	-.04	.23			
Technology impact (GQ11)	1.50	0.69	.09	.04	-.05	-.12	.22	.13	-.04		
Repeating activities (GQ12)	1.74	0.62	-.30*	.12	-.01	-.06	.26*	-.36**	-.20	.01	
Daily summary (F1.1)	2.02	0.95	.08	.13	-.06	.07	-.17	-.08	.13	.28*	-.04
Daily summary compressed (F1.2)	2.41	0.99	.03	-.03	.03	.06	-.20	-.13	-.12	-.04	-.08
Daily summary extended (F1.3)	1.98	1.03	.09	.24	-.01	-.14	.07	-.22	.09	-.07	.05
Speech navigation (2.1)	1.80	0.81	.08	.07	-.14	.02	-.02	-.12	-.13	.01	.04
Speech input (F2.2)	1.61	0.82	-.03	-.04	-.09	-.22	.03	-.08	-.04	.10	-.03
Speech input long text (F2.3)	1.73	0.89	-.15	-.14	.06	-.27*	.14	-.17	-.08	.07	.03
Explanation (F3.1)	1.70	0.94	.46***	.29*	-.02	-.14	-.04	-.29*	.03	.19	-.04
Explanation influence (F3.2)	2.39	0.87	.34**	.33**	.01	-.03	.00	-.18	.18	.22	-.02
No explanation (F3.3) - Inverted	2.92	0.95	.07	-.10	.07	-.19	.13	-.32**	.18	.03	.20
Worktime recording (F4.1)	2.35	1.16	.05	.20	.10	-.06	-.15	-.24*	.03	-.13	.05
Replace keyboard (F4.2)	2.89	0.95	.18	.00	-.24*	.18	-.19	-.03	.21	.16	-.08
Prediction (F4.3)	2.00	1.02	.32**	.15	.08	.01	.03	-.45***	.14	.22	-.03
Speech search (F4.4)	1.64	0.89	-.17	.03	-.07	.20	-.16	-.30*	-.26*	-.05	.10

Source: Authors' work
*Note: p < .001 *** p < .01 ** p < .05 ***

Table 7(continued)
Correlation Matrix nominal characteristics and ordinal features

	F1.1	F1.2	F1.3	F2.1	F2.2	F2.3	F3.1	F3.2	F3.3	F4.1	F4.2	F4.3
Daily summary compressed (F1.2)	.24											
Daily summary extended (F1.3)	.38**	.23										
Speech navigation (2.1)	.14	.04	.20									
Speech input (F2.2)	.10	.08	.19	.57***								
Speech input long text (F2.3)	.23	.11	.38**	.35**	.67***							
Explanation (F3.1)	.36**	.10	.31*	.11	.05	.16						
Explanation influence (F3.2)	.56***	.16	.46***	.21	.16	.26*	.58***					
No explanation (F3.3) - Inverted	.24	-.02	.15	-.13	-.06	.10	.19	.28*				
Worktime recording (F4.1)	.37**	.22	.48***	.41***	.41***	.37**	.15	.37**	.08			
Replace keyboard (F4.2)	.43***	.29*	.16	.26*	.23	.17	.06	.43***	.06	.43***		
Prediction (F4.3)	.51***	.22	.32**	.18	.24*	.32**	.49***	.58***	.39**	.29*	.27*	
Speech search (F4.4)	.40***	.30*	.24	.46***	.42***	.42***	.23	.29*	.15	.44***	.30*	.44***

Source: Authors' work
*Note: p < .001 *** p < .01 ** p < .05 ***

A non-parametric correlation analysis by using spearman's rank-order correlation was done to assess the nature of the connection among the analysed variables. The item Gender (GQ1) as a binary variable was removed in order to avoid analysing correlations between binary and nominal variables (Gogtay & Thatte, 2017). The items Industry (GQ5) and ERP system (G10) as nominal variables were removed from the matrix during the analysis, as no meaningful order for the evaluation can be established. The excluded characteristic can be useful for further analysis regarding differences between users of different ERP systems, but since nearly 60% of the participants are users of the ERP system Vemas.NET, more than 45% participants are in the IT-Industry and almost 70% of the participants are male, more samples of–especially female users - of other ERP systems and industries have to be collected to perform a valid analysis. Item no explanation (F3.3) was inverted because the question was negated. The age (GQ2) was not collected as a numerical value due to data protection, but as a Likert scale with the following coding: 1: 18-25, 2: 26-35, 3: 36-45, 4: 46-55, 5: >55.

Table 7 presents the correlation matrix for nominal characteristics and ordinal feature variables of the survey. The cross-correlation within the features are only shown for the sake of completeness. The correlations between the features are not considered, as no relevant conclusions can be drawn. Spearman's correlation coefficients as a standardised and symmetric rank coefficient in [-1,1] revealed the highest correlation with r=.46 is between age (GQ2) and F2.3 – Speech-Input long text and the highest negative correlation with r=-.45 is between participant type (GQ8) and F4.3 - Prediction. The presented maximum and minimum r-values from the correlation matrix are indicating the presumed weak correlation between the characteristics and the feature sets. More details regarding the descriptive analysis and the correlations will be discussed in the next chapter.

Discussion

The majority of the participants (68,2%) agreed, that speech-input is not able to fully substitute input devices like keyboard, touchscreen or mouse, so the IPA is recognised as an addition to traditional input methods, especially for search-functions (F4.4 – 87,9%), speech-input (F2.2 – 84,9%) and navigation (F2.1 – 84,8%). One explanation for this result might be that this type of usage is already well known by the personal use of IPA's, but surprisingly the summary-feature (F1.1), also well know from Amazon's Alexa, is only rated positively by 69,7% of the participants. Further research will show whether the request for the enrichment of the summary (F1.3 - 72,7%) or a compressed summary (F1.2 – 56,1%) will improve the user-acceptance.

The speech-interaction feature with explanation mode received a positive rating of 78,8%, but surprisingly 72,7% of the participants also agreed, that there is no explanation via IPA necessary. Therefore, further research is needed to explain in which situation and specific context this feature is relevant. Since 75,8% agreed to the need for prediction in combination with an explanation further research is also necessary to analyse the key-indicators for an IPA in this business context in the area of predictive analytics. More than 56% of the participants agreed, that the pre-evaluation of the key figures (F3.2) will influence their decision-making, this underpins the importance of this feature and justifies further research in this area.

The correlation matrix showed that there are only weak correlations between the participant characteristics and the feature sets. Referring to the literature the approach of analysing correlations between nominal variables and ordinal variables measured with a Likert scale can be regarded as appropriate (Norman, 2010). The highest positive correlation between the characteristics and feature sets is within age

(GQ2) and F3.1 - explanation with r=.46, indicating as implication step the older the participant, the higher the usefulness of the explanation feature. This outcome may contribute to the correlation between age (GQ2) and personnel responsibility (GQ3) with r=.29, indicating that the chance for being responsible for personnel increases with age, but the job position (GQ4) is not correlating (r=-.02) with the usefulness of the explanation feature (F3.1). From this, it follows a general statement that the function has a greater benefit for decision-makers is not valid. The highest negative correlation is within participant—type (GQ8) and F4.3 - prediction with r=-.45. This correlation is most probably not valid, because the participant-type expresses how the participant has made the experience with the artifact. The item only asks for the assessment of the usefulness for future implementation, so in fact, the user was not able to experience the prediction here delivering an estimation. This underpins the weak dependencies and justifies considering the functional evaluations as almost independent of the characteristics.

Conclusion

This paper aimed to analyse the usefulness of specific IPA-features to support complex workflows in a business context. As part of the feature set, a new function called explanation-mode was developed and introduced to the scientific community, as well as to the business world. For the purpose of this research, a survey was conducted with questions about individual characteristics, ERP- and IPA experience and ratings regarding specific and testable IPA features. By using descriptive statistics and a correlation matrix, the collected data were analysed and interpreted. As discussed in the previous chapter the correlation between the individual characteristics and the usefulness of the features is weak, so the conclusion aligns with other researches in the private environment (Han & Yang, 2018), that satisfaction and continuance intention is mainly affected by the task attraction. Since expectations between private customers and business-users are different more studies in the area of IPA in business-context are necessary to clarify the main drivers for continuance intention for IPA in business cases. For that purpose, the IPA-artifact will be extended and requested features like the search-function (F.4.4) will be implemented and existing features like the summary-function (F1.1) extended according to the user-request for more details and higher information density (F1.2 + F1.3).

The explanation mode – as a new and so far, unknown feature – got a high rate of acceptance, but further researches are necessary to work out the impact on decision-making and usefulness in daily business tasks, because also more than 72% agreed, that there is no special need for an explanation. By implementing prediction (F 4.3) to the IPA, the usefulness of an explanation might increase. This will be verified within further studies.

Limitations that can be addressed in future research are that the IPA was only tested in German language and with a relatively small number of participants. For further research, the IPA will support English to increase the number of possible users.

The artifact in combination with the survey was able to provide deep insights into the user-acceptance of specific features in a business context. Based on this result further development of the artifact and more research is necessary to work out details about feature usage – especially the explanation mode - and key-indicators for acceptance to adequately answer the research question raised in this article.

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About the authors

Daniel Hüsson, M.A. is head of consulting at a German ERP system provider and advises customers in the area of process optimization. After completing a part-time bachelor's degree in business administration and a master's degree in business informatics, he is currently researching the use of artificial intelligence in processes of medium-sized companies in the service sector as part of a doctoral program at Universidad Católica San Antonio de Murcia Avda. de los Jerónimos, Spain (UCAM) in cooperation with FOM Essen, Germany. His research focuses on the use of intelligent personal assistants to control complex workflows and to prepare information in a user-friendly way. He is also research fellow at the Institute for IT Management & Digitization (ifid). The author can be contacted at **daniel.huesson@fom-net.de.**

Alexander Holland is a Full-time professor at FOM University of Applied Sciences for information and process technologies and procedural programming technology. After successfully completing his studies in computer science at the University of Dortmund, Alexander Holland received his doctorate at the TU Dortmund University in 2008. Prior to this, he worked as a technical consultant and project manager for information and knowledge management at the computer group Hewlett-Packard between 1997 and 2001. Later he was a research assistant at the universities of Dortmund and Siegen. From 2007 to 2011 Holland was deputy director of the research center for knowledge management and intelligent systems at the University of Siegen. His research interests are computational intelligence, graphical modelling, decision theory, decision support systems, distributed systems, soft computing applications and relationship discovery in knowledge management. The author can be contacted at **alexander.holland@fom.de.**

Rocío Arteaga Sánchez is an Assistant Professor at UCAM (Catholic University of Murcia), Spain. She received her International PhD in Business Administration from the University of Huelva and she was visiting researcher at Cardiff University. Her research interests are centered on the impact of Internet on education, banking, e-commerce, and the acceptance and usage of new information technologies such as Moodle, WebCT, enterprise resource planning (ERP), social networks in education and business. She has published in leading journals including Computers & Education, Computers in Human Behavior and Journal of Promotion Management. The author can be contacted at **rarteaga@ucam.edu.**

IoT and Smart Home Data Breach Risks from the Perspective of Data Protection and Information Security Law

Goran Vojković, Melita Milenković
University of Zagreb, Faculty of Transport and Traffic Sciences
Tihomir Katulić
University of Zagreb, Faculty of Law, Croatia

Abstract

Background: IoT and smart devices have become extremely popular in the last few years. With their capabilities to collect data, it is reasonable to have concerns about the protection of users' personal information and privacy in general. **Objectives:** Comparing existing regulations on data protection and information security rules with the new capabilities provided by IoT and smart devices. **Methods/approach:** This paper will analyse information on data collected by IoT and smart devices and the corresponding legal framework to explore whether the legal framework also covers these new devices and their functionalities. **Results:** Various IoT and smart devices pose a high risk to an individual's privacy. The General Data Protection Regulation, although a relatively recent law, may not adequately regulate all instances and uses of this technology. Also, due to inadequate technological protection, abuse of such devices by unauthorized persons is possible and even likely. **Conclusions:** The number of IoT and smart devices is rapidly increasing. The number of IoT and smart home device security incidents is on the rise. The regulatory framework to ensure data controller and processor compliance needs to be improved in order to create a safer environment for new innovative IoT services and products without jeopardizing the rights and freedoms of data subjects. Also, it is important to increase awareness of homeowners about potential security threats when using IoT and smart devices and services.

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Introduction

A current buzzword in the field of information technology – IoT (Internet of Things) -is expected to create a whole new sector of products and services. Recent Cisco

research estimates predicted a 43% year on year growth of IoT connections (Bhattacharjya et al., 2018). Unfortunately, it is also increasingly connected with the rise of information security incidents and potential personal data breaches with significant impact on the privacy of individuals around the world (Lin et al. 2016). Legal science, especially in the field of data protection has only recently started to acknowledge the scope of the problem (Bu-Pasha, 2020; Edwards, 2016; Yang et al., 2019).

Sometimes referred to as the internet of everything or industrial network, IoT is a broad term that encompasses various technologies. Most commonly it is understood as an adaptable technology allowing machines and devices to interact with each other over the Internet. It allows for remote control and access through existing network infrastructure, provide opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit in addition to reduced human intervention (Balamurugan et al., 2018). It however creates an increasingly complex environment to ensure the recognized fundamental rights such as privacy and data protection (Geneiatakis et al., 2017). While there is a particular research into the effect smart home and smart city development has had on the protection of rights and freedoms of individuals, there are many issues and aspects that need to be visited and considered when considering the mechanisms applicable from the current legal framework. The current state of legal science explores unequivocally legal issues of transborder transfer of data (Sullivan, 2019), trustworthiness of personal digital assistants (Furey & Blue, 2019), efforts in establishment of user centric privacy (Skarmeta et al., 2019) to ideological resistance to smart home platforms as strongholds of digital capitalism (Goulden, 2019). Therefore, remarkably underlying the conflict between the struggling efforts of lawmakers and the indominable march of information technology development. With that in mind, the focus here is to analyse whether current provisions can be used to approach data protection and information security issues and serve as adequate compliance mechanisms.

The security threats posed by IoT devices have already been described in the literature (Jurcut et al., 2020). When we include more data collection capabilities enabled by smart meters (Iskraemeco, 2019) we come to a new situation that is not foreseen by the existing legal framework. Nor does the General Data Protection Regulation (GDPR, European Commission 2016a), as a new regulation, and consumer protection regulations, adequately regulate these new areas of possible violations of personal privacy. In this paper, using technical knowledge and comparing it with the legal framework, our intention to show to what extent the legal framework can be applied, and where amendments are needed. We will use the provisions, and recitals of regulations that speak about the purpose of regulations. This explanation is important because targeted interpretation. Targeted or teleological interpretation or interpretation from the status of only one of the many methods of interpretation or interpretation came to the most important, decisive method (Kačer & Ivančić-Kačer, 2019, p. 400).

IoT devices provide services to all kinds of applications through data gathering, identification, processing and communication capabilities. IoT connects infrastructure components and services for smart homes and offices, smart city infrastructure and is applicable in various fields of work – from general industry to real estate, healthcare, public safety. In principle, IoT generally allows for more interactive and efficient transportation and power utilities, etc. (Tzafestas, 2018). Developing IoT infrastructure can be expected to contain massive numbers of different sensors that collect, process and transfer data in addition to already widespread personal information processing

devices that are omnipresent in daily use such as personal computers, smartphones, television sets, game consoles and digital media reproduction devices.

Because of these characteristics, IoT is a technology of interest for modern hackers and cybercriminals. "While IoT deployments have been receiving much hype, their unique characteristics coupled with their interconnected nature indeed present new security challenges. Various technical difficulties, such as limited storage, power, and computational capabilities hinder addressing IoT security requirements, enabling a myriad of vulnerable IoT devices to reside in the Internet-space. Indeed, unnecessarily open ports, weak programming practices coupled with improper software update capabilities serve as entry points for attackers by allowing malicious re-programming of the devices, causing their malfunction and abuse" (Neshenko et al., 2020). Another point to consider is that the data that are generated around a single device may not be sensitive in itself. However, Iot networks usually consist of a large number of interconnected devices and when data is combined with data generated from other devices, it can reveal information such as the consumer habits, patterns of behaviour, and other data which may present significant risk for rights and freedoms of data subjects. New functionality brings new data security and privacy challenge, experts noticed that the weakest links of IoT can be driven by the low-cost devices with low security and cryptography technologies (Vongsingthong & Smanchat, 2015). Obviously, as IoT as a broad term encompasses many potential uses, it is not possible to cover all the issues and questions in the space available. In this paper we deal mostly with risks and challenges facing IoT smart home devices and not the IoT in industrial environment (smart containers and similar) in general, although it might not be possible to draw an exact line between such uses judging from the way these devices are incorporated into wide area networks. The General Data Protection Regulation has been in force only two years, from 25th May 2018. Meanwhile, the replacement of many measuring devices with smart meters has begun. Such smart meters that provide the utility provider with a significantly better insight into the life and habits of the user, require precise regulation. Users need to be aware of what kind of data is being collected on them. Furthermore, a large number of other smart and IoT devices do not have quality protection. Consumers need to be aware of this, which is not within the scope of the GDPR, but consumer protection regulations. In this paper, we would like to raise awareness of the need to apply and improve the legal framework.

Therefore, we prove why IoT devices represent a higher risk for personal data than previous monitoring technologies. After all, we put into perspective that technology and GDPR, including recitals, show us the purpose of Regulation. Since the GDPR includes information security requirements, and security is also important for devices that are not directly connected to service providers, we analyse the IoT and information security regulation with typical cases of IoT security breaches. As many metering devices do not collect user names directly (e.g. a three-tenant apartment), we analyse whether the data of such devices is still personal data. . Finally, concluding that the GDPR does not provide all the answers related to the safety, we also analyse the legal framework for consumer protection and make proposals for new regulations.

IoT personal data processing as a source of risk

While obviously far more efficient than previous monitoring devices, the IoT based devices equipped with sensors that can obtain personal data present a potentially considerable risk for personal data breaches and consequently rights and freedoms of data subjects. For example, electricity suppliers change the existing electricity consumption meters in households to the new digital meters which, as they are

connected to the Internet and allow various levels of internet access, represent a significant fraction of total IoT devices currently in use.

In a corridor of a residential building, on a standard electricity meter, the consumption in the accounting period, and day/night consumption are stored locally. The data on consumption is available only to a person physically in front of the meter, and that person can usually see the actual current consumption per rotation speed. On the other hand, a question whether a person is currently present in the household and is using an electrical appliance can usually only be ascertained by directly observing the meter, in the SE Europe the meter is usually positioned in the corridor of the building. These appliances are now being replaced by smart meters running as IoT devices.

As a local example, let us consider the function of a typical meter such as the "Iskraemeco AM550" electricity meter which is extensively being installed with users in the Republic of Croatia (further: Croatia). The device offers several ways of communication that exclude a need for manual readings such as Full DLMS-COSEM and IEC 1107 compliance; four independent communication interfaces: Optical port, RJ11, for in-house display, M-bus, wired and wireless, WAN/NAN Communication modules – PLC G2/G3, and point-to-point 2G/3G/4G. The manufacturer itself states that specific user applications for "Smart Grid" features are new levels of ability to customize the meter (Iskraemeco, 2019). The device is capable of measuring much more than electricity consumption itself, it also provides two-way ''energy'' measurements, active energy and power, 4Q reactive energy & power, apparent energy & power, instantaneous value of voltage, current, power factor, frequency and power and an absolute measurement of active energy & power (Iskraemeco, 2019).

This device has been singled out as an example due to the fact it has been installed in many households in Croatia and the region, however there are many similar devices that can be found in the market elsewhere. It is obvious that a device that has so far only measured the power consumption has been replaced by a much more capable one, one that now also measures several other values that can directly or indirectly be used to follow and profile the user behaviour through time, presenting a potential new risk for the data subjects.

Another example can a be smart water meter. One of these products readily available in the European market is "Apator smart +" class of water meter. For this example, we can use S SMART+ - VANE-WHEEL SINGLE-JET DRY WATER METERS (DN15-20). It is described thus: " For measuring the flow and volume of water with a temperature up to 30 °C or 50 °C, or warm water with a temperature up to 90 °C in the closed-circuit system with the full flow of the flux, and on the maximum working pressure up to 16 bar (PN16)." Features of device include: " Pre equipped for installation of radio module for communication in the Wireless M-Bus, impulse module and M-Bus module" (APATOR, 2019).

If that module is installed reading the collected data is quite simple: "Wireless M-bus is a complete solution for wireless reading of various scales. Communication takes place at 868 MHz according to the wireless M-bus protocol (standard EN 13757-4: 2005). The ''Walk-By-Read mode'' uses a handheld reader or a laptop equipped with a Bluetooth converter. In most cases, we perform the drive-by reading, meaning that our smart car equipped with antennas and a Bluetooth converter can come in front of the building and all internal water meters are read automatically and when we enter the shaft to read the main water meter, we immediately know if there is any difference in the reading " (Vodoservis Mate, 2019).

Communication standard is widespread and documented: BS EN 13757-4:2005 Communication systems for meters and remote reading of meters. Wireless meter readout (radio meter reading for operation in the 868-870 MHz SRD band). Water meter does not collect an extensive data set like electricity meter, but one who has access and collects data daily or every few days can collect sensitive data, for example when households is empty. Experts agree that using Internet of Things technologies leave many of the safety concerns ultimately with and in the hands of the consumer. (Tzafestas, 2018).

Should an unauthorized and potentially malicious user obtain access to the data of the electricity meter, there could be unintended but potentially very serious consequences for the data subject. For example, if data on power consumption could be established, with knowledge of the energy and consumption of individual devices, the malicious users could easily obtain real time and historical data about data subjects habits and behaviour such as when the resident comes home from work or other functions, which is the optimal room temperature preferred or even when energy intensive appliances such as ovens or vacuum cleaners are being used indicating activity or habits. Additionally, it could be ascertained when the occupant/data subject is showering, whether there is more than one person in the apartment, when and how long they watch television or spend time in various places in the household. What once was a simple record of electricity consumption now is representing a detailed record of personal life and habits.

Speaking from the legal perspective, the current situation with the lack of security of connected products has been somewhat helped by the fact that manufacturers have not been held responsible with respect minimum information security levels of their product. Since the consumer awareness is still low, there have not yet been enough cases to establish the clear frame of their liability. Since there is no regulatory nor economic incentive, the market fails to provide appropriate measures. (Opinion Consumers and IoT security, 2019). This makes the devices extremely vulnerable, when there is no obligation to install updates or apply similar measures, even middle skilled hacker can jeopardize device.

IoT devices can also be misuse for DDoS attacks. "Consumer products that fall in the IoT category are connected products. Their connectivity will typically be to a service accessible over wide-range (e.g. Internet) protocols and optionally to a smartphone application accessible over short-range protocols (e.g. Bluetooth, WLAN, etc.). In scenarios where IoT products are compromised and used in a distributed Denial-of-Service (DDoS) attack, it is the former type of connection that is exploited by malicious actors" (Opinion Consumers and IoT security, 2019).

IoT and General Data Protection Regulation

While the new European general framework of data protection, the General Data Protection Regulation (GDPR), does not specifically mention IoT devices, nor do the national application laws such as the Croatian General Data Protection Regulation Application Act, it does feature a number of recitals and provisions applicable to data collection through smart home devices and IoT.

In preamble, the Regulation in Recital 6 of the GDPR acknowledges that: "Rapid technological developments and globalization have brought new challenges for the protection of personal data. The scale of the collection and sharing of personal data has increased significantly. Technology allows both private companies and public authorities to make use of personal data on an unprecedented scale in order to pursue their activities. Natural persons increasingly make personal information available publicly and globally. Technology has transformed both the economy and

social life and should further facilitate the free flow of personal data within the Union and the transfer to third countries and international organizations, while ensuring a high level of protection of personal data" (European Commission, 2016b).

The legislative response to these developments from the perspective of data protection, apart from the General Data Protection Regulation and associated Directives and Regulations such as the Directive 2016/680 and the Directive 2016/680 and the Regulation 2018/1725, has been mostly through the national implementations acts dealing with the position and competences of independent national supervisory bodies and regulating the issues left by the GDPR to the national legal systems, as well as updating national laws to comply with data protection principles set forth by the Regulation.

According to a study by the Global Privacy Enforcement Network in 2016, most of the connected devices fail to adequately explain to customers how their personal data is processed which is now a direct violations of the transparency principle and applicable provisions of the General Data Protection Regulation. Failure to inform data subjects on the details of processing is perhaps not surprising given the extent to which IoT services involve significantly more parties than traditional services, for example, sensor manufacturers, hardware manufacturers, IoT operating systems vendors, IoT software vendors, mobile operators, device manufacturers, third party app developers, however it does represent a significant breach of data subjects rights.(Borelli et al., 2015).

Naturally, IoT products and services allow for collecting large amounts of data, some of which may be of potentially of sensitive nature. As far as the idea of a device that communicates with people or generally exchanges information with the environment in order to facilitate certain tasks, e.g., a washing machine that automatically orders detergents is a concern. It is obvious that certain safeguards need to be undertaken as not to jeopardize the privacy of the users. The Regulation mandates that the service provider ensures the safety and security of processing.

The Regulation takes this further in Recital 39 elaborating on the principles of data protection, especially the principles of purpose limitation, storage limitation and data minimization: "Natural persons should be made aware of risks, rules, safeguards and rights in relation to the processing of personal data and how to exercise their rights in relation to such processing. In particular, the specific purposes for which personal data are processed should be explicit and legitimate and determined at the time of the collection of the personal data. The personal data should be adequate, relevant and limited to what is necessary for the purposes for which they are processed. This requires, in particular, ensuring that the period for which the personal data are stored is limited to a strict minimum. Personal data should be processed only if the purpose of the processing could not reasonably be fulfilled by other means. In order to ensure that the personal data are not kept longer than necessary, time limits should be established by the controller for erasure or for a periodic review."

The volume of data that IoT products and services collect can contain personal and sensitive data interesting to a wide array of third parties ranging from financial institutions such as banks and insurance companies, to communications and entertainment service providers as well as market researchers etc.

The integration of home and IoT brings new forms of risks, and residents' perception on these new risks is quite important for the development of smart home technologies. IoT devices use wide array of sensors that collect and process staggering amounts of data. A number of authors have recognized several key points regarding the application of the GDPR to IoT processing, mostly focusing on issues regarding identifying appropriate legal basis (such as the prevalent and often inappropriate use

of consent which is unsuited to many IoT situations), struggle of IoT service operators with data protection principles enshrined by the Regulation such as principles of transparent, fair and legal processing, data minimisation and data security – confidentiality and integrity (Bastos et al., 2018).

These authors correctly suggest that data breach reporting provisions may present, at least at this point in development, a challenging requisite for IoT service and product providers as both identifying risk and determining consequences of a data breach in IoT environment that may number thousands or hundreds of thousands of distinct devices that may work largely independently or predominantly collaborate in a network which is a potentially daunting exercise with no clear cut forensic protocols or assessment schemes.

Another interesting point these authors raise, on which we agree is the requirement of data protection by design and by default as stipulated by the Article 25 of the GDPR. Taking into account the conditions set forth by the GDPR may not be an easy task in development of new innovative IoT devices and services. Cost of implementation of appropriate measures may be prohibitively high considering the relatively simple nature of sensors and monitoring devices that limit the ability of manufacturers to effectively implement efficient technical and organisational measures to help comply with GDPR requirements.

Similar observations were made previously by other authors, notably Wachter who conducted a systematic analysis of available literature in 2018 and identified a number of key issues, some going back to papers published years before GDPR which was adopted in 2016, especially including security and consent. To previously outlined GDPR requirements, Wachter also adds provisions regarding certain data subjects' rights, general security requirements for data controllers and data protection impact assessment provisions (Wachter 2018a).

 Most IoT devices have a physical aspect that demands ensuring the physical safety regarding the device as well as the user and the environment that the device is deployed in. This integration between cyber-security and physical safety raises the need for a new approach to these problems and development of sufficient security controls (Columbus, 2018). Smart household appliances such as electricity meters, toasters, TVs, refrigerators, and other smart household appliances can also cause some major issues as they gather a wealth of data and life habits of natural persons living in these households (e.g. the exchange of data between home appliances).

On average, current research shows that the regular smart home ecosystem is one comprised of about 20 smart devices, including the household gateway or router (Pascu, 2018).

Also, this may represent potential threat in the event of exploitation of such data, given that these are personal data of natural persons through which third parties can monitor and use their habits.

In 2014, the European Commission issued a recommendation regarding the preparations for the roll-out of smart metering strategies (European Commission (2014)). In this Recommendation, data protection and security considerations are outlined. It's also quite ironic that mobile phones act as a tracking device so hackers can use their   location information to steal data, hurt or at least find out natural persons daily routines and behaviour patterns.

With respect to IoT in context of smart homes, data protection laws demand several considerations mandated by the General Data Protection Regulation and potentially expanded on by national application laws such as *privacy by design and by default*, adequate analysis and treatment of risks to rights and freedoms of data subjects, processing in compliance with the principles of processing and on established and

properly evaluated legal basis (especially concerning potential for widespread unlawful secondary use of collected data).

Users who enthusiastically accept IoT or those that are compelled to do so, i.e. through obligatory replacement of electricity meters are usually not aware of the extent of the processing – the type, nature and volume of personal data collected, let alone their potential (mis)use. The Regulation now mandates that data controllers inform data subjects on the purpose, volume and scope of their processing.

The data controllers, and by extension their data processors offering Internet of things devices and services are required, starting with the Article 5 of the GDPR, to behave in an accountable way towards personal data, processing the data in accordance with the principles and compliance mechanisms put forth by the Regulation.

Through registration process and information channels offered to their users, data subjects using such devices and services should be notified about the nature, volume and scope of personal data processing.

The controllers should adopt proper technical and organizational protection measures, assert the level of risk to the rights and freedoms of their data subjects and regulate their relations with data processors as regulated by the Article 28 of the Regulation.

Needless to say, controllers should carefully examine the processing operations conducted by their devices and services, establish proper and applicable basis for personal data processing and rely on contractual and consent basis according to standards regulated by the new legal framework as well as existing practice as put forth by the Article 29 Working Party and the European Data Protection Board guidance documents, national supervisory body guidance and opinions and established legal practice.

Data controllers responsible for IoT infrastructure will need to develop ways to let users exercise their data protection rights. Some of those rights, such as the right of data portability are there to prevent unwanted user lock-ins often observable in different IT industry fields. There is also a question of user control over collection and processing of data. As before, principles of personal data processing and now firmly recognized and established rights of data subjects and their firm enforcement should help mitigate the feeling of the loss of user control and foster a safer environment for further development of these technologies.

The level of control that data subjects enjoy over their data is largely dependent on how well the manufacturers of IoT based equipment and products manage to inform their customers about the nature and purpose of data their devices collect. This includes both what the data collected is used for and what the likely consequences for the users are (Open Rights Group, 2019). This is the reason why it is necessary to make amendments to the Regulation at Member States level, according to which manufacturers must inform consumers with the installation of new IoT devices in their households on which data can be collected by the particular device.

IoT and information security regulations

As the structure and organization of the Internet does not take into account the borders between nations and other established parameters of competence, the problems concerning the availability and regular service of Internet service providers may have an obstructive effect on one of the Member States or the EU as a whole. Safety and security of network and information systems and the personal data processing that underlines so much of the current Internet economy is the key for development of the internal digital single market as well as increasingly for public

safety as more and more communal infrastructure services rely on networked technology for more efficient and smarter function.

As the EU lawmakers adopted the Network and Information Security Directive, its main objective was to raise the level of Member State cooperation in establishing and maintaining a high level of network and information security throughout the EU (European Commission, 2016b).

Establishing cooperation bodies, defining responsibilities and designating contact institutions in Member States, and adopting national information and network security strategies was a required formal step in this effort, however the regulation of information security obligations for providers in Member States was required by transposing the Directive into national legal systems by 2018. In reality, this process took a while longer but was finally completed in early 2020 with 13 Member States adopting a single national law as the transposition measure and 15 Member States adopting or updating two or more national laws which most of the Member States achieved through one or more national transposition measures.

In the case of Croatia, the transposition of the NIS Directive was carried out through provisions of the Act on Cyber Security of Essential Service Operators and the Digital Services Providers – The Cyber Security Act of key service providers and digital service providers (Hrvatski Sabor, 2018a). It contains the relevant definitions of key terms and concepts (Article 5), applicable criteria for appointing essential service operators and digital service providers (Articles 6-13, Annex I&II), as well as establishing obligations for these service providers in order to maintain adequate level of cybersecurity (Articles 14 through 24).

While the essential service providers are recognized and designated directly by the Act on the basis of NIS Directive Criteria and the comparative practice and experiences of other Member States, the recognition and designation of digital services providers is subject to a procedure. This procedure includes, alongside of criteria as regulated by the Cyber Security Act, designation by the competent body, in this case the Ministry of Economy, Entrepreneurship and Crafts (Hrvatski Sabor, 2018a, Articles 1-3).

Foreseeable use of IoT in offering certain essential services such as power and water distribution, as well as proliferation of smart home devices will trigger recognition and designation of controllers of these services as essential or digital service providers. These controllers are now obliged to implement technical and organizational measures to effectively manage risks as well as measures to prevent and mitigate effects of information security incidents on the security and safety of information systems (Hrvatski Sabor, 2018a, Article 14).

In particular, essential services operators need to implement such technical and organizational measures to effectively ascertain the incident risk, prevent, discover and solve information security incidents and mitigate incident effect to the lowest possible impact level (Hrvatski Sabor, 2018a, Article 15).

In turn, digital services providers when implementing required technical and organizational measures need to ensure safety of systems and installations, incident discovery and solving, maintain service continuity, adequately monitor, audit and test implemented measures and follow recognized information security standards in information security (Hrvatski Sabor, 2018a, Article 16).

The provisions of the Cyber Security Act of 2018 were operationalized in the provisions of the national Regulation on Cyber Security of Essential Service Operators and Digital Service Providers which was also enacted in 2018 (Hrvatski Sabor, 2018c). As there is no case law to examine following the start of application of the new regulations, at this moment speculation about their applicability is purely theoretical.

While the measures contained in these provisions represent an organisational and financial burden for the service providers, they do *prima facie* lead to higher degree of security and the Regulation demands that essential service operators create and manage an information security policy that needs to define goals and guidelines how to preserve the continuity of function of key systems, assess and manage risks, describe the system of information security management including the auditing of implementation of cybersecurity measures, provide key operational security procedures and include organisation and implementation of educational and awareness raising efforts. The Regulation further regulates the obligation of identified essential service providers to ensure physical security of the key systems, to ensure the availability of equipment required for continuing function and maintenance of essential systems etc. The essential service providers are required to manage contractual relations with external service providers that may affect the key systems, including assessing risks before contracting outsourced services and products.

Essential service providers are also mandated to control access to essential system premises, log and note access to essential systems, implement antimalware and anti-denial-of-service (anti-DOS) controls as well as manage development, research and continuity of operation of essential services. The operators are required by the Regulation to conduct vulnerability assessments, and in cases of serious security incidents to notify competent authorities designated by the Cyber Security Act.

Example cases of IoT security breaches

Practical use of IoT is already riddled with numerous incidents and disclosed or discovered vulnerabilities that may reveal the incident threat level and risk for users' rights and freedoms. Some of them were reported on by mainstream news or technology magazine, such as the case of SAM Seamless Network in 2019 (Narendra, 2019)

Smart home appliances offer new venues for attack. An attacker can hack into the smart home system and unlock the front door, open windows or turn on appliances causing damage to the home of the victim. These new type of smart home attacks result in new forms of risks for the residents (Denning et al., 2013). Cameras (security cameras of baby monitor) can be hacked and used for illegal access or join into a zombie network with the purpose to commit a distributed denial of service attack (Wallace, 2018). Garage doors collect data on when you usually arrive home from work, giving tech-savvy thieves information they need to plan a break in. There are many similar examples, and new devices and uses are connected into smart home platforms practically on everyday basis.

The fast growth and proliferation of devices and associated risks would benefit from a systematic overview and classification. One such classification groups risks into the five categories (Apiumhub, 2018):

1. Risk to personal data and privacy: The Internet of Things presents a higher risk to personal data processing.
2. Technical vulnerabilities in authentication: As IoT devices are connected through the network, they usually employ some sort of cloud interface. Its vulnerability may lead to compromise of data subject security.
3. Human factor: As IoT is a relatively new technology, the staff at companies offering these services and products are relatively uninformed which hightens the risks to information systems and data subject personal data
4. Inadequate data encryption: IoT networks usually lack sufficient data encryption capabilities.

Risks of having an increasingly complex information system: the more devices, people, interactions and interfaces, the more the risk for data security also increases. It means that there is more variety and diversity in the system, so the challenge of managing all points in the network to maximize security also increases. Some of the worst case scenarios of IoT attacks that have so far been noted by security researchers include content streaming platform attacks, massive malware distribution attempts, hacking of increasingly connected smart vehicles as well as medical devices:

1. In October 2016, the largest DDoS attack ever occurred on service provider Dyn using an IoT botnet, followed by the crash and unavailability of large sections of the Internet, including Twitter, Guardian, Netflix, Reddit and CNN. This IoT botnet was enabled by malicious software called Mirai. Once infected with Mirai, computers constantly searched the Internet for vulnerable IoT devices, and then used known default usernames and login passwords, contaminating them with malware. Among the devices that were attacked were digital cameras and DVR players.

2. In 2017, the US Food and Drug Administration (FDA) confirmed that certain medical devices had vulnerabilities that could allow hackers to access the devices such as pacemakers and defibrillators used to monitor and control patients' heart functions and prevent heart attacks. Because of the vulnerability of the transmitter, hackers could control the shocks, manage the incorrect pacing, and drain the battery.

a) 3. An IBM affiliated security research website reported a possibility of an attack targeting an Internet connected vehicle. A team of researchers was able to take total control of a Jeep SUV using the vehicle's CAN bus (Dunlap, 2017). The Jeep computer needed a firmware update, and it used the Sprint mobile network, and a team of experts realized they could make the car behave the way they wanted: make it run off the road, slow down and speed up potentially endangering the occupants of the vehicle or bystanders. We can conclude that IoT affects personal data and generally information about people's' habits and their movement, in two (2) ways:

   a) As smart devices are technologically supported by IoT, they collect much more data than "dummy" devices,
   b) IoT devices, on the contrary, are much more vulnerable to hacking or other forms of abuse than classical devices.

These mentioned issues make security issues far more complicated, both legal and technological. Huawei forecasts 100 billion IoT connections by 2025, and McKinsey Global Institute suggests that the financial impact of IoT on the global economy may be as much as $3.9 to $11.1 trillion by 2025 (James, 2015).

Smart devices obviously have benefits for both consumers and businesses. In 2017 alone, the market for these devices brought in $ 84 billion, almost 16% more than in 2016, according to a report by Ablondi (2018). By 2023, 274M homes worldwide, or 14% of all households, will have at least one type of smart system installed (Strategy Analytics, 2018).

While there are various ways to protect consumers from the IoT security threats – education about information security basics as an integral part of digital literacy, changing default privacy and security settings and managing personal access codes etc. - some age long accepted practices still apply in the digital domain. When buying an IoT device or home appliance it is important to know that buying a reliable device from a reputable supplier means greater chance of the supplier satisfying EU data protection and information security regulations such as naming representatives or having accountable subsidiaries in the EU. Such suppliers will have conducted data

protection impact assessments and other compliance activities for their products and the companies themselves, have invested into information security standard certification and have a history of understanding the modern regulatory framework in contrast to cheap products from mostly unknown suppliers available only through wholesale Internet commerce sites.

Safety wise smart home device suppliers and platforms operators should create vulnerability management program. Such program should identify and fix device weaknesses that can emerge over time – a common reason would be the use of outdated operating systems or antivirus software for personal use. "Users' right to data protection and right to privacy must be balanced in the design and governance of identification technologies in the IoT" (Wachter, 2018b).

Therefore, the appropriate measures must be taken to make smart homes safer and more suitable for life. It is also necessary to carry out a careful assessment of safety risks, which must be preceded by security implementation to ensure that all underlying problems are detected immediately and that timely protection measures have been taken.

Discussion

Is IoT Data necessarily a Personal Data?

IoT devices obviously create interesting new legal and policy challenges that lawmakers have not encountered before. At the same time, IoT technologies add to many issues that already exist and manifest in data protection practice (Rose et al., 2015). Utility companies and other similar service providers may claim that the data they collect on IoT devices is not personal data, that is, they do not fall within the scope of GDPR. It is also clear why - the theses we cite in this article state that sensitive personal data may be involved, and the storage and processing of such data must be conducted in accordance with the rules imposed by Regulation. It is not only a matter of formally defining information as personal, but also a matter of security. Art. 32 of the Regulation has the following on the issue of data controller obligations concerning Security of processing: " Taking into account the state -of -the -art, the costs of implementation and the nature, scope, context and purposes of processing as well as the risk of varying likelihood and severity for the rights and freedoms of natural persons, the controller and the processor shall implement appropriate technical and organisational measures to ensure a level of security appropriate to the risk, including *inter alia* as appropriate: (a) the pseudonymisation and encryption of personal data; (b) the ability to ensure the ongoing confidentiality, integrity, availability and resilience of processing systems and services; (c) the ability to restore the availability and access to personal data in a timely manner in the event of a physical or technical incident; (d) a process for regularly testing, assessing and evaluating the effectiveness of technical and organisational measures for ensuring the security of the processing."

Based on the evaluation of the established ECJ and national supervisory body practice and applicable WP29 and EDPB guidelines, data collected by IoT may indeed represent personal data if it relates to an identified or identifiable natural person, and in some cases it may even reveal sensitive data such as data relating to health, biometric data and data related to aspects of data subject behaviour..

The easiest way to avoid the extra cost coming from obligations to ensure safe and secure processing of such data is to deny that data in question are personal information. Therefore, we consider it important to establish here that personal

information is what is indeed at stake. Such an issue is important not only for IoT meters but also for other IoT devices which collect data on the activities of natural persons.

GDPR Art. 4. defines: "'personal data' meaning any information relating to an identified or identifiable natural person; 'data subject'; an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person".

Following the coming into force of the Lisbon Treaty and the Charter of Fundamental Rights protection of personal data in the EU has been defined as a fundamental right separate from the right to privacy. GDPR, Preamble 1 also states that "The protection of natural persons in relation to the processing of personal data is a fundamental right. Article 8(1) of the Charter of Fundamental Rights of the European Union (the 'Charter') and Article 16(1) of the Treaty on the Functioning of the European Union (TFEU) provide that everyone has the right to the protection of personal data concerning him or her." Also, Preamble 39 quotes: "Any processing of personal data should be lawful and fair."

The question of what belongs to personal data has already been extensively analysed in legal literature and the judicature of ECJ (i.e. regarding the dynamic ip addresses in the Case C-582/14: Patrick Breyer v Bundesrepublik Deutschland). One of the earliest examples is the one published by the UK's Information Commissioner's Office (ICO), analysing the provisions of the UK Data Protection Act 1998 (DPA). ICO's document "Determining what is Personal Data" states: "It is important to remember that it is not always necessary to consider 'biographical significance' to determine whether data is personal data."

This document also cites an example of a case of collecting water measurement data: "A utility company may not record the name of the occupier of the house to which it provides water, but may simply note the address of the property and address all bills to 'the occupier'. Data concerning the water consumption for a particular address will be personal data about the occupier where this data determines what that individual will be charged for. In this last example, even without a name associated with the water consumption data, this data will be personal data in that it determines what the occupier will be charged and the occupier is identified, even without a name, as the person living at the property in question and is therefore distinguished from other individuals. Also, if necessary, the water company is likely to be able to easily obtain the name of, if not the occupier, then at least the registered owner of the property" (Determining what is personal data, 2012).

In countries where utility bills typically come labelled with a user's name, this data represents personal data. Further let's consider that the scope of personal data in practical, if not legal sense, is wider today than it was twenty years ago and on the basis of which these examples are cited. Recent literature supports this view: "It should be noted that personal data can relate to more than one person. For example, the location of a person at any particular time may also constitute the personal data of other known individuals in the same location. Joint property ownership can amount to the personal data of two persons. The content of an email sent by a tenant living in an apartment block complaining about his neighbour may contain information relating to both the complainer and the person about whom the complaint was made. A page of text recording a discussion between two individuals, perhaps including a detailed exchange of views or a disagreement, may be the personal data of both" (Carey, 2018, pp. 14).

Utility providers, telecoms, and other companies can relatively easily collect information about individuals residing in a residential facility, e.g. apartments or houses; consumption bills are tied to the name of the natural person; telecoms additionally offer various benefits of "family packages" to gain an accurate family image), and therefore we can conclude that the data that can be traced on the habits of householders and guests using IoT devices, whether metric or otherwise are undoubtedly personal information, even when they are not individualized, e.g., data on the electricity consumption of an apartment where two people reside.

Comparison of different categories of such data may pose a particular privacy risk, e.g. a utility company in a local government unit may collect data from different measuring devices as well as from other sources, e.g., local video surveillance of parking lots. A negligent or malicious operator comparing such information could get a very accurate and sensitive image of one's movements and habits, and deeply invade a person's privacy.

IoT and customer protection rules

The European Consumer Protection Framework does not regulate IoT and smart devices in terms of informing IoT device users of the ability to collect data by such devices. This is understandable because the legal framework is outdated (Council Directive 93/13/EEC of 5 April 1993, Directive 98/6/EC of the European Parliament and of the Council, Directive 2005/29/EC of the European Parliament and of the Council and Directive 2011/83/EU of the European Parliament and of the Council). National regulations, such as the Croatan Customer Protection Act provides only a brief reference in the need to comply with data protection regulations (Hrvatski Sabor, 2018b).

The new proposed legal framework partly addresses the issue of data collection through the introduction of new digital services (EU to modernize Act on Consumer Protection). Thus, it is proposed that: "In respect of personal data of the consumer, the trader shall comply with the obligations applicable under Regulation (EU) 2016/679." Also interesting is the following provision regarding the provision regarding the use of personal data by the trader, considering the obligations of the trader in the event of termination(Council of the European Union, 2019).

However, there is no obligation on the trader to explicitly inform the user about the ability to collect data from an individual smart device, e.g., electricity meter. This is in stark contrast with the provisions of the GDPR, from the basic principles of processing to the right of data subjects to be informed and to access their data. Here, we mention the Croatian practice - the dummy meter is being replaced by a smart device, where the user only signs a record of the change of the meter, but is not familiar with the new possibilities of collecting data on the changed device, except in the case of self-information.

Conclusion

The focus of this paper was to present the applicable data protection and information security regulative context to the rise of Internet-of-Things data processing paradigm, also to outline the activities that data controllers and processors should undertake to mitigate possible data breaches. Even though personal data protection has been recognized as a fundamental right of individuals in the EU for almost two decades, and after almost the same development period, now there is an established information security regulatory framework with obligations for essential service operators and digital service providers. There is still much effort required to increase awareness of both service providers and the homeowners about potential security

threats that may be possible when using these devices and services. IoT rapidly occupies the global market which brings unprecedented benefits mostly from improved efficiency, accuracy and economic benefits. It changed the world of wi-fi connected devices; thus, they are becoming more interconnected in a smart grid and can easily reduce human intervention which was the idea from the beginning of development.

Our research has confirmed that users should be protected and acquainted with the smart devices implemented into their households according to the GDPR, bearing in mind that utility service install smart devices into their households priorly without letting users know what type of device is being installed, and without their proper consent. Future research should analyse developing comparative law and discuss best practices, especially on the level of EU Member States. The new laws and regulations transposing the NIS Directive and accompanying the GDPR present an opportunity to improve regulatory framework to ensure data controller and processor compliance and create a safer environment for new innovative IoT services and products without jeopardizing the rights and freedoms of data subjects.

The paper predicts and gives examples of practical implications showing that this can sometimes be detrimental to utility users because they are not aware of their rights, and thus do not even recognize potential security threats that cannot be ruled out. In the end, however, the complexity of smart home infrastructure may very well prove impossible to apply standard information security solutions to smart devices such as smart TVs, connected home appliances or connected energy sensors and water distribution services. Therefore, integrated security approach, risk identification, risk management and ultimately accountable behaviour of data controllers and other service providers is of foremost importance.

In this paper we explained how such devices bring numerous savings nevertheless on the other hand IoT brings unsuspected risks in the area of personal data protection and security of infrastructure. As number of IoT and smart home device security incidents continues to rise, it is going to be quite difficult to ensure safe and secure processing of user data without empowering users themselves through active decision-making about the security status of their own IoT home network.

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About the authors

Goran Vojković, PhD, Associate Professor, Chair of Transport Law and Economics, University of Zagreb, Faculty of Transport and Traffic Sciences. He was born in Split in 1971. He has more than twenty years of work experience in the civil service and private sector, working on different types of jobs; from the Governmental Office Counsellor to the Head of Governing Council of the Port Authority of the port of Vukovar. For four years he was a member of Supervisory board of JANAF company, and, for two terms, he was an external member of the Committee for Legislation of the Croatian Parliament. Also, he has a great experience working on the EU projects both in Croatia and Bosnia and Herzegovina. Currently, he works as an Associate Professor at the Faculty of Traffic and Transport, University of Zagreb, and at the University North, and he co-operates with the other higher education institutions in Croatia. The author can be contacted at **goran.vojkovic@fpz.hr.**

Melita Milenković, LL.M., Research and Teaching Assistant, Chair of Transport Law and Economics. Faculty of Transport and Traffic Sciences, University of Zagreb. She was born in Slavonski Brod, Croatia, she graduated from the Faculty of Law, University of Osijek where she obtained her Master's degree in Law. Currently, she is employed as a Research and Teaching Assistant at the University of Zagreb, Faculty of Transport and Traffic Sciences, Chair for Transport Law and Economics. She is at the 3rd year of doctoral studies programme at the University of Ljubljana, Faculty of Law, presently in the final phase of drafting and submitting a thesis under the title: "Comparative Analysis of Concessions for Managing Airports – the Applicative Croatian Model". She has written papers and articles in the field of Administrative Law, Transport Law, ICT Law and Public Procurement Law. The author can be contacted at **melita.milenkovic@fpz.hr.**

Tihomir Katulić, PhD, Assistant Professor, ICT Law Department, Faculty of Law, University of Zagreb. Teaches undergraduate and graduate courses in Information Technology Law ranging from Personal Data Protection and Privacy in Electronic Communications, Internet Governance, Introduction to Information Security and Intellectual Property. Member of the Internet Society, Croatian Academy of Legal Sciences, Croatian Copyright Society, International Association of Privacy Professionals and Internet Governance Forum. Certified ISO 27001 and ISO 37000 lead auditor and an experienced data protection consultant. Occasionally writes opinions and columns for Croatian magazines Bug, Mreža, Banka, Infotrend, Novi Informator, Poslovni dnevnik, Privredni vjesnik and Sistemac on topics ranging from data protection, copyright, digital media, information security, computer crime to electronic commerce and internet governance. The author can be contacted at **tihomir.katulic@pravo.hr.**