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HOUSING PRICE FUNDAMENTALS THROUGH THE BUSINESS CYCLE

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ABSTRACT

We examine the fundamental determinants of nominal home price growth from 1995 to 2012 across 300 metropolitan areas in the U.S. This sample period provides a trough-to-trough time period that allows for analysis through a complete business cycle. By using a supply-to-demand ratio for home price appreciation, we identify a straightforward and powerful method for predicting home price appreciation across markets. We suggest an alternative and simple method for addressing endogeneity in house prices and include a comprehensive measure of human capital. We find five significant factors: home supply growth, personal income growth, human capital, an ocean dummy, and geographic constraint.

KEY WORDS

housing, real estate, house price forecasting

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R2, R31

1 INTRODUCTION

For the past decade, much literature on housing markets and prices has focused on the housing bubble – its existence, its size, and its causes (e.g. see Gallin, 2006; Glaeser et al., 2008; Huang and Tang, 2012; Shiller, 2005; Akerlof and Shiller, 2009). As the housing market now stabilizes after an egregious boom and bust cycle in the 2000s, we can reexamine the fundamentals of housing prices with the added benefit of hindsight. This paper examines factors that explain the home price growth disparity between cities in the U.S. through a complete business cycle.

In the long run, the literature suggests that regional home price growth is determined mainly by local fundamentals. Local fundamentals can be summarized into two categories: demand factors and supply factors. Demand

factors include mostly economic factors, such as income growth, employment growth, and population growth of a city, as well as non-economic factors, e.g. its amenities and climate. It is not surprising that when a city has a higher income, employment, and population growth, or has a more temperate climate, the home demand in the city will rise. Supply, summarized as the growth of building permits, is determined mainly by three factors: (1) the cost of land, which varies according to the availability of developable land (natural factor), (2) government regulations (man-made factor), and (3) physical building costs. In the following analysis, by and large, we assume that the growth of costs of building a home and its quality improvement does not vary significantly across the country.

While the literature on determinants of housing price is considerable, most of it is focused on either one or several demand-side or supply-side factors. Few have analyzed a comprehensive supply-and-demand framework. For instance, Malpezzi et al. (1998) find that income level and past income growth are positively related to housing prices and rents in 1990. Larger cities generally have higher housing prices. Changes in population are not a significant predictor. More stringent regulations predict higher housing prices and rents. Moretti (2004) summarizes the social return of human capital. He suggests that a city with high human capital will increase its productivity beyond an individual level, reduce criminal participation, improve voters' political behavior, and create land price premiums. Glaeser et al. (2005) suggest that since 1970, housing price appreciation has been accompanied by large reductions in residential development, mostly in coastal cities. The limited housing supply is driven mostly by the result of a changing regulatory regime that makes large-scale development increasingly difficult in expensive regions. Quigley and Raphael (2005) also find that the stringency of regulation is the main reason for the disparity of housing supply and housing prices across 407 cities in California. In addition to regulation, Green et al. (2005) find that high population density predicts low supply elasticity. Saiz (2010) calculates the exact measurements of undevelopable land in cities, which could contribute to the supply inelasticity of a city.

Our study proposes a simple but holistic empirical model by using the latest period (1995–2012) of data. This paper provides three contributions to the literature. (1) By focusing on a cross-sectional analysis across 300 or so metropolitan areas over a long span of time rather than panel data (time series and cross section), our estimators will be largely free of the influences of non-fundamental factors that may have contributed to the housing bubble. These include psychological fads, panic, irrational expectations of future home prices, and subprime mortgage fiascos. Because of the wide range of our sample size, we propose a simple alternative partition method to improve the endogeneity problem. (2) We calculate a simple supply-to-demand ratio. The variable, which embodies the basic idea of supply elasticity, has significant explanatory prediction abilities. (3) We use a new measurement of human capital for metropolitan areas: the UCLA City Human Capital Index. This index represents the average educational attainment of residents in a city. As an educational/human capital factor, we suspect that this variable that we have constructed is more comprehensive and more representative than the variable that most of the literature has been using, i.e. the percentage of bachelor's degrees held by residents in a city.

We find five significant determinants of home price level and growth: home supply growth, personal income growth, human capital, an ocean dummy, and a measure of geographic constraint. The rest of the paper is organized as follows. Section 2 presents the data and the supply-to-demand ratio. Section 3 reports empirical results. Section 4 provides the robustness check. Section 5 handles the endogeneity problem. Section 6 discusses the human capital factor. Section 7 offers policy implications. Section 8 concludes.

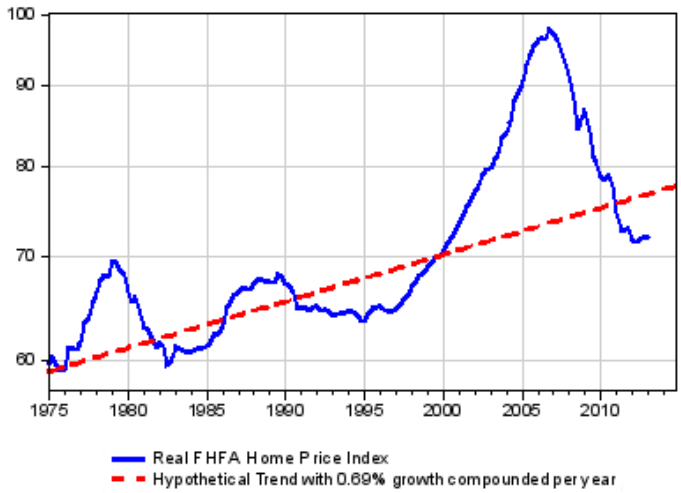

Fig. 1: FHFA single-family real home price index from 1975Q1 to 2012Q3 for the U.S.
Sources: Federal Housing Finance Agency, and the consumer price index is from Bureau of Labor Statistics.

2 DATA AND THE SUPPLY-TO-DEMAND RATIO

Fig. 1 shows the real single-family home price index, based on the nominal home price index adjusted by the consumer price index, from the Federal Housing Finance Agency (FHFA) for all transactions in the U.S. With 20/20 hindsight, we can see three housing bubble and bust cycles over the past four decades. The first is in the late 1970s, the second in the late 1980s, and the third in the 2000s. During these periods, real home prices eventually return to an invisible, hypothetical trend[1] with some overshooting rolling below the trend. In other words, the mean-reverting home prices suggest that fundamental forces are in fact driving the home price appreciating trend in the long run and that the trend is not a random walk.

More importantly, Fig. 1 implies that the estimations of conventional fundamental analyses, either panel or time series analyses, on housing price dynamics might be contaminated by these bubble-bust cycles. Even though some studies explicitly investigate the bubble elements using fundamental factors, the difficulty of identifying the bubble and bust could bias their results. Fig. 1 also illuminates that 1995 and 2012 were the bottom of the housing price cycles. The appreciation from 1995 to 2012 seems to be equal to the appreciation of the hypothetical fundamental trend (dotted line) from 1995 to 2012.

Following the 5-year housing boom period (2002 to 2006) and the 5-year slump period (2007 to 2011), 2012 is the beginning of the housing market recovery. As a result, we believe that 2012Q3 will be a reasonable ending point for our fundamental analysis. In other words, the home price change from 1995 to 2012 is not contaminated by non-fundamental factors such as psychological fad and panic, irrational expectation of future home prices, subprime mortgage fiascos, etc. Thus, we suggest that our sample period and our single period return will provide a more accurate estimation of fundamental determinants of housing price appreciation than most recent literature.

Fig. 2 displays the nominal single-family home price growth from 1995Q1 to 2012Q3 according to the FHFA for the 30 largest metropolitan statistical areas (MSAs) in the U.S. We can see that San Francisco has the highest home price growth – 142% (5% compounded growth per year) over the past 18

[1] In Fig. 1, we draw a hypothetical trend with a 0.69% growth compounded per year beginning with index 58 in 1975Q1.

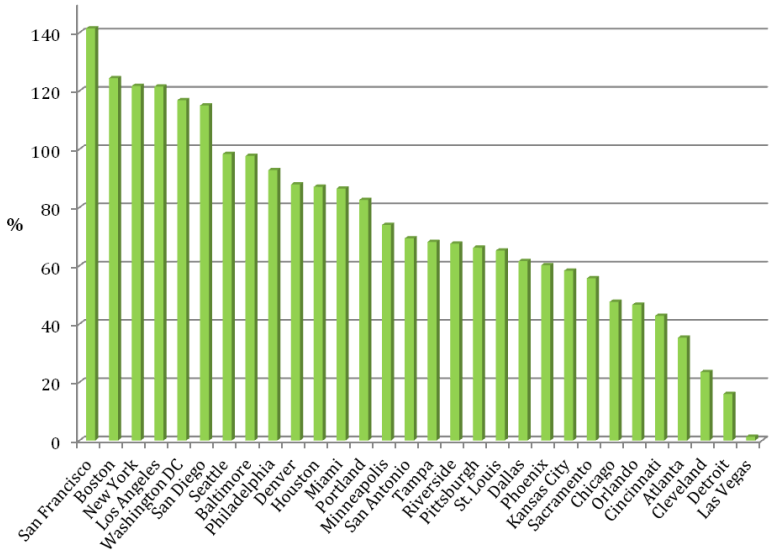

Fig. 2: Single-family home price growth from 1995Q1 to 2012Q3 for the 30 largest metropolitan areas
Source: Federal Housing Finance Agency.

years, followed by Boston's 124%, New York's 122%, Los Angeles's 122%, and Washington D.C.'s 117%, down to Miami's 87%, Phoenix's 60%, Chicago's 48%, Atlanta's 35%, Detroit's 16%, and Las Vegas' barely 1%.[2] What explains this prodigious difference of home price growth across cities? In answering this, we can use the estimated coefficients from cross sections to forecast the long-term home price appreciation among cities within a time series context.

2.1 The Ratio of Building Permit Growth to Personal Income Growth

In theory, the gap between the growth of supply and the growth of demand in a city can predict long-term home price appreciation. Basic economic principles suggest that the bigger the gap between supply and demand, the smaller the home price appreciation. That is, if supply is rising more quickly than demand, home prices should fall; alternatively, if demand is outpacing supply, home prices should rise. Additionally, when facing the same amount of positive demand shock, an inelastic housing supply will cause home prices to increase rapidly, while an elastic supply will prevent home prices from rising too much. For simplicity's sake, we use the personal income growth, which potentially includes all income, employment, and population growth of a city, as a representative variable of demand. By and large, we assume that the cost of building a home and its quality improvement does not vary significantly across the country.

Next, to understand the gap between supply and demand, we construct the ratio of total building permit growth to personal income growth:

$$\mathrm{SDR} = \frac{\mathrm{TBP/P}}{\mathrm{PIG}},$$

where SDR is supply-to-demand ratio, TBP is total building permits issued 1995 to 2012, P is population in 2003, and PIG is personal income growth 1995 to 2011.

[2]The other famous housing price index is the S&P/Case-Shiller Home Price Index, which considers home quality and a broader sampling but only covers 20 cities. Its home price appreciations for major cities are not significantly different from FHFA's as shown in column 2 of Tab. 1. For instance, according to the Case-Shiller index, the nominal home price appreciation between March 1995 and September 2012 is as follows: Boston: 123%, Los Angeles: 127%, Washington D.C.: 110%, Miami: 71%, Phoenix: 58%, Chicago: 36%, Atlanta: 19%, and Detroit: 9%.

Fig. 3: The correlation between home price growth (1995-2012) and the ratio of permit growth to personal income growth (1995–2011)
Sources: Home prices are from the Bureau of Federal Housing Finance Agency, the permit number is from the U.S. Census, and the personal income growth and population is from the Bureau of Economic Analysis.

For the ratio of permit growth to personal income growth, the numerator is the total number of building permits issued from 1995 to 2012 over a metro's population in 2003[3] (middle point of the sample period), multiplied by 100. The denominator is the nominal total personal income growth from 1995 to 2011. If the ratio is very large, meaning that home supply outpaces demand, we expect a lower home price appreciation. If the ratio is very small, meaning that home supply does not catch up with demand, we expect a higher home price appreciation.

Fig. 3 presents a simple correlation between these two variables among 303 metropolitan areas[4] in the nation. The home price growth rate is calculated by the FHFA nominal single-family home index (all transactions) from 1995Q1 to 2012Q3. The scatter chart supports our simple theory. The downward-sloping line states an inverse relationship between the supply-to-demand ratio and home price growth. From the sample of 303 cities, the mean of the supply-to-demand ratio is 8.2 and the median is 7.7.

In Tab. 1, we list the 30 largest MSAs' home supply-to-demand ratio and the home price growth over this 18-year period. It is obvious that Northeastern and Coastal Californian cities have a less than accommodating home supply to meet their demand. As a result, they have higher home price growth and less affordable housing than other cities. Saiz (2010) uses the median home price, number of households, and physical and regulatory constraints from 1970 to 2000 to calculate the supply elasticity of metro areas, as shown in column 4 of Tab. 1.

If we run a simple OLS regression with the dependent variable as the nominal home price growth from 1995 to 2012 and the independent variables as our supply-to-demand ratio as well as Saiz's elasticity measurement. As shown in Tab. 2, we find that our simple supply-to-demand ratio has an R^2 of 0.13, which is much higher than Saiz's elasticity with an R^2 of 0.04. In other words, the supply-to-demand ratio seems to be a fairly easy barometer for home price appreciation. On the other hand, Saiz's

[3]Apparently, a bigger city will issue more building permits over time. To control for city size, we divide the total building permits issued from 1995 to 2011 by the city's population in 2003.

[4]There are 365 metropolitan statistical areas, but building permit data is available for only 303 metropolitan areas.

Tab. 1: Home price growth (1995–2012) and the supply-to-demand ratio for the 30 largest cities in the U.S.

		FHFA home price appreciation 1995–2012	Case-Shiller home price appreciation 1995–2012	Supply-to-demand ratio	Saiz (2010)'s supply elasticities
1	San Francisco	142	107	1.8	0.66
2	Boston	124	123	3.3	0.86
3	New York	122	108	4.4	0.76
4	Los Angeles	122	127	3.3	0.63
5	Washington DC	117	110	7.4	1.61
6	San Diego	115	117	4.7	0.67
7	Seattle	98	94	7.6	0.88
8	Baltimore	98	N/A	5.3	1.23
9	Philadelphia	93	N/A	4.9	1.65
10	Denver	88	92	9.3	1.53
11	Houston	87	N/A	7.9	2.30
12	Miami	87	71	6.9	0.60
13	Portland	83	78	7.2	1.07
14	Minneapolis	74	62	8.9	1.45
15	San Antonio	69	N/A	7.5	2.98
16	Tampa	68	55	10.6	1.00
17	Riverside	68	N/A	8.2	0.94
18	Pittsburgh	66	N/A	4.9	1.20
19	St. Louis	65	N/A	8.5	2.36
20	Dallas	62	N/A	9.1	2.18
21	Phoenix	60	58	11.9	1.61
22	Kansas City	58	N/A	9.6	3.19
23	Sacramento	56	N/A	8.6	N/A
24	Chicago	48	36	7.9	0.81
25	Orlando	47	N/A	13.4	1.12
26	Cincinnati	43	N/A	9.5	2.46
27	Atlanta	35	19	14.3	2.55
28	Cleveland	24	23	7.9	1.02
29	Detroit	16	9	10.6	1.24
30	Las Vegas	1	10	16.0	1.39

Source: Home price is from the Federal Housing Finance Agency, supply to demand ratio is calculated by the author, and supply elasticities are from Saiz (2010).

elasticity has much higher explanatory power on the log median home price level.

Note that in this paper we use only the single-family home price because of the data availability. However, for the building permits issued, we include both single and multi units. We assume that even the number of multi-unit permits will have an impact on the single-family home price growth. That is because when the supply of multi units is abundant, it will ease the demand for single units, therefore reducing the price appreciation of single-family homes.

Tab. 2: OLS estimations with dependent variable: home price growth between 1995 and 2012

Dependent variable	**Home price growth (1995–2012)**		
Supply-to-demand ratio	−2.17***		−2.37***
	(0.32)		(0.36)
Saiz's (2010) elasticity		−3.43***	−3.88***
		(1.06)	(1.00)
N	303	249	241
Adjusted R^2	0.13	0.04	0.18

Note: The numbers in the parentheses indicate standard errors, * indicates a 10% significance level, ** indicates a 5% significance level, and *** indicates a 1% significance level.

3 ESTIMATIONS

In the previous sections, we use a single variable – supply-to-demand ratio – to explain the difference of home price growth across cities. This ratio will be able to explain 13% (adjusted R^2) of variation of home price appreciation across cities. Now, we take a broader view to see how all of the major factors predict home price appreciation across cities from 1995 to 2012. The baseline OLS model is Equation (1) and estimation results are shown in Tab. 3.

$$\begin{aligned}\text{Home price growth} = \alpha &+ \\ &+ \beta_1 \cdot \text{Home supply} + \\ &+ \beta_2 \cdot \text{Economy} + \\ &+ \beta_3 \cdot \text{Human capital} + \\ &+ \beta_4 \cdot \text{Climate} + \\ &+ \beta_5 \cdot \text{Ocean} + \\ &+ \beta_6 \cdot \text{City size} + \\ &+ \beta_7 \cdot \text{Household size} + \\ &+ \beta_8 \cdot \text{Geography} + \\ &+ \beta_9 \cdot \text{Regulation} + \epsilon \end{aligned} \tag{1}$$

The dependent variable is the nominal FHFA home price growth from 1995Q1 to 2012Q3. Here we examine and explain the estimation of all these potential factors:

(1) Home supply: total building permits from 1995–2012 over the 2003 population. In order to consider home supply from existing homes due to the out-migration occurring in cities such as Detroit, we include those declining populations divided by average household size (2.6 people) as additional home supply.

(2) Economy: nominal personal income growth from 1995–2011. In Model 1 of Tab. 3, two major factors – supply (building permits/population) and demand (personal income growth) – account for 24% of the variation (R^2). Both variables are statistically significant at a 1% level. As predicted, home supply has the negative coefficient, which means a larger home supply will result in lower home price appreciation.

(3) Human capital: We use the UCLA City Human Capital Index in 2008. This index is computed based on the average educational attainment of adult residents in an area. We discuss the construction of this variable in more detail in Section 6 below. We suspect that a more educated city will create a home price premium for reasons such as safety and better school districts. In Model 2, human capital is statistically significant at a 1% level. More importantly, the human capital factor boosts the R^2 from 0.24 (Model 1) to 0.37, which demonstrates that it is an important determinant.

(4) Climate: the average temperature in January. It is well known that a migration from the Snow Belt to the Sun Belt has been occurring since technology advancements such as air conditioning have come into play. It is of interest to see if the weather still plays a role in affecting home price growth. In Model 3, it is statistically significant at a 5% level. But considering the fact that the R^2 increased only from 0.37 to 0.38, it does not add too much explanatory power.

Tab. 3: Multiple regression estimations with dependent variable: home price growth between 1995 and 2012

Model	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Home supply growth (1995–2012)	−2.06*** (0.33)	−2.36*** (0.38)	−2.48*** (0.39)	−2.47*** (0.31)	−2.57*** (0.30)	−2.68*** (0.32)	−2.70*** (0.32)
Personal income growth (1995–2011)	0.42*** (0.05)	0.45*** (0.05)	0.42*** (0.05)	0.43*** (0.05)	0.50*** (0.05)	0.53*** (0.06)	0.53*** (0.06)
Human capital 2008		1.56*** (0.25)	1.79*** (0.29)	1.23*** (0.24)	0.64** (0.27)	0.57* (0.31)	0.64* (0.33)
Climate			0.25** (0.05)	−0.07 (0.10)	−0.05 (0.10)	−0.20* (0.12)	−0.20* (0.12)
Ocean				23.58*** (3.66)	22.60*** (4.08)	17.01*** (4.31)	15.88*** (4.61)
City size 2003 (millions of people)					1.60*** (0.60)	1.94*** (0.64)	1.95*** (0.64)
Household size					−28.50*** (7.67)	−31.40*** (8.33)	−29.90*** (8.93)
Geography						0.37*** (0.07)	0.38*** (0.07)
Regulation index							−1.58 (1.75)
N	303	303	303	303	303	245	245
Adjusted R^2	0.24	0.37	0.38	0.46	0.50	0.57	0.57

Note: The numbers in the parentheses indicate standard errors, * indicates a 10% significance level, ** indicates a 5% significance level, and *** indicates a 1% significance level.

(5) Ocean dummy: For cities facing either the Atlantic Ocean or the Pacific Ocean, we assign them as 1[5]. Otherwise, 0. As Rappaport and Sachs (2003) point out, there might be two premiums for cities adjacent to the ocean. First are amenities, and the second is higher productivity and convenience of international trade and traveling. In Model 4, the ocean dummy is statistically significant at a 1% level. And it increases explanatory power from 0.38 to 0.46. However, the January temperature becomes insignificant after the ocean factor is added. This implies that the Sun Belt premium we used to see may have been fading away during the period of 1995 to 2012. The ocean factor is a more appropriate candidate for natural amenities in terms of the demand of homes.

(6) City size: the 2003 population. We suspect that the size of a city could partly represent its amenities, e.g. a more diversified lifestyle and a more public infrastructure. In Model 5, it is statistically significant at a 1% level.

(7) Household size: Given the same population, the larger the household size, the lower the demand of homes will be. Therefore, we suspect that the household size has an inverse relationship with home price growth. In Model 5, indeed it has a negative sign and is statistically significant at a 1% level.

(8) Geographic constraint: Saiz (2010) constructs a land unavailability index for cities in the U.S. based on the mountainous areas and internal waters of cities. The index is presented as the percentage of undevelopable area within a 50-km radius of a metro center. As a supply-side factor, we suspect that a higher value in the index will increase the building cost and therefore home price growth over time. In Model 6, it is statistically significant at a 1% level. It is unclear why this determinant, which is fixed and is easily known, will still produce the expected returns. This seems to contradict the efficient market theory. One possible reason is that facing uncertain demand, the scarcity

[5]We consider coastal cities as those cities whose centers are within 80 km of the Atlantic or Pacific Ocean. We do not consider cities along the Great Lakes or the Gulf of Mexico (except cities in Florida) because the main underlying implication is their amenities.

will create more volatility of home price growth. And this high volatility will need to be compensated for by higher expected return (higher home price appreciation in the long run).

(9) Regulation: As mentioned earlier, studies have shown that environmental and zoning regulations could defer permit and home construction and increase building costs. We suspect that it could explain the higher home price appreciation, which cannot be captured by the home supply factor. For the proxy of regulation, here we adopt the Wharton Residential Urban Land Regulation Index, created by Gyourko et al. (2008). In Model 7, the variable is not statistically significant.

In summary of these seven models, we find that, except for climate (January temperature) and regulation, all other factors are persistently significant and their coefficients are relatively stable.

4 ROBUSTNESS CHECK

In the previous section, we use the nominal FHFA housing price index as the dependent variable. Here, as a robustness check, we use the nominal log median housing prices of MSAs as the alternative dependent variable from American Community Survey of 2010. Tab. 4 presents the estimation results. Comparing Tab. 3 and 4, we find most of the results are consistent. For instance, home supply growth, personal income growth, human capital, an ocean dummy, city size, and geographic constraint are mostly statistically significant at a 1% level. It is worth noting that in Tab. 3, we focus on the home price growth in the past two decades (1995 to 2012). In Tab. 4, we could say we focus on the infinite home price growth because the home price level in 2010 is the accumulative result of all previous home price appreciations in MSAs.

The difference is as follows: (1) Household size has an expected negative impact on home price growth between 1995 and 2012 as shown in Tab. 3 while it has an unexpected positive impact on home price level in 2010 as shown in Tab. 4. The reason is unclear. (2) Regulation is not statistically significant on home price growth (Tab. 3) while it is statistically significant on the price level (Tab. 4). This could imply that a more stringent regulation indeed boosts the building costs and prices in MSAs prior to 1995. But that impact fades away during the period of 1995 to 2012. (3) Earthquakes1 are not statistically significant on home price growth while they are statistically significant on the price level. Model 14 in Tab. 4 has an R^2 of 0.74. Combining Tab. 3 and 4, we could conclude our models and partial correlation inferences are robust and reliable.

5 ENDOGENEITY PROBLEM

The preceeding analysis is useful for in-sample forecasting, but drawing inferences for real-time policy use or out-of-sample forecasting requires further investigation. In particular, in Tab. 3 and 4, our results may be biased because some of right-hand-side variables are endogenous. For instance, home supply growth, personal income growth, human capital level, and city size will be affected by home price growth. To resolve the endogenous problem, the literature usually uses instrumental variables. However, due to the lack of valid instrumental variables, we propose two alternative methods to refine our estimation.

First, we change the sample periods of those endogenous variables to the earlier years or periods. Instead of using the home supply growth and personal income growth from 1995 to 2012, we only use the home supply growth and personal income growth from 1995 to 2003. Although there is an overlapping period (1995 to 2003) for dependent variables and endogenous variables, it is less likely that the

Tab. 4: Multiple regression estimations with dependent variable: log median home price 2012

Model	8	9	10	11	12	13	14
Home supply growth (1995–2012)	−0.00 (0.01)	−0.01** (0.00)	−0.01*** (0.01)	−0.01*** (0.00)	−0.01*** (0.00)	−0.01*** (0.00)	−0.01*** (0.00)
Personal income growth (1995–2011)	0.00*** (0.00)	0.00*** (0.00)	0.00*** (0.00)	0.00*** (0.00)	0.00** (0.00)	0.00*** (0.00)	0.00*** (0.00)
Human capital 2008		0.03*** (0.00)	0.04*** (0.01)	0.03*** (0.00)	0.04*** (0.01)	0.04*** (0.01)	0.03* (0.01)
Climate			0.01*** (0.00)	0.00 (0.00)	0.00 (0.00)	−0.00 (0.00)	−0.00 (0.00)
Ocean				0.46*** (0.06)	0.41*** (0.05)	0.22*** (0.06)	0.16*** (0.05)
City size 2003 (millions of people)					0.02*** (0.01)	0.03*** (0.01)	0.03*** (0.00)
Household size					0.73*** (0.14)	0.70*** (0.18)	0.58*** (0.17)
Geography						0.01*** (0.00)	0.01*** (0.00)
Regulation index							0.12*** (0.02)
Earthquake							0.14 (0.03)
N	304	304	304	304	304	246	246
Adjusted R^2	0.05	0.29	0.33	0.46	0.58	0.66	0.74

Note: The numbers in the parentheses indicate standard errors, * indicates a 10% significance level, ** indicates a 5% significance level, and *** indicates a 1% significance level.

Tab. 5: Multiple regression estimations with dependent variable: home price growth between 1995 and 2012

Model	1	2	3	4	5	6
Home supply growth (1995–2003)	−3.24*** (0.63)	−3.25*** (0.64)	−3.38*** (0.64)	−3.24*** (0.58)	−3.19*** (0.59)	−3.78*** (0.65)
Personal income growth (1995–2003)	0.84*** (0.16)	0.70*** (0.15)	0.64*** (0.15)	0.61*** (0.14)	0.60*** (0.15)	0.78*** (0.18)
Human capital 1990		1.22*** (0.26)	1.42*** (0.28)	0.92*** (0.24)	0.90*** (0.24)	0.88*** (0.26)
Climate			0.24 (0.11)	−0.04 (0.10)	−0.05 (0.10)	−0.20* (0.12)
Ocean				23.28 (3.66)	22.49*** (3.89)	16.39*** (4.86)
City size 1998 (millions of people)					0.72 (0.79)	1.03 (0.80)
Geography						0.29*** (0.08)
N	300	300	300	300	300	244
Adjusted R^2	0.16	0.23	0.24	0.33	0.33	0.43

Note: The numbers in the parentheses indicate standard errors, * indicates a 10% significance level, ** indicates a 5% significance level, and *** indicates a 1% significance level.

Tab. 6: Multiple regression estimations with dependent variable: log median home price 2012

Model	8	9	10	11	12	13	14
Home supply growth (1995–2003)	−0.02*** (0.01)	−0.02** (0.01)	−0.03*** (0.01)	−0.02*** (0.01)	−0.02*** (0.01)	−0.03*** (0.01)	−0.02*** (0.01)
Personal income growth (1995–2003)	0.02*** (0.00)	0.01*** (0.00)	0.01*** (0.00)	0.01*** (0.00)	0.01** (0.00)	0.01*** (0.00)	0.01*** (0.00)
Human capital 1990		0.04*** (0.01)	0.04*** (0.01)	0.03*** (0.00)	0.03*** (0.01)	0.03*** (0.00)	0.03*** (0.00)
Climate			0.01** (0.00)	0.00 (0.00)	0.00 (0.00)	−0.00** (0.00)	−0.00*** (0.00)
Ocean				0.42*** (0.06)	0.37*** (0.06)	0.18*** (0.05)	0.19*** (0.05)
City size 1998 (millions of people)					0.04*** (0.01)	0.04*** (0.01)	0.04*** (0.01)
Geography						0.01*** (0.00)	0.01*** (0.00)
Earthquake							0.12*** (0.03)
N	301	301	301	301	301	245	245
Adjusted R^2	0.21	0.44	0.47	0.58	0.60	0.69	0.71

Note: The numbers in the parentheses indicate standard errors, * indicates a 10% significance level, ** indicates a 5% significance level, and *** indicates a 1% significance level.

Tab. 7: Multiple regression estimations with dependent variable: home price growth between 2004 and 2012

Model	1	2	3	4	5	6
Home supply growth (1995–2003)	−1.41*** (0.36)	−1.41*** (0.36)	−1.41*** (0.32)	−1.43*** (0.32)	−1.50*** (0.40)	−1.47*** (0.49)
Personal income growth (1995–2003)	0.00 (0.10)	−0.01 (0.11)	−0.01 (0.12)	−0.01 (0.12)	0.01 (0.12)	0.08 (0.15)
Human capital 1990		0.03 (0.18)	0.03 (0.22)	0.10 (0.23)	0.14 (0.24)	0.16 (0.23)
Climate			−0.01 (0.10)	0.04 (0.11)	0.04 (0.11)	−0.04 (0.10)
Ocean				−3.48 (2.83)	−2.31 (2.98)	−1.35 (3.68)
City size 1998 (millions of people)					−1.06 (0.75)	−0.72 (0.67)
Geography						−0.05 (0.06)
N	301	301	301	301	301	245
Adjusted R^2	0.09	0.08	0.08	0.08	0.09	0.09

Note: The numbers in the parentheses indicate standard errors, * indicates a 10% significance level, ** indicates a 5% significance level, and *** indicates a 1% significance level.

home price appreciation between 1995 and 2012 will cause the growth of personal income or home supply between 1995 and 2003. For the human capital level, we use the data in 1990 instead of 2008. This would be sufficiently exogenous. For city size (population), we use 1998 instead of 2003. Since we do not have the data of regulation in the earlier year, we exclude it in the regression.

The estimation results are displayed in Tab. 5. By and large, we get a similar result as that in Tab. 3. Home supply growth, personal income growth, human capital levels in 1990, the ocean dummy and geographic constraints

are all statistically significant at a 1% level. The only difference is the city size in 1998, which becomes statistically insignificant.

In Tab. 6, following Tab. 5 for adjusting the sample periods of endogenous variables, we use the log median home price as the dependent variable. The results in Tab. 6 are consistent with those in Tab. 4. Again, this proves that our determinants' predictions are robust and more likely exogenous. It is worth noting that we use the human capital level of 1990, and it still can predict home price growth from 1995 to 2012 as well as the median home price in 2010. Not only do we know that human capital is an important determinant of home price premium, but also that it is a good long-term predictor because of its persistence.

In Tab. 7, we extend our alternative method to an extreme. We change our sample period of the home price growth to the period of 2004 to 2012. In this case, we exclude any possibility of endogeneity. The results, however, are not appealing. First, the R^2 is low (around 0.09). Second, only home supply growth is statistically significant while all other variables become insignificant. One possible reason for this result is that the second half of the sample period (2004 to 2012) experienced the swift housing price bubble and bust. Thus this period is not an ideal sample period for the long-term fundamental analysis.

6 HUMAN CAPITAL

One contribution of this paper is that we use the UCLA Human Capital Index, which calculates the mean of residents' education attainments, rather than the percentage of bachelor's degree or higher used by all the literature, if they use any related variable at all. In other words, our variable is a more comprehensive indicator of human capital in MSAs than the simple percentage of higher educated residents.

We compute the index based on three parts with corresponding population percentages as follows. We do not consider the migration factor of human capital because there is no available data.

(1) For those residents who are above 25 years of age, we calculate the CHCI by assigning the attained schooling years using the following categories:

- Category 1: Less than 9th grade: we assign 5 schooling years (50 CHCI points) for this percentage of residents.
- Category 2: 9th to 12th grade: we assign 10 schooling years.
- Category 3: High school graduate: we assign 12 schooling years.
- Category 4: Some college, no degree: we assign 13 schooling years.
- Category 5: Associate's degree: we assign 14 schooling years.
- Category 6: Bachelor's degree: we assign 16 schooling years.
- Category 7: Graduate or professional degree: we assign 18 schooling years.

(2) For those residents who are between 18 and 24 years of age, we estimate the CHCI by assigning the schooling year with the following categories:

- Category 1: less than high school graduate: we assign X schooling years, in which X is estimated by the CHCI average of Categories 1 and 2 from Part (1) in the same region.
- Category 2: High school graduate: we assign 12 schooling years.
- Category 3: Some college or associate's degree: we assign Y schooling years, in which Y is estimated by the weighted average of Categories 4, 5, 6, and 7 from Part (1) in the same region.
- Category 4: Bachelor's degree or higher: we assign 16 schooling years.

(3) For those residents who are between 5 and 17 years of age, we forecast their future potential CHCI based on the CHCI average of

Tab. 8: Multiple regression estimations with dependent variable: home price growth between 1995 and 2012

Dependent variable	**Home price growth 1995 to 2012**		**Log median home price 2010**		**Home price growth 1995 to 2012**		**Log median home price 2010**	
Endogenous variable	**The whole sample**		**The whole sample**		**The earlier period of year**		**The earlier period of year**	
Model	**(7)**		**(14)**		**(6)**		**(14)**	
Home supply growth	−2.70*** (0.32)	−2.69*** (0.32)	−0.01*** (0.00)	−0.01*** (0.00)	−3.78*** (0.65)	−3.68*** (0.64)	−0.02*** (0.01)	−0.02*** (0.01)
Personal income growth	0.53*** (0.06)	0.50*** (0.06)	0.00*** (0.00)	0.00*** (0.00)	0.78*** (0.18)	0.68*** (0.18)	0.01*** (0.00)	0.01*** (0.00)
City human capital index	**0.64* (0.33)**		**0.03* (0.01)**		**0.88*** (0.26)**		**0.03*** (0.00)**	
Bachelor's degree		**0.64*** (0.21)**		**0.02*** (0.00)**		**1.21*** (0.22)**		**0.03*** (0.00)**
Climate	−0.20* (0.12)	−0.19* (0.11)	−0.00 (0.00)	−0.00*** (0.00)	−0.20* (0.12)	−0.19* (0.11)	−0.00*** (0.00)	−0.01*** (0.00)
Ocean	15.88*** (4.61)	15.89*** (4.36)	0.16*** (0.05)	0.16*** (0.04)	16.39*** (4.86)	16.32*** (4.47)	0.19*** (0.05)	0.21*** (0.05)
City size (millions of people)	1.95*** (0.64)	1.65** (0.66)	0.03*** (0.01)	0.02*** (0.01)	1.03 (0.80)	0.55 (0.85)	0.04*** (0.01)	0.04*** (0.01)
Household size	−29.90*** (8.93)	−31.70*** (6.63)	0.58*** (0.17)	0.22* (0.11)				
Geography	0.38*** (0.07)	0.38*** (0.06)	0.01*** (0.00)	0.00*** (0.00)	0.29*** (0.08)	0.31*** (0.07)	0.01*** (0.00)	0.01*** (0.00)
Regulation index	−1.58 (1.75)	−2.31 (1.66)	0.12*** (0.02)	0.11*** (0.02)				
Earthquake			0.14*** (0.03)	0.15*** (0.03)			0.12*** (0.03)	0.13*** (0.03)
N	245	245	246	303	244	245	245	245
Adjusted R^2	0.57	0.58	0.74	0.78	0.43	0.47	0.71	0.74

Note: The numbers in the parentheses indicate standard errors, * indicates a 10% significance level, ** indicates a 5% significance level, and *** indicates a 1% significance level.

the CHCI of residents from Part (1) in the same region with the following weighted adjustment of their current school enrollment rate:

- Category 1: 5 to 9 years old: if the area's enrollment rate is, say 94%, 94% will be assigned CHCI calculated from Part (1) and 6% of this area's residents will be assigned as 2 schooling years.
- Category 2: 10 to 14 years old: if the area's enrollment rate is Z, Z will be assigned CHCI calculated from Part (1), and $1 - Z$ of this area's residents will be assigned as 7 schooling years.
- Category 3: 15 to 17 years old: if the area's enrollment rate is Z, $1 - Z$ of this area's residents will be assigned as 11 schooling years.

Does our human capital index provide more value than the traditional measurement of human capital? Surprisingly, based on the results in Tab. 8, the answer is no. The percentage of bachelor's degree seems to (1) have a higher R^2 by 0.04 on average than city human capital index, and (2) have larger t-statistics. The possible reasons are twofold: First, the percentage of bachelor's degree has a higher standard deviation while the city human capital index has a lower standard deviation because it is calculated based on the average number of schooling years. Second, the average number of schooling years of residents could be more correlated to other variables, such as household size. Nevertheless, both human capital index and bachelor's degrees provide equivalently insightful inferences on housing price appreciation.

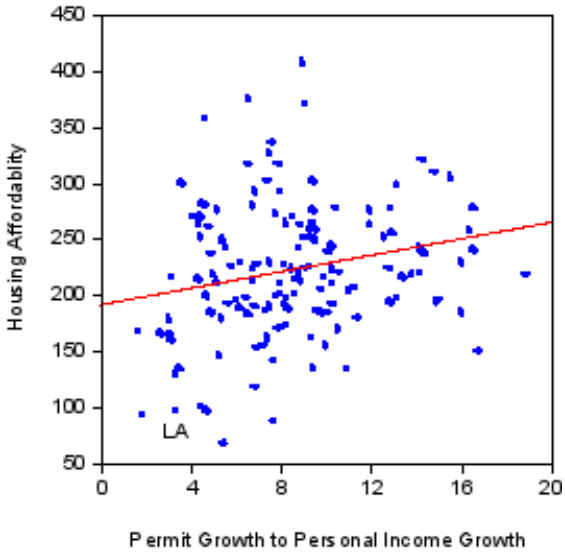

Fig. 4: The correlation between housing affordability in 2011 and the ratio of permit growth to personal income growth (1995–2011)
Sources: Housing affordability is from the National Association of Realtors, permit numbers are from the U.S. Census, and the personal income growth and population is from the Bureau of Economic Analysis.

7 POLICY IMPLICATIONS

This paper has an important practical use for policymakers concerned with housing affordability through its emphasis on distinguishing between cyclical fluctuations in housing prices and long-term, though-the-cycle trends. Most demand-side factors are broader in nature than housing-policy specific factors. For instance, if regional home price growth is driven by demand factors, such as income growth, employment growth, population growth, or human capital enhancement (educated workers migration or local school improvement), it is a symbol of the vibrant and resilient trend or cycle. Residents should embrace the situation and celebrate with the steadily rising home prices.

Yet, if the regional home price growth is driven by the supply factor, which means that a limited number of building permits is driving up the home price, then we suggest that it will hamper a city's growth. Less affordable housing will increase the cost for renters and immigrants who may come to the city. As a result, it will also increase the cost of businesses as employers offer higher wages to compensate for the higher cost of living that employees are facing. Fig. 4 shows the correlation between our simple supply-to-demand ratio and the housing affordability index. An adequate number of construction and building permits in line with the demand of homes in a city is more likely to temper home price appreciation and to provide affordable housing.

Policymakers must distinguish between cyclical and trend factors in constructing housing policy. Our simple supply-demand ratio can be valuable in this task. Many macroeconomic demand-side factors, such as income growth, are drivers of housing demand, and it would be inappropriate to respond at a local level to cyclical fluctuations in income growth with active policy. Rather, policymakers should seek to balance supply and demand through the business cycle, by ensuring that supply is allowed to keep up with long-term trends rather than cyclical fluctuations.

8 CONCLUSIONS

Based on the FHFA nominal home price growth from 1995 to 2012 and the Census nominal median home price in 2010 for MSAs, this paper identifies several determinants to predict the home price growth and home price level: (1) Home supply growth, measured by the total permit growth. (2) Personal income growth, which captures a region's growth of population, employment, and income. (3) Human capital level, measured by the city human capital index and the percentage of residents holding a bachelor's degree or higher. (4) Ocean dummy, which demonstrates the amenities provided by facing the Atlantic or Pacific Oceans. (5) Geographic constraints, measured by Saiz (2010)'s percentage of undevelopable area in a city.

This paper provides three contributions to the literature: (1) The selection of our single sample period could avoid the complex issues that accompany housing bubbles and busts. Moreover, we propose a simple sample partition method to improve the endogeneity problem. (2) We calculate a simple supply-to-demand ratio, as a proxy of supply elasticity, which could be an easy measurement to determine whether or not a city has an adequate home supply to fit its demand in the long run. (3) We provide an alternative measurement for a city's human capital and verify the importance of education and a skilled workforce to a city's housing market.

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RISK MANAGEMENT AND PERFORMANCE OF LISTED BANKS IN GHANA

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ABSTRACT

The objective of the study was in two parts; first, to construct an overall risk index to ascertain risk level of banks listed on Ghana Stock Exchange (GSE), second, to ascertain whether there is a significant relationship between risk management and bank performance. Secondary data of all listed banks on GSE over the period 2007–2014 was used and a panel regression data approach and a risk index were constructed for all listed banks. Findings show that, banks listed on Ghana Stock Exchange have declining risk indexes on average over the latter part of the study period indicating that the Ghanaian Banking Regulator may have to impose additional prudential and regulatory requirements to ensure banks remain solvent. We also find evidence that risk management is positively related to performance of GSE listed banks when the latter is measured from ROE perspective.

KEY WORDS

capital adequacy, risk management, Ghana stock exchange, bank performance, risk index

JEL CODES

G21, G28, G32, G38, L25

1 INTRODUCTION

In recent world economy, risk management has become a very important tool for financial institutions. Banks form large proportion of the world's leading companies and have critical role to play in the economy of every country and the world economy at large. Essentially, financial institutions' core business involves risks taking in conditions of uncertainty. The global financial sector is expanding with additional banks springing up every day, this coupled with world financial crises makes it imperative to determine the risk levels of banks and in addition examines the effects it has on their performance. Banking business involves

taking risk and ensures that the consequences arising from deposits, granting of loans and trading portfolios are mitigated (Jaiye, 2009). In Ghana, the enactment of the new Banking Act of 2004, Act 673, introduce universal banking license, which enable banks to provide various banking services. Currently, there are 32 registered banks (Bank of Ghana, 2016) with seven listed on Ghana Stock Exchange (GSE).

Bloom and Milkovich (1998) therefore defines as the possibility of an adverse event happening and its negative effect affects firms. It is the uncertainty that may lead to adverse variations of profitability or losses (Bessis, 2002). The fundamental issue presented in both definitions suggests that, risk present two different outcomes, however, managers are mostly concerned with the adverse outcome. The effort to manage risk (the adverse outcome) is to ensure that risks are taken with full awareness and knowledge, defined purpose with understanding to enhance measurement and mitigation. However, it does not involve prohibition or prevention of risk taking activity. Most of the global financial crises would not have occurred with proper risk management; hence, risk must optimally be managed by banks'.

There exist at least three reasons why managers engage in risk management activities. First among them is the manager's self-interest of protecting their position and wealth in the firm. Secondly, the cost of possible financial distress, thus; significant losses of earnings which can result in stakeholders losing confidence in the operations of the firm, loss of competitive strategic position in the industry, withdrawal of license and even bankruptcy. Finally, the imperfection nature of the capital market is one of the reasons for risk management (Oldfield and Santomero, 1995). One of the approaches to deal with this is to build confidence in stakeholders by listing on the stock market. This establishes a lasting connection with foreign banks, which offer medium to long-term benefits in terms of financial intermediation in the economy. In order to achieve this, there is the need for a proper risk management in order to optimally manage risk. Vast number of literature suggests an enormous effect of risk management on performance of bank and other financial institutions. However, evidence to show the position of listed banks is still limited. Studies of Odonkor et al. (2011), Naïmy (2005), Uwuigbe et al. (2015) and Boahene et al. (2012) have all examined risk and performance of bank, however, in most cases, they focus on the entire banking industry. Our objective is to fill this gap by ascertaining the risk levels of banks listed on the GSE and assess how it impact on their performance in Ghana. The study is therefore organized as follows. Section 2 provide a review of literature on the subject while Section 3 explains the methodology used. Section 4 and Section 5 present a discussion of the results; and conclusion respectively. With our approach, firstly, we determine the overall risk levels of listed banks on Ghana Stock Exchange; we adopt an index proposed by Hannan and Hanweck (1988) and construct a risk index following Altman z-score approach. Using risk index we are able to determine both risky and safer listed banks for the period 2007–2014. Secondly, we focus on GSE listed banks, which is the first study to determine the overall risk levels of banks listed on GSE. Since the last decade, the stock market of Ghana has been an emerging market of promise above established average performance.

2 LITERATURE REVIEW

In this section we present literature on major risks influencing banks in Section 2.1, in Section 2.2 we provide literature on the management of these risks and finally provide an empirical literature in Section 2.3.

2.1 Bank Risks

Koch and MacDonald (2000) describe credit risk as the uncertainty that counterparties to a loan and derivatives transactions might default, this implies that a party to a transaction

fails to honour his part of the obligation by settling the interest and principal at agreed time. This is consistent with opinion of Fabozzi et al. (2010) which states that credit risk is a type of risk involving the likelihood that an obligator of a financial instrument will not be able to fulfill the associated obligation on timely basis. Credit risk is the common and greatest risk affecting bank performance in the financial industry. Credit risk may be firm specific or systematic. Firm specific credit risk is the risk of default of a firm whose borrowing is linked to a particular project, which the bank has entered into. However, systematic credit risk relates to default that is linked to macroeconomic indicators, which affects all borrowers (Saunders and Cornett, 2006).

Market risk is the uncertainty relating to financial institutions' earnings on their business portfolio (Saunders and Cornett, 2006). Certainly, market risk could is caused by fluctuations in market conditions such as market volatility, interest rates, and market liquidity as well as asset prices. Pyle (1997) posits that market risk is the variations in the asset value due to changes in contributory economic factors such as equity and commodity prices, exchange rates, interest rate. It has to do with losses of on and off balance sheet positions of banks arising from unfavourable changes in market prices. In the banking sector, financial institutions battle with three key market risk factors: foreign exchange rates, liquidity and interest rates (Bank of Tanzania, 2010).

This is the risk that, unfavourable exchange rate fluctuations leads to loss during a period in which banks have open position on forward, spot or both in the same foreign currency (Raghavan, 2003). Generally, foreign exchange market dominates all the financial markets. According Bessis (2010), it is the risk of incurring losses because of changes in exchange rates. These losses arise due the mismatch existing between the value of assets, capital and liabilities that are denominated in foreign currencies or foreign receivables and foreign payables mismatch expressed in a local currency. Wood and Kellman (2013) states four major activities that takes place in foreign exchange markets: buying and selling of foreign currency to enable customers execute commercial trade transactions; buying and selling of foreign currencies for customers to be able to have better standing in investment; buying and selling of foreign currencies for hedging purposes and buying and selling of foreign currencies for speculative purposes.

Gup and Kolari (2005) have described liquidity risk as the probability that a bank may not be able to perform its obligations to its depositors and provide the needs of borrowers by turning assets to liquid assets immediately with minimum loss with the ability to borrow funds when required and at the same time have enough funds available to undertake profitable securities trading transactions. Liquidity is a necessity for financial institutions in order to compensate for expected and unexpected fluctuations on the balance sheet to enhance growth (van Greuning and Brajovic Bratanovic, 2009). However, some banks integrate the need to plan to cater for growth and unexpected credit expansion, the risk here should be regarded more correctly as the potential for funding crisis (Santomero, 1997). According to Basel committee on Bank supervision (2008), the basic role of banks during maturity transformation of short-term deposits into long-term loans makes them essentially vulnerable to liquidity risk of the bank as an institution and the market as a whole (systemic). There are two fundamental circumstances from which liquidity risk may arise. Firstly, depositors of banks' might pursue to withdraw their financial claims instantly. In this regard, the bank may need to meet this sudden demand by resorting to borrowing or selling of assets. Secondly, liquidity risk may also occur banks are suppliers of off balance sheet loan obligations. If borrowers decide to draw on their loan obligations, it must have immediate resources to fund it quickly, hence the demand for liquidity.

The main circumstance under which interest rate risk arises is the mis-match between assets and liabilities of bank's portfolio. This usually occurs since banks' assets and liabilities are highly dependent on interest rates. Interest rate risk can be classified into reinvestment and

refinancing risk. The latter is the risk that the cost of borrowing funds will be higher than the current returns earned on invested assets. However, the former, the risk that returns on funds will not exceed the cost of funds (Saunders and Cornett, 2006). Kanchu and Kumar (2013) posit that, interest rate risk is the vulnerability of financial institutions to the fluctuations of interest rate; hence interest rate risk has potential negative impacts on the net interest income. Such fluctuations affect, earnings, assets value, off balance sheet liability items as well as cash flow. From earnings perspective, it focuses on the analysis of the impact of variations in interest rates on accrual or reported earnings in the near term. This could be computed as net interest income equivalent to the difference between total interest income and total interest expenses (Kanchu and Kumar, 2013). Four main sources of interest rate risk that financial institutions encounter are: yield curve risk, basis risk, repricing risk and optionality. Most often, discussions on interest rate risk stems from timing disparities in the maturity of fixed rates and repricing of floating rates of bank liabilities, assets and off balance sheet positions (van Greuning and Brajovic Bratanovic, 2009).

2.2 Managing Risk

The major task of risk management is to enhance shareholders' return incorporating bank performance. The motivation of banks' risk management comes as a result of underperformance. Highlighting more on the essence of implementing a risk management program, Cebenoyan and Strahan (2004) states that, risk management increases banks' reputation and opportunity to be attractive to customers in building their portfolio of fund resources; it also improves bank's efficiency as well as profitability. According to Moreno (2006), banks' capacity to manage it risk partially depends on how well interbank market is organized and operated. A specific fear is the vulnerabilities existing in the banking system in the form of shocks that might reduce liquidity in the interbank market. This could be a significant source of spreading financial crisis.

In an attempt to mitigate shocks, some banks might choose to withdraw liquidity from interbank market. Turner (2006) states that, there are two general inferences that arose in debate regarding the management of recent risk that banks face. Firstly, there has been a radical change in the nature of macroeconomic risk. External vulnerabilities which usually lead to imprudent macroeconomic policies and intensified earlier banking crisis have significantly disappeared. However, other views suggest that some domestic macroeconomic risks were severe recently than a decade ago. Secondly, lending activities of banks were informed by a better risk assessment management approach. At the same time, modern techniques have given rise to new risks, which were difficult to quantify (Moreno, 2006). The application of quantitative risk management techniques by banks in developing markets has expanded significantly. There is a growing trend in the market indicating that valuations are based on market prices; quantification of risks are done mainly using VaR models; risk scoring models are used in the assessment of credit risk to household and small business borrowers. Bank portfolios are stress-tested for various adverse scenarios; moreover, pricing and provision for credit facilities are increasingly grounded on quantitative assessments.

2.3 Empirical Literature

Risk of a firm as illustrated by portfolio theory of Donaldson (2000) was a new model for performance-driven organisation change where risk plays a pivotal role. Whether a firm is probable to effect adaptive changes or not; and whether there is the likelihood of growing or not, there is the need to have an understanding of the level of its risk. The awareness created by stock market downturns in 2000 and 2001 shows that, the underlying risk of financial institutions and the industry is equally important just like the financial performance of firms (Orlitzky and Benjamin, 2001). For practical and managerial significance, managers are not only concerned

with possible factors and consequences of financial performance levels but also their risk. The difference between future bankruptcy and organizational health of firms are determined by management's ability to manage risk.

Studies on risk management and financial performance have been essentially conceptual focusing on theoretical frameworks provided by regulators (Soyemi et al., 2014). The major objective of bank management is to maximize shareholders' return showing bank performance. However, this comes at a cost of increasing risk levels (Tandelilin et al., 2007). In the long-run, the market as well as events in the environment penalize the attitude of increasing bank risks. As a result, principals and agents are more concerned about the level of risk incurred by the banks (Bloom and Milkovich, 1998). Hence, managements' motivation for managing risk stems from risks that can result in underperformance. In this sense, Schroeck (2002) and Nocco and Stulz (2006) present two contrasting views. Thus, the latter stress that the implementation of effective enterprise risk management (ERM) by firms (banks) results in competitive advantage in the long-run relative to firms who manage and monitor risks separately. However, the former propose that ensuring best practices through the establishment of effective and prudent risk management practices increases earnings. In this regard, we suggest a holistic approach of managing risk.

Bettis and Thomas (1990) found that, low risk level allows for proper planning since low risk firms are able to project their future cash flows with greater level of certainty. As a result, Odonkor et al. (2011) suggest that firms with low risk face minimum uncertainty in relation to future business opportunities as well as opportunity cost regarding performance. Moreover, Smithson and Simkins (2005) conclude that firm value is increased when firms risk levels are lower, hence, it could be inferred that, financial institutions need to put in significant measures to mitigate their risk exposure. Carey and Stulz (2005) stress that financial institutions that are too risky could lose substantial proportion of their franchise. Merton and Perold (1993) in earlier studies underscored that risk management is exclusively vital for financial institutions since their liabilities serve as the main source of shareholders wealth. In addition, Merton and Perold (1993) give an instance where long dated derivatives written by financial institutions would ordinarily be shut out of market provided credit rating of vehicles used to write such derivatives fell below an A rating. Since the value of franchise depends on risk, a bank or financial institution has an optimal risk level at which shareholders' value is maximized. However, risk maximization is certainly not optimal since franchise value cannot be ascertained without bearing risks, hence; firms always bear costs and enjoy benefits when there is an increase in risk level (Carey and Stulz, 2005).

Bruner (2011) offers another dimension that, taking excessive risk enhances performance. Thus, a reduction in the risk-free rate of interest to minimum levels led to credit expansion, which was an aggressive quest for yield among investors. Therefore, key global financial crisis were attributed to excessive ambition of management and board, in so doing, they take excess risk to boost prices of stock.

Zhang et al. (2013) studied the relationship between market concentration, risk-taking and bank performance and conclude that banks taking a lower level of risks perform better with prudent risk management practice. Moreover, this study served as a foundation to suggest that BRICs' banking sectors were severely affected negatively during the 2007–2008 global economic meltdowns. Moreover, findings by Jafari et al. (2011) show that total risk management and performance have a significant positive association especially with firms found in investing in modernizations research capacities research and development as well as intellectual property.

Digging into specific risks that banks face, Ogilo (2012) analyzed how credit risk affects commercial bank in Kenya using CAMEL indicators and found that financial performance of banks are strongly affected by these indicators. Similarly, Nawaz et al. (2012) found that credit risk management significantly impact

on profitability of Nigerian banks and posit that management need to be cautious when establishing credit policy which may inversely affect profitability and operation of banks to ensure judicious utilization of deposits.

In the Ghanaian context, Odonkor et al. (2011) investigated the effect of bank performance with a panel data of 18 banks for the period 1997–2008. Evidence shows that lower risk levels increases bank performance; furthermore, it was established that bigger banks are able to accommodate more risk leading to higher performance when there is an interaction between size and risk. Boahene et al. (2012) suggest that there is a positive and significant relationship between credit risk and bank profitability. This is enough evidence to conclude that despite high level of credit risk in the Ghanaian banking industry, some banks continue to earn high profit. In a related study, Ariffin (2012) however, show that liquidity risk and performance of banks in Malaysian banking industry cannot always be predicted using the traditional finance theory of high risk and high return approach. This implies that performance (measured by ROA and ROE) may decline because of liquidity risk. The trend in liquidity of Islamic banks was inconsistent during the period of financial crises. Moreover, Arif and Nauman Anees (2012), show bank profitability is negatively affected by liquidity risk with non-performing loans and liquidity gap as the major contributing factors.

3 METHODOLOGY

3.1 Data

The banking industry in Ghana was considered as the population and this is made up of 32 registered banks (Bank of Ghana, 2016). Seven out of these, which were listed on the Ghana Stock Exchange (GSE), were selected. These were banks that have been on the stock market for the last 10 years with 4 of them been indigenous Ghanaian banks. Data covering the period 2007–2014 was used for the analysis and we relied on secondary data based on audited annual accounts of these banks as well as the statutory returns submitted to Bank of Ghana. Other data used such as inflation and exchange rate. Data on inflation and exchange rate were sought from databases of Ghana Statistical service and Bank of Ghana respectively.

3.2 Performance Indicators

We follow the approach of Naïmy (2005) in determining our performance indicators; hence, we adopt return on assets (ROA) and return on equity (ROE) as the performance measures. The former is regarded as the having prominence as the accounting measure of performance and is a critical element of loan quality in terms of determining bank performance (Naïmy, 2011). ROE however, measures performance from shareholders perspective, hence, measure accounting profit per dollar of book value of equity capital, which can be computed by dividing net income by total equity. However, this can be decomposed into equity multiplier or leverage factor and return on capital (Naïmy, 2011).

Therefore:

$$\mathrm{ROE} = \mathrm{ROA} \times \mathrm{EM},$$

where ROA is defined as net income divided by total assets and EM is total assets divided by total equity. By this, we provide a gauge of an institution's leverage base equity multiplier.

3.3 Risk Index

In this study, we construct a Risk Index as proposed by Hannan and Hanweck (1988) which measure perceived insolvency of banks. Various studies that have investigated risk management issues have adopted the risk index and these include: Nash and Sinkey (1997); Blaško and Sinkey (2006); Eisenbeis and Kwast (1991); Sinkey and Nash (1993); Liang and Savage (1990); Naïmy (2005), Odonkor et al. (2011) and Ofoeda et al. (2012). Risk index captures

the overall risk of banks' and indicating the risk taking behaviour of banks and since it is constructed based on financial ratios, it is appropriate for investigating risk management and bank performance. The variability of ROA offers a comprehensive measure that indicates credit risk, operational risk, interest rate risk, liquidity risk and other risk that hinder the realization of banks' earnings (Naïmy, 2011). The standard deviation of ROA is regarded as a good measure of variability of ROA while CAP (inverse of equity multiplier or equity capital to assets ratio) of banks, is often used as a proxy for risk for financial institutions since high level of capital provide protection for banks. Therefore, ceteris paribus, we can conclude that, highly capitalized banks bear less insolvency risk. We provide the Risk index through a combination of CAP, ROA and standard deviation of ROA. The empirical form of this index is

$$\mathrm{RI} = \frac{\mathrm{ROA} + \mathrm{CAP}}{\sigma \mathrm{ROA}},$$

where RI = risk index for the various banks under study; ROA = return on assets for each institution for each year; CAP = inverse of equity multiplier of equity capital to assets ratio.

Risk index (RI) measures measure the extent to which a bank's accounting earnings can fall until it reaches negative; it is expressed in units of standard deviation of ROA. According to Naïmy (2005), risk index is an appealing risk measure since it includes ROA, which is a widely accepted accounting indicator of overall bank performance. An industry standard to measure bank safety and soundness is book capital adequacy while variability of ROA serves as the standard measure of risk in financial economics (Sakyi et al., 2014). Although, there is no defined level for risk index, it is expected that, risky firms would have a lower risk index and vice versa.

3.4 Econometric Model

Bank performance literature underscore a number of factors that affect performance of financial institutions, these include risk, other firm level factors such as size, leverage; market factors such as market share and macroeconomic factors including inflation and exchange rate. On this basis, we use a modified panel regression model of Dietrich and Wanzenried (2011) which is also in line with that used by Odonkor et al. (2011) and Sakyi et al. (2014).

$$\begin{aligned}\mathrm{BKPER}_{it} \quad = \quad & \alpha_i + \alpha_1 \mathrm{RI}_{it} + \alpha_2 \mathrm{SIZE}_{it} + \\ & + \alpha_3 \mathrm{CAP}_{it} + \alpha_4 \mathrm{LQT}_{it} + \\ & + \alpha_5 \mathrm{NPL}_{it} + \alpha_6 \mathrm{INF}_{t} + \\ & + \alpha_8 \mathrm{EX}_{t} + \epsilon_{it},\end{aligned}$$

where BKPER = performance of banks ROA and ROE (ROA is defined as bank net income divided by total equity while ROE is bank net income divided by total equity); α_0 = constant term; RI = risk index, a measure of risk management; SIZE = size of bank calculated as the natural log of total assets; CAP = a measure of bank solvency measured as the ratio of book value of equity capital to total assets; LQT = a measure of bank liquidity and it is measures as total advances divided by total deposits; NPL = non-performing loans is an indicator of a bank's credit risk, therefore reflects a bank's credit quality and it is measured as the proportion of net nonperforming loans in net bank loans measures it; INF = inflation is measured by using the annual inflation rate of Ghana statistical service; EX = exchange rate measured as the average annual exchange rate Bank of Ghana; i = represent each of the individual banks for the study; t = represent the time specific effect; ϵ = residual term.

3.5 Explanation of Variables

In this study, a positive relationship is expected between risk index and performance (ROA and ROE) of listed banks. That is to suggest that, a bank with lower level of risk is probable to have more credit available, which offers banks the opportunity to increase productive assets and profitability (Cebenoyan and Strahan, 2004)

Size of a bank is usually measured by the natural log of total assets, hence the higher the size of a bank, the higher its ability to take risk (Saunders et al., 1990). Large firms

are more diversified; therefore, hold more assets than smaller ones. The former are able to better manage and have in place better financial and organizational structure (Psillaki et al., 2010). In the financial sector, potential economies and diseconomies of scale are generally captured using firm size. It therefore controls for the variations of in cost and product and risk diversification depending on the size of the bank. Empirical evidence on size provides mixed results. Thus, Short, (1979), Bikker and Hu (2002), Ben Naceur and Goaied (2008) all establish a positive relationship between size and performance. However, Kasman et al. (2010) find a negative and statistically significant relationship with net interest margin (performance). Moreover, Kosmidou et al. (2005) establish that small firms display higher profitability relative to larger firms. On this basis, we expect size to be positively or negatively related to performance of banks.

Solvency measure (CAP) implies that financial institutions are expected to maintain adequate capital for the purpose of long-term stability. High level of equity capital of a bank eventually lowers its risk of insolvency and vice versa (Maji et al., 2011). As a high RI indicates lower insolvency risk, a positive association between RI and our solvency measure (CAP) is expected to be positive.

Liquidity of a bank is generally measured as the ratio of liquid cash liquid cash assets to total assets. Following the classical concept of liquid assets in bank management literature, the definition of bank liquid assets include cash and bank balance, money at call and short notice and short-term investment (Alger and Alger, 1999). Usually, higher liquidity ratio is understood as having a positive effect on the stability of a bank. However, excessive investment in liquid assets is likely to affect the profitability of the bank; therefore, a trade-off between liquidity and profitability is necessary.

Non-performing loans (NPL): non-performing loans arises from a banks inability to recover loans and advances from clients. Therefore, the ratio of net non-performing loans to net loans and advances has been widely accepted and used as a measure of credit risk by researchers (Maji et al., 2011). Banks total loans divided by total assets and ratio of loans provision to total assets have also been widely used as a measure of credit risk; however, in this study the ratio of net non-performing loans to net loans and advances is used as an indicator of credit risk. Credit risk increases when the ratio of net non-performing loans to net loans and advances increases, hence, theoretically, a negative relationship is expected between non-performing loans (credit risk) and risk index.

Inflation and its relationship with bank performance (profitability) is labeled ambiguous. The effect of inflation on bank performance largely depends on whether there is a similar rate of change in wages as well as other operating expenses. Evidence to support the impact of inflation on bank performance (profitability) are mixed. Studies have shown that higher inflation rate results in higher bank performance (profitability) (Guru et al., 2002 and Jiang et al., 2003). However, others found a negative relationship (Abreu and Mendes, 2002 and Ayadi and Boujelbène, 2012). Mostly in developing countries, Demirgüç-Kunt and Huizinga (1999) observe that banks are less profitable in inflationary environment especially those with high capital ratio. When income of banks rises rapidly compared to its cost, it extends a positive effect on profitability, hence increase bank performance and vice versa. In this study, we expect inflation and bank performance to have an inverse relationship.

Exchange rate measures the impact of environmental conditions on the banking industry. However, the resultant impact largely depends on whether the adopted exchange rate regime is fixed or flexible. In case of the former, Domaç and Martinez Peria (2003) show that exchange rate diminish the probability of crisis in the banking industry in developing countries, hence, profit is increased. However, in previous findings Eichengreen and Arteta (2002) detected that both fixed and flexible regimes are vulnerable to banking crisis, which implies low levels of profitability. Therefore, exchange rate is expected to have a negative effect on profit levels of banks.

4 RESULTS AND DISCUSSION

4.1 Discussion of the Risk Level of Banks Listed on Ghana Stock Exchange

The risk levels of Ghanaian listed banks are computed for the period of study and presented in the Tab. 1. The overall risk index for individual banks listed on Ghana Stock Exchange (GSE) improved from an average of 25.93 in 2007 to a peak of about 33.3 in 2010 and steadily fell to about 26.54 in 2013 but with a sharp fall in 2014 hitting 8.58. This could be attributable to the harsh economic conditions in 2014 resulting from the major power outages facing many industries in the country and hence increasing banks risks exposures.

Tab. 1 also indicates that UT Bank was the most risky bank over the period scoring the lowest risk index and averaging around 2.28 whilst the average risk index over the entire period was about 25.93. This could therefore be attributed to tough competition that it has faced since it converted from financial Service to bank in 2007. Our findings further suggest that, SSG Bank was the safest among all the banks constantly out preforming all the other banks over the entire period except in 2014 and recorded the highest average risk index of 54.28 for the period under review. This may be attributed to its conservative banking philosophy. All indigenous Ghanaian banks; GCB, CAL and UT had average risk index of about 13, 22.58 and 2.28 far below the overall average of 25.93 except HFC which scored a risk index of about 6.5 above the overall average. In contrast non-indigenous Ghanaian banks except SCB which recorded a risk index slightly lower the overall average all other non-indigenous Ghanaian banks; ECB and SGG had risk index of about 39.61 and 54.28 respectively which were far above the overall average. It therefore be inferred that the Non-indigenous Ghanaian banks were a lot safer than the indigenous Ghanaian banks. This could be as a result of the more strenuous prudential regulatory risk management frameworks which overseas banks are subjected to.

4.2 Regression Results

The purpose of the study was to determine the relationship between risk management and performance of listed banks. In achieving this objective, a panel linear multiple regressions was adopted using the Least Square Estimator for simplicity of exposition, further research can examine the robustness of the regression results using a more robust estimators such as the GMM. Return on Assets (ROA) and Return on Equity (ROE) were used as the main performance indicators while Risk Index (RI) was used as a proxy for risk management. The results presented in Tab. 2 indicate that 77.97% of the disparity in the return on asset is explained by the independent variables. The p-value of 0.000 explains that the explanatory variables are significant because it is below the significance level of 0.05.

Tab. 3 shows that R^2 (coefficient of determinations) value of 0.6011 indicates that 60.11% of the variation in the return on equity is attributed to the independent variables. The p-value of 0.00 explains that the explanatory variables are significant because it is below the significance level of 0.05.

4.2.1 Regression Analysis for ROA

This section presents analysis of regression results using ROA as the dependent variable (Tab. 4).

In our first regression analysis, we use ROA as the dependent variable to investigate the relationship between bank performance and determinants of bank performance. Our results suggest that, risk management (RI) had no significant relationship with bank performance. This was inconsistent with evidence of Jafari et al (2011) which suggest that companies improve their performance by managing their risk exposure; hence there is a significant positive relationship between performance and risk management. Bank size and capital adequacy had no significant with bank performance (ROA) was inconsistent with earlier findings of: Stiroh and Rumble (2006), Pasiouras and Kosmidou (2007), Ben Naceur and Goaied (2001),

Tab. 1: Risk Level of Banks Listed on Ghana Stock Exchange (GSE)

Bank	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**Average**
HFC (Bank 1)	14.83	15.99	31.02	50.88	47.09	61.33	29.11	10.08	32.54
GCB (Bank 2)	21.89	18.78	12.68	14.13	6.69	9.97	13.30	6.60	13.00
CAL (Bank 3)	43.89	21.48	20.54	22.62	20.58	23.92	17.27	10.36	22.58
ECB (Bank 4)	22.10	36.37	51.86	52.32	43.82	50.43	49.07	10.92	39.61
SGG (Bank 5)	48.03	61.07	79.71	62.45	59.75	54.12	59.23	9.91	54.28
SCB (Bank 6)	30.77	15.56	23.49	28.07	29.74	24.84	14.36	8.74	21.95
UT (Bank 7)	0.00	0.78	2.07	2.75	2.54	3.84	2.81	3.45	2.28
Average	25.93	24.29	31.62	33.32	30.03	32.63	26.45	8.58	25.93

Tab. 2: Summary of regression results for ROA

Source	**SS**	**dF**	**MS**	**Number of obs.** $= 56$
Model	0.0511	8	0.0064	$F(8, 47) = 20.79$
Residual	0.0144	47	0.0003	Prob $> F =$ 0.0000
Total	0.0655	55	0.0012	$R^2 =$ 0.7797
				Adj $R^2 =$ 0.7422
				Root MSE = 0.0175

Tab. 3: Summary of regression results for ROE

Source	**SS**	**dF**	**MS**	**Number of obs.** $= 56$
Model	1.5613	8	0.1952	$F(8, 47) = 8.85$
Residual	1.0360	47	0.0220	Prob $> F = 0.0000$
Total	2.5973	55	0.0472	$R^2 = 0.6011$
				Adj $R^2 = 0.5332$
				Root MSE = 0.1485

Tab. 4: Regression results of coefficients of the predictor variables for ROA

ROA	**Coef**	**Std. Err.**	t	$P > \|t\|$	**95% Conf. Interval**	
RI	0.0000	0.0000	1.47	0.149	−0.0000	0.0000
SIZE	−0.0002	0.0003	−0.54	0.591	−0.0009	0.0005
CAP	−0.0135	0.0275	−0.49	0.625	−0.0689	0.0419
NPL	−0.1213	0.0165	−7.35	0.000	−0.1545	−0.0881
CIR	−0.0862	0.0067	−13.00	0.000	−0.0995	−0.0729
CON	0.0747	0.0205	3.64	0.001	0.0335	0.1160
INF	0.0562	0.0239	2.35	0.023	0.0081	0.1043
EX	0.0131	0.0033	3.97	0.000	0.0064	0.0197
_CONS	0.0588	0.0083	7.11	0.000	0.0421	0.0754

Note: Dependent variable: ROA 5% significance level

Bourke (1989), Kosmidou et al. (2005) and Dietrich and Wanzenried (2011), respectively. There is a significant relationship between non-performing loans and performance of listed with a coefficient of −0.12130 (approx. −0.12) indicating the degree of effect of return on assets. It could therefore be inferred that an increase in non-performing loans leads to a decline in profit since banks mostly service non-performing loans with their profit. Relative to earlier studies, our findings is consistent with by Miller and Noulas (1997).

Moreover, Cost to income ratio also exhibited similar feature as it also had significant negative relationship with ROA with a coefficient of −0.0861995 (approx. −0.09). Implication is that bank expansion cost as well as administrative cost decrease performance. This substantiates evidence by Athanasoglou et al. (2008) but contradicts evidence by Molyneux and Thornton (1992). In addition concentration (CON) measured by market share of listed banks had significant positive relationship with performance (ROA) with coefficient of 0.074. Thus, as banks expand their market share; it has positive effects on their profitability. By these results, our study shows consistency with findings of Bourke (1989), Molyneux and Thornton (1992) and Bawumia et al. (2005). Macroeconomic variables such as inflation and exchange rate had significant positive relationship with ROA with coefficient of 0.056 and 0.013 respectively suggesting little impact on ROA.

4.2.2 Regression Analysis for ROE

In this section, we test the relationship between ROE and the explanatory variables of the study. This section presents analysis of regression results using ROE as the dependent variable.

In the second aspect of our regression analysis, we measure bank performance by return on equity (ROE). We found a significant positive relationship between ROE and risk management (RI) with a coefficient of 0.00023 suggesting that there is little impact on performance. Our results were consistent with evidence of Jafari et al. (2011) which suggest a significant positive relationship between performance and risk management. However this contradicts our earlier results which measured performance by ROA.

Moreover, findings show that, bank size has no significant impact on ROE which is consistent with earlier findings when ROA was used. This implies that whether shareholders increase their equity or not, it does not impact on either ROA or ROE. Macroeconomic variables such as inflation and exchange rate also had no significant impact on ROE. Capital adequacy of listed banks was found to have a significant negative effect on ROE with a coefficient of −0.8913554 (approx. −0.89); this defeats earlier results which showed that capital adequacy and ROA had no significant. It may therefore be deduced that, as banks maintain high capital ratios in order to mitigate unexpected shocks of the market, ROE may also decline and vice versa.

Non-performing loans of listed banks had a significant negative relationship with ROE with a coefficient of −0.3180098 (approx. −0.31). It implies that ROE is adversely affected by non-performing loans indicating the extent of impact is high. The implication is that, as banks non-performing loans increases, it decreases their profit since it is their main source of servicing non-performing loans. Relative to earlier studies, our findings is consistent with by Miller and Noulas (1997). Furthermore, cost to income ratio is negatively related to ROE with ROE with a coefficient of −0.64505026 (approx. −0.64). This implies that banks incur a lot of administrative and operational cost in their operation and this has negative impact on their performance (ROE) although they pass it onto customers. Undoubtedly, the results suggest that cost to income is a major determinant of ROE. This evidence supports earlier findings using ROA and further confirms evidence by Athanasoglou et al. (2008), however, it contradicts evidence by Molyneux and Thornton (1992). Similar to finding on ROA and evidence of Bourke (1989), Molyneux and Thornton (1992) and Bawumia et al. (2005), concentration (CON) had a significant positive relationship with performance (ROE) with coefficient of 0.9288215 (approx. 0.92). Our evidence confirms that, the major determinant that has negative impact on ROE (bank performance) is market share.

5 CONCLUSION

Based on the summary of risk level of GSE listed banks computed using the risk index suggested by Hannan and Hanweck (1988), it was found that, the safest GSE listed bank for period under study was SGG Societé Generale Bank. General impression is that, indigenous Ghanaian listed banks has lower risk index relative to foreign listed banks. However, the most risky GSE listed bank was UT bank. From the panel data regression analysis, it was found that there is a positive relationship between risk management and performance when the letter is measured by ROE and not ROA. However, risk management does not have a stronger impact on bank performance (ROE) which implies that, as banks increase their risk management practices it results in a marginal increase in banks' ROE.

Overall listed banks in Ghana have weakening risk management index over the entire study period suggesting that banks may be exposed to undue economic uncertainty and this may call for additional capital to cushion bank against insolvency. We, recommend that the Ghanaian banking regulator and bank management may need a rethink of the approaches in the management of their risks and need to be cautious when establishing risk management frameworks and policies to ensure judicious use of deposits to enhance bank performance.

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ECONOMIC ADJUSTMENT OF DEFAULT PROBABILITIES

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ABSTRACT

This paper proposes a straightforward and intuitive computational mechanism for the economic adjustment of default probabilities, allowing the extension of the original (usually one-year) probability of default estimates for more than one period ahead. The intensity of economic adjustment can be flexibly modified by setting the appropriate weighting parameter. The proposed mechanism is designed to be useful especially in the context of lifetime expected credit losses calculation within the IFRS 9 requirements.

KEY WORDS

credit risk, probability of default, economic adjustment, economic forecast, IFRS 9

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1 INTRODUCTION

Default probabilities are an essential component of modern credit risk analysis and management in credit institutions, particularly banks. Since accepting deposits and granting loans are the fundamentals of financial intermediation, which is one of the core functions of banks, credit risk is under detailed scrutiny in the banking industry. Credit risk is generally understood as the potential that a borrower or counterparty will fail to meet its contractual obligations (see BCBS, 2000). For banks it is of great importance to evaluate credit risk related to potential clients (loan applicants), as well as to actual clients. This is done within credit scoring, which is a process for prediction of the probability that a loan applicant or a client will default (Hand and Henley, 1997). Hence, credit scoring is commonly divided into application credit scoring (for evaluating loan applicants) and behavioural credit scoring (for evaluating actual clients).

For the past few decades credit scoring has undergone substantial development. Two periods can be distinguished – up to the 1970s (when a qualitative approach dominated, with the credit officer's judgement as the main decision tool) and after the 1970s (when a quantitative approach dominated, with statistical credit scoring models as the main decision tools). For a discussion on history-related topics see Thomas (2000) or Abdou and Pointon (2011). Regarding statistical credit scoring models, logistic regression has built a position above others and has become the standard, especially because of its simple and intuitive character, and also for the relatively good results it provides (Crook et al., 2007). An overview of other models, including more sophisticated ones, is provided for example by Li and Zhong (2012) or Lessmann et al. (2015).

Credit risk evaluation is crucial not only for internal credit decisions, but also for financial regulatory purposes. Since the introduction of the Basel II capital requirements framework in 2004 (see BCBS, 2004) behavioural credit scoring models and modelling of the probability of default has been paid even greater attention in the banking industry. In the context of the Internal Ratings-Based Approach (IRBA) for the calculation of credit risk capital requirements, the Probability of Default (PD) represents one of the four fundamental input parameters. The others are Loss Given Default (LGD), Exposure at Default (EaD) and Maturity (M). Therefore, as a regulatory requirement, banks must hold an adequate level of capital, especially to cover potential unexpected losses (see BCBS, 2004 and CRR, 2013).

Regulatory credit risk requirements will be further deepened from 1/1/2018 when the international financial reporting standard IFRS 9 Financial instruments should come into effect. The widely discussed IFRS 9 standard will also strengthen the link between credit risk and accounting, and substantially affect banks' economic results. Under IFRS 9 banks are required to calculate and recognise loss allowances based on the so-called expected credit losses model. In 2018 IFRS 9 will replace the IAS 39 standard that works with the so-called incurred loss model. Replacing the incurred loss model with the expected credit losses model involves a significant methodological change. According to the expected credit losses model, loss allowances should be estimated based on expectations, meaning before some adverse event (typically the default of a client) has (potentially) occurred. Moreover, either 12-month expected credit losses or lifetime expected credit losses associated with a given asset or a group of assets should be estimated, depending on whether a significant increase in credit risk has occurred since initial recognition. For details see IFRS Foundation (2015).

There are also several methodological differences between the Basel framework and the IFRS 9 requirements. Among the most significant are the following: Within Basel requirements, mostly one-year PDs are estimated. Within IFRS 9, as a part of lifetime expected credit losses calculation, multi-period (lifetime) PDs will have to be estimated. Moreover, Basel requires the estimation of PD and LGD with prudential measures (such as considering an economic downturn), however, IFRS 9 requires the estimation of credit risk parameters having a "neutral" character. Also, under Basel the PDs are commonly estimated more as through-the-cycle (neutralising economic fluctuations) to achieve a lower volatility of credit risk capital requirements. On the other hand, under IFRS 9 the PDs should be more "real-time" estimates, hence point-in-time, including forward-looking information (especially macroeconomic forecasts). For a more thorough description of the differences between the Basel and IFRS 9 frameworks, see Deloitte (2013).

The main goal of this paper is to present a straightforward and intuitive computational mechanism for the economic adjustment of default probabilities, allowing the extension of the original (usually one-year) PD estimates for more than one period ahead. The proposed mechanism is designed to be useful especially in the context of lifetime expected credit losses calculation within the IFRS 9 requirements.

The relationship between default probabilities, or more generally transition probabilities (considering a case with more rating grades),

and macroeconomic variables (or the business cycle) has been investigated and modelled by researchers within various applications, especially since the beginning of the 21st century – see Nickell et al. (2000), Bangia et al. (2002), Koopman and Lucas (2005), Duffie et al. (2007), Bellotti and Crook (2009), Figlewski et al. (2012), or Gavalas and Syriopoulos (2014). Gavalas and Syriopoulos (2014) note that gross domestic product has proven to be a key macroeconomic variable in the discussed context.

This paper is organised in the following way. Section 2 briefly describes the methodology and data used. Section 3 analyses the relationship between credit risk and selected main macroeconomic variables. As a result, an "economic adjustment coefficient" is estimated that is used in the subsequent section. Section 4, which is the core of the paper, introduces a straightforward and intuitive computational mechanism for the economic adjustment of default probabilities. Section 5 is the conclusion.

2 DATA AND METHODOLOGY

To investigate the relationship between default probabilities and macroeconomic factors, the following variables (in the context of the Czech Republic) will be used:

- share of non-performing loans (NPL) – the share of residents' and non-residents' non-performing loans to gross loans, source: Czech National Bank;
- gross domestic product (GDP) – chain linked volumes, index (2010 = 100), source: Eurostat;
- unemployment (UNE) – percentage of active population, source: Eurostat;
- three-month interest rate (IR3M) – three-month money market interest rate (PRIBOR), source: Eurostat;
- harmonised index of consumer prices (HICP) – annual average index (2015 = 100), source: Eurostat.

The time series are with a yearly frequency and cover the period from 2002 to 2015. In this paper, the variable NPL is treated as a proxy for default probabilities/credit risk.

Also, in the illustrative applications in the next section, the official economic forecasts of the Czech National Bank are utilised, in both the baseline and adverse scenarios – see Financial Stability Report 2015/2016 (CNB, 2016).

In the first place, graphical and correlation analyses will be performed. After that, a simple linear regression model with NPL as a dependent variable and the other variables as covariates will be estimated by the standard ordinary least squares method (with heteroscedasticity and autocorrelation robust standard errors). Based on this regression, the composition of the economic adjustment coefficient will be determined. This coefficient will then be used in a subsequent step to adjust default probabilities to reflect the current and forecast economic conditions.

This procedure allows the separation of economic adjustment of default probabilities from their original estimates. In other words, this logic allows to better distinguish between idiosyncratic and systemic risks. Idiosyncratic risk is understood as risk specific to individual clients or groups of clients. Systemic risk is understood as risk that influences clients as a whole (typically economic development). An analogous logic is followed also for example by Sousa et al. (2013). Due to its transparency, the described procedure is also attractive from a managerial point of view.

Regarding the economic adjustment of default probabilities itself, a straightforward logic will be used. It will be assumed that in the next period, a client can either default or not. Conditionally on this outcome, the probability of default for subsequent time periods is estimated. Based on this reasoning, probabilities of default and non-default have to sum up to 1 in every period. In other words, the probability of default (PD) may be considered as the

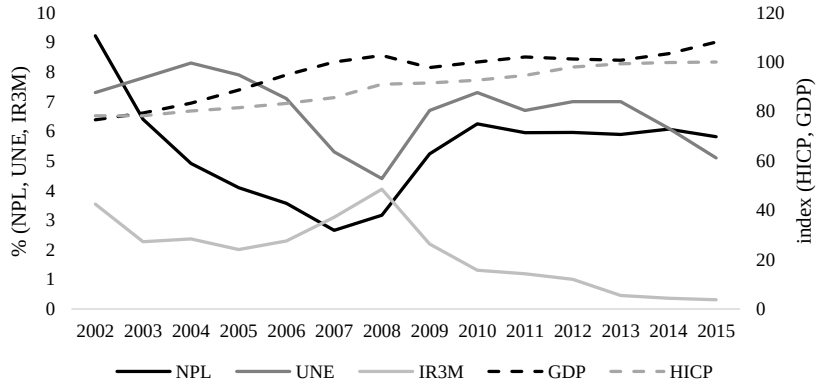

Fig. 1: Development of the considered variables (in levels) in the period 2002–2015

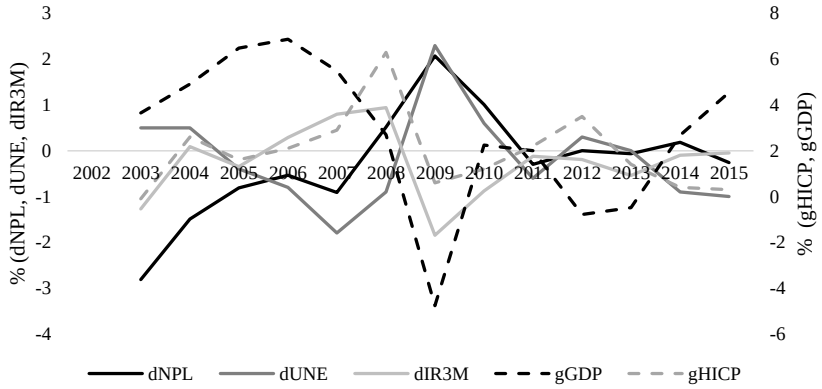

Fig. 2: Development of the considered variables (in changes) in the period 2003–2015

complement of the probability of non-default (PND) to one, i.e. $PD = 1 - PND$. No curing is assumed.

In this place, it should be also noted that this paper does not deal with the original estimates of (usually one-year) default probabilities.

3 CREDIT RISK AND ECONOMIC VARIABLES

3.1 Graphical Analysis

First, a graphical analysis of the share of non-performing loans and macroeconomic variables will be conducted. Fig. 1 depicts NPL and the selected macroeconomic variables in levels (NPL, UNE and IR3M in %, HICP and GDP as indices). Fig. 2 illustrates their changes that are of more interest in this paper (differences in variables originally in %, growth rates of variables originally as indices).

Focusing more on the dynamics of the time series (Fig. 2), it can be seen that there is a visible co-movement (in the opposite direction) of dNPL and gGDP, especially from 2007. Among others, similarly synchronised dynamics on an aggregate level can also be observed even in the case of dUNE and gGDP. However given the nature of these variables this is not surprising. A more detailed view will be provided within a correlation analysis in the next subsection.

3.2 Correlation Analysis

The correlation matrices of the considered variables in levels and changes are presented in Tab. 1 and Tab. 2.

Tab. 1: Correlation matrix of variables in levels

	HICP	IR3M	UNE	GDP	NPL
NPL	0.03	−0.25	0.37	−0.37	1.00
GDP	0.89	−0.50	−0.69	1.00	
UNE	−0.50	−0.10	1.00		
IR3M	−0.72	1.00			
HICP	1.00				

Tab. 2: Correlation matrix of variables in changes

	gHICP	dIR3M	dUNE	gGDP	dNPL
dNPL	0.12	−0.20	0.33	−0.64	1.00
gGDP	0.08	0.59	−0.69	1.00	
dUNE	−0.31	−0.85	1.00		
dIR3M	0.70	1.00			
gHICP	1.00				

The correlation matrix of variables in changes confirms the above-mentioned statements and also shows the strong negative correlation between dIR3M and dUNE and the strong positive correlation between dIR3M and gHICP. However, regarding correlations of macroeconomic variables with dNPL, only gGDP can be considered as relevantly correlated (−0.64). A mild correlation can be also observed between dNPL and dUNE (0.33).

3.3 Economic Adjustment Coefficient

In this subsection, the economic adjustment coefficient (henceforth just "EAC") is calculated using the simple linear regression model estimated by the ordinary least squares method (with heteroscedasticity and autocorrelation robust standard errors). At first, the regression model takes the following form:

$$\begin{aligned} \mathrm{dNPL} \quad = \quad & \beta_0 + \beta_1 \cdot \mathrm{dUNE} + \beta_2 \cdot \mathrm{dIR3M} + \\ & + \beta_3 \cdot \mathrm{gGDP} + \beta_4 \cdot \mathrm{gHICP} + \epsilon. \end{aligned}$$

However, after the backward elimination procedure, only gGDP remained statistically significant, as it can be seen from the summary in Tab. 3.

Therefore the EAC consists only of the impact of the GDP growth. Based on the analyses performed above, this result is not surprising – GDP growth is highly correlated with NPL changes. Even though some correlation between dNPL and dUNE was observed, dUNE was excluded from the model because it is highly correlated with gGDP. Hence, only gGDP remained in the model and was proven to be a significant macroeconomic variable in terms of its relationship with credit risk. This finding corresponds to the findings of the authors mentioned above, e.g. Gavalas and Syriopoulos (2014).

4 COMPUTATIONAL MECHANISM

4.1 Theoretical Framework

In this core section of the paper, a computational mechanism for economic adjustment of default probabilities is proposed. As was stated in the Section 2, a straightforward logic is used. Assuming that a client is assigned a certain probability of default in a given time period, in the next period this client can either default or not. Conditionally on this result, the probability of default for subsequent time periods is estimated. For the sake of clarity it can be repeated that this reasoning also implies that probabilities of default and non-default have to sum up to 1, and therefore the probability of default (PD) may be considered as the complement of the probability of non-default (PND) to one, i.e. PD = 1 − PND. No curing is assumed.

Intuitively, if the one-year PD of a client is 5% in year t, this client will default with a probability of 5% and survive with a probability of 95%. In order to calculate the two-year PD, it has to be assumed that the client will survive

Tab. 3: Results of the final regression model for EAC estimation

Dependent: dNPL	**Coefficient**	**Std. error**	***t*-ratio**	***p*-value**	**Sig.**
Constant	0.38	0.31	1.21	0.25	
gGDP	−0.23	0.06	−4.01	0.00	***
Coef. of determination R^2	0.41	Adjusted R^2			0.36
F-statistic $(1, 11)$	16.07	p-value (F)			0.00
Log-likelihood	−16.66	Akaike inf. criterion			37.32

the first year. Therefore, the probability of non-default (or survival) in the next two years from t is $0.95 \cdot 0.95 = 90.25\%$. Based on the described logic, the PD equals one minus the probability of non-default, i.e. $\text{PD} = 1 - 0.9025 = 9.75\%$.

This mechanism can be written in a general form as

$$\text{PD}\,(t+n) = 1 - \big(1 - \text{PD}\,(t+1)\big)^n,$$

where $\text{PD}\,(t+n)$ is the PD for a desired time horizon (n being a number of time periods ahead) and $\text{PD}\,(t+1)$ is the original one-year PD. For the two-year PD, this formula yields the same result as above. If it is assumed that the three-year PD is desired to be estimated, the formula yields $\text{PD}\,(t+3) = 14.26\%$. However, this formula does not take the economic forecast into account. As was mentioned above, this is the main issue addressed in this paper.

The economic forecast will be incorporated in the following way:

$$\text{PD}\,(t+n) = 1 - \\ - \prod_{k=1}^{n} \Big(1 - \big(\text{PD}\,(t+1) + \Delta_{t+k} \cdot \lambda \cdot w\big)\Big),$$

where Δ_{t+k} denotes a forecast change in the GDP growth in period $t+k$ compared to the base period t, λ denotes the economic adjustment coefficient (from the analysis performed above, it is known that $\lambda = -0.233$), and w represents a weighting that is placed for the economic adjustment effect.

Furthermore, it may be desirable to set a certain threshold for default probabilities. The floor of 0.03% that is set for PD in CRR (2013) in the context of credit risk capital requirements calculation will be considered here as well. Therefore the final formula for the multi-period default probability estimation incorporating economic forecast takes the form

$$\text{PD}\,(t+n) = 1 - \prod_{k=1}^{n} \big(1 - \min\,(X, 1-\tau)\big),$$

where X is $\max\big(\text{PD}\,(t+1) + \Delta_{t+k} \cdot \lambda \cdot w, \tau\big)$ and τ is the floor value – in this case $\tau = 0.0003$.

4.2 Practical Application

For the practical application of the economically adjusted $\text{PD}\,(t+3)$ estimation, the official economic forecasts of the Czech National Bank are used – see Fig. 3 (CNB, 2016).

The forecast growth rates of GDP in baseline and adverse scenarios (as annual averages) together with Δ_{t+k} are summarised in Tab. 4. Since the value in 2016 Q1 is known and the adverse scenario begins in 2016 Q2, the annual average for 2016 is obtained as an average of 2016 Q2–Q4.

Tab. 4: Summary of the forecast GDP growth rates for 2016–2018

	GDP growth rate		**Δ (base = 2015)**		
	baseline	**adverse**	**baseline**	**adverse**	
2015	4.30		–		–
2016	2.28	−4.39	−2.02	−8.69	Δ_{t+1}
2017	3.42	−3.28	−0.88	−7.58	Δ_{t+2}
2018	3.51	−0.74	−0.80	−5.04	Δ_{t+3}

The last parameter that needs to be set is the weighting w for the economic adjustment effect. Regarding the weighting, its setting fully depends on the practitioner and application. Tab. 5 summarises the PD estimates for up to three years ahead, taking the economic forecast in the both scenarios into account, and considering the weightings $w = 0.5$ and $w = 1$.

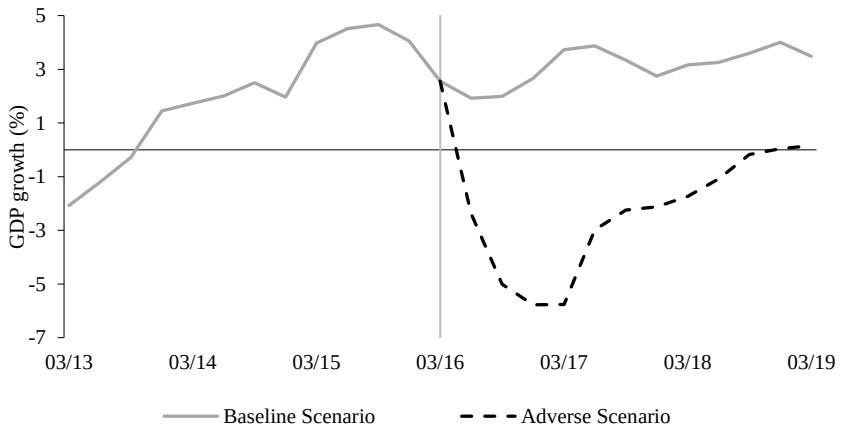

Fig. 3: The quarterly GDP growth forecast of the Czech National Bank (year-on-year changes in %)

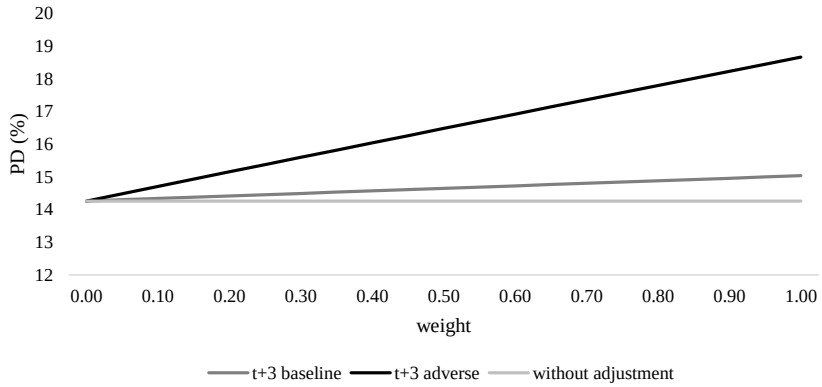

Fig. 4: Three-year PD using different weightings for economic adjustment

Tab. 5: Summary of PD estimates (in %) under different assumptions

Time period	**PD with no adjustment**	**PD** ($w = 0.5$) **baseline**	**adverse**	**PD** ($w = 1$) **baseline**	**adverse**
$t+1$	5.00	5.24	6.01	5.47	7.02
$t+2$	9.75	10.07	11.54	10.39	13.32
$t+3$	14.26	14.65	16.48	15.04	18.67
Difference	–	0.39	2.22	0.78	4.41

The economic adjustment mechanism works as expected and desired. It can be seen that the GDP growth in 2015 is relatively very high. In years 2016–2018, there is still positive GDP growth (in the baseline scenario), but not as high as in 2015. Therefore, the original one-year PD of 5% was estimated in an optimistic economic environment. The proposed mechanism takes this fact into account and with the mildly slower forecast GDP growth in subsequent years it slightly increases the estimated PD. Naturally, in the adverse scenario this increase is significantly stronger. It can also be observed that the intensity of the economic adjustment can be adapted in a flexible way by setting the weighting w – the higher the weighting, the more intense the economic adjustment is. For this application this fact is also illustrated in Fig. 4.

5 CONCLUSION

This paper has proposed a straightforward and intuitive computational mechanism for economic adjustment of default probabilities, allowing to extend the original (usually one-year) PD estimates for more than one period ahead. The proposed mechanism is designed to be useful especially in the context of lifetime expected credit losses calculation within the IFRS 9 requirements. Economic adjustment is based on the official economic forecasts of the Czech National Bank and the estimated economic adjustment coefficient reflecting the relationship between credit risk and economic variables. The intensity of economic adjustment can be adapted in a flexible way by setting the corresponding weighting parameter.

At the end it can be noted that the proposed computational mechanism assumes "only" a non-default or default state of the client or financial instrument (depending on the definition of default). However, especially within IRBA, banks use rating systems with multiple rating grades. In the case of these rating systems, not only default probabilities would have to be adjusted, but also all other transition probabilities between individual grades. Therefore, an extension and generalisation of the proposed computational mechanism using the theory of Markov chains is the subject of further research.

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THE IMPORTANCE OF CORPORATE AND SOCIAL INVOLVEMENT IN THE IMPLEMENTATION OF CLIMATE FRIENDLY PROJECTS

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ABSTRACT

Everyday people have been experiencing changes in weather and climate. The question is whether we are really on the top of a tendency or we just overstate the weather change because of our heuristic mentality? If the negative tendency of change is adopted we must involve climate friendly technologies in the strategic decision making process of enterprises. On the other hand, the important thing to keep in mind is that the main motor of the strategy is the profit. In case of the latest climate related strategies the problem is the hard quantification of the real profitability because it also depends on external effects. In spite of the classical investment analysis, the cost-benefit analysis is able to take into account negative and positive external effects. In case of strategic decision the new technologies or methods are also confronted with resistance. In the strategic decision making process we should calculate with these resistances as well. The aim of this study is to highlight those long-term calculation methods and business models which are able to consider the external effects of projects and examine the real profitability and break-even point in case of bad climate tendency scenarios. This paper presents a new method which includes the cost-benefit analysis and the change equation.

KEY WORDS

climate strategy, environmental project development, cost-benefit analysis, internalization (pricing of externalities), change management

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1 INTRODUCTION

In case of strategic decisions, the importance and the rate of economic and ecological aims is a key question on an individual, corporate and society level. The economic and the ecological aims have different importance in decision making. The question is how can we involve these aims in our calculations? The technology changes result in more environmentally friendly equipment in numerous fields of our life. Regarding profit calculations the conventional and the green technologies are equal. This equation is highly true in case of nowadays oil price reduction. In our opinion this price reduction is temporary but it makes question about the adaptation of environmental friendly or low-carbon methods. People with system-based thinking are not cheated with these temporary changes because they think in long-term projects with long-term effects.

During the last few years we have conducted numerous projects which examined low-carbon projects from the economic and ecological point of view. The cost-benefit analysis (CBA) was the main method for making proposals about climate-centered development opportunities for the transportation and agriculture sector. Based on our latest researches we would like to show the critical points of cost-benefit analysis and present a new method to calculate the external effects and the openness/closeness of changes together. In our method the human factor has an important role in the strategic decision. We would like to define a new mathematical model to examine the viability of the certain environmental initiatives. Our model is based on the CBA and the change equitation model. We attempt to mix these two methods into one model.

2 THEORETICAL FRAMEWORK

The success of environmental projects is a complex issue which may be approached from two different aspects. The first is the efforts of governmental decision-makers which can be assessed through the governmental regulations (Fogarassy et al., 2008). The other aspect is the so-called 'target audience' which includes attitude towards environmental targets of industrial/business stakeholders and society. The resistances to environmental initiatives have long been a known problem regarding environmental projects. The reason of these resistances is the main motivation factors of the business sector which are the followings: profit maximization, ensuring competiveness and market position. Climate policy measures have a strengthening role in the European Union and based on this trend a new phenomenon called 'Carbon Leakage' appeared among the member states. The term refers to the situation that may occur if, for reasons of costs related to climate policies, businesses were to transfer production to non-EU countries with laxer emission constraints. The adaptation of EU environmental norms and Best Available Technologies (BAT) would lead to excessive burden on the industry. In some cases, outsourcing the production out of the EU and then transporting the product back is cheaper and better achieved at company level (Horváth et al., 2015).

The social attitude shows a different view. It can be followed through the mechanism of The Environmental Kuznets Curve (EKC) which has been established in the early 1990s. The logic of the EKC assumes that the local environmental conditions depend on the change in GDP per capita. In the early stages of economic growth environmental degradation and pollution increase, but beyond some level of income per capita (which will vary for different indicators) the trend reverses. Therefore, at high-income levels, economic growth leads to environmental improvement. The EKC defines two impact indicators. One is the continued growth of technological standards which are able to operate on low environmental impact.

The other indicator is more important for our research aspects since it is the social attitude. The EKC stated that the people prefer a clean environment after a certain level of quality of life. The social attitude indicator leads to establish interest organisations (NGO's) and exercises pressure on government to make legalisations in order to preserve the environment. The hypothesis of the EKC is that the need for environmental preservation comes from the society which will be satisfied by decision makers (Stern, 2004).

The authors of this paper have different a point of view. Our earlier studies show that the society often realizes environmental problems without making efforts to solve or prevent them. The reason is very simple and similar to the companies': matching environmental needs goes together with an expensive life-style. The aim of this paper is to show a model which is able to handle the industrial and social attitude. We would like to define the resistance point and the solution for minimising this resistance. In order to achieve that, we are going to use cost-benefit analysis (CBA) and change equation model.

3 METHODOLOGY AND DATA

The CBA is the most well-known decision supporting method. The aim of the method is to calculate with the economic and social benefits and costs of the investment. In the case of decision making the calculation of the benefits and disadvantages (on corporate and social level as well) is the hardest part of the CBA. The question is how to price the benefits or the disadvantages during the calculation process. First of all we must clarify what does "benefit" mean in the CBA. The benefit is an advantage which comes from the project in monetary terms. The "cost" is a value which is lost in the project in monetary terms (Mishan, 1982). The social and economic CBA answers the following questions: (1) What is the amount of the social benefits of the project and how much subsidies are required from the government to reach these benefits? (2) How much is the social profitability of the project on regional level?

In our earlier economic calculation only the extra values against the conventional technology were calculated. Kovács and Székely (2006) called this model extra profit calculation. In order to use that model on a social level, the externalities must be identified and measured economically.

3.1 Pricing the externalities in the CBA

The CBA interprets the benefits and costs in monetary terms. It means that it generates a concrete value for the positive and negative effects of the investment. CBA has three different kinds of "benefits": (B_1) direct effects, (B_2) indirect effects, (B_3) spill-over effects. The costs are divided into the following groups: (C_1) preparation costs, (C_2) implementation costs, (C_3) public procurement costs, (C_4) negative social effects.

Concerning the strategic decision making period of the strategic management there are many methodologies to support decision makers in order to choose the most viable scenario for their company. Lately, a lot of new criteria emerged regarding this process which restrict the freedom of decision making. One of these new factors is the increasing importance of environmental values. In the CBA, the negative social effects include the value of environmental damages (Kovács et al., 2014). The environmental damages are the most common externalities. Externalities do not appear in sales and it is hard to define the value of them in monetary terms. The most common problem in case of environmental protection projects is that the externalities are not priced. This is the reason why these projects have incorrect clarity (Fogarassy and Bakosné Böröcz, 2014).

The most important effects of the low-carbon projects are the changes in the greenhouse gases balance (GGB). The CBA in case of climate policy has two key parts. The first part is the real changes in GGB indicated by the project on national or regional level. The changes of GGB may occur in reduction, or sometimes by increasing, because of inefficient implementation. The second part is the break-even point of the investment under the life-cycle of the projects. The break-even point is very important because the weak point of the low-carbon projects appears when the market is not able to react on the aims and equipment of these initiatives.

According to the requirements of the European Union the supported project must be viable in economic and ecological aspects as well. The financial efficiency is a significant factor in the recognition of the project during the subsidizing process. Fogarassy et al. (2015) completed a CBA model with the factors which are able to calculate with the quote prices of the EU Emission Trading System (1). They used the following modified CBA equation to examine the profitability of low-carbon projects:

$$\mathrm{AI_{pv}} = -\Big(\underbrace{\mathrm{IC}-\mathrm{DI}}_{\substack{\text{Decision on}\\ \text{development}}}\Big) + \Big(\underbrace{\mathrm{AS}-\mathrm{AC}}_{\substack{\text{Effects of}\\ \text{operation}}} \pm \underbrace{\mathrm{IE}}_{\substack{\text{Indirect}\\ \text{effects}}} \pm \mathrm{GHG_i}\Big)_{\mathrm{pv}}, \quad (1)$$

where $\mathrm{AI_{pv}}$ = the present value of additional income; IC = the additional investment cost of the equipment to be purchased (EUR); DI = possible support and discounts (EUR); AS = the additional sales revenue resulting from the additional yield or increase in quality attributed to using the given technology (EUR/year); AC = the balance of the given technology's additional costs and its possible savings (EUR/year); IE = the indirect economic impacts (environmental effects, effects on society) of using the given technology and the value of GHG reduction (EUR/year); $\mathrm{GHG_i}$ = the indirect effects on emissions of using the given technology, based on the value of the decrease in GHGs as per the EU ETS quota forecast (EUR/year); pv = present value.

The essential of the upper equation is the "Indirect effects". This factor includes the greenhouse gases (GHG) decreasing based on the prices on the quota trade. The present paper shows a scenario from an earlier research which illustrates a case study with the modified CBA equation. The scenario takes place in the transportation sector which means a modernization of city-transporting. The project evaluated in that research is a good example for the involvement of civil society in the climate friendly transportation system. Based on the price forecast of greenhouse gas quotes the scenario is viable in economic and environmental aspects as well (Fig. 1).

3.1.1 Details of examined scenarios

It is necessary to define the environmental effects and the probability of resources invested in case of the assessed projects. Besides the carbon-orientation matrix which summarizes environmental effects (Fig. 1) there are some more characteristics, that need to be examined. The CBA model is to carry out two cases. In the first case the hypothesis was that the conditions are compatible with the present policy and financial scheme towards 2030 which is the end of the next program period of the EU. It is relevant to evaluate the effects of the latest climate policy until 2030. According to other scientific research this case is called 'Business as usual' (BAU) in the scenario analysis. Regarding the second case our CBA model calculates with a project which indicates greenhouse gas emission reduction. We used two various groups of indicators to evaluate the projects from an environmental and financial point of view. These two indicator groups are the 'carbon-efficiency' and the 'financial return' measures. The transportation model presented in this paper is a pilot project stating the following characteristics: increase the use of mopeds in city transportation instead of cars, government provides the financial support for buying mopeds.

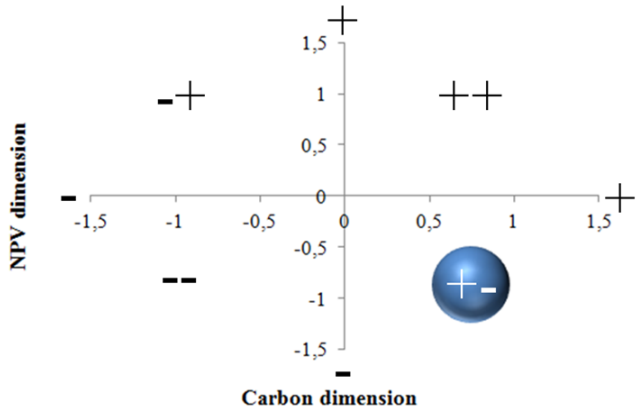

Fig. 1: Carbon-orientation matrix of the projects with corporate and social involvement (Fogarassy et al., 2015)
Notes:
−+: A project is implemented that increases emissions and the investment does not provide a return within the lifecycle.
++: A project where the invested costs show a tendency of providing a return, but the activity itself was not suitable for decreasing GHG emissions.
−−: Emissions can only be decreased with high costs on which there will be no return.
+−: Acceptable scenarios that enable CO_{2e}[1] decreases to be attained while also providing a return on investments over a longer period of time. (Investments that are recoverable even after their lifecycles, with externalities that can change in line with political preferences.)

Carbon-efficiency indicators of transportation project

Fig. 2 illustrates the CO_2 emission change of the project which is the most important indicator in the carbon-efficiency research. It shows the change of CO_2 balance compared to BAU in transportation sector. The adaptation of this transportation project generated decrease in the GHG emissions.

We can see in Fig. 3 the structure of changes which makes us able to measure the efficiency. We need this examination because the future scenarios predict increase in total kilometers travelled but the project must influence the level of GHG emissions even in these circumstances. Fig. 3 shows that the emission per kilometer is also decreased due to the use of mopeds in city transportation, so the total GHG balance can be lowered despite the growth in travelling distances.

Fig. 4 demonstrates the low-carbon technology contributions in the environmental effects. In this case there is no major change in the transportation project. This indicator is useful in cases with renewable energy involvement.

Financial indicators of transportation project

First of all the net present value (NPV) of the transportation project is shown in Fig. 5. This NPV is corrected with the difference of the BAU and the moped project according to the CBA model. In addition the externalities are also calculated in this indicator. Important externality of the moped project is the reduction in car transportation indicating longer life time of cars which results in further savings.

The possibility of return of income in the lifecycle of transportation project is illustrated in Fig. 6. The internal return rate (IRR) is 25% which is a very good value meaning that the project is investable. Other options regarding this indicator are the following: the project is considered for implementation between 0% and −10% with it's acceptable social losses, the

[1] CO_{2e} is the basic level of greenhouse gas emission measurement which expresses the relative global warming potential (GWP) of these gases interpreted in CO_2. CO_2 has a GWP of 1, while methane (CH_4) has a warming potential value of approximately 25 (on a 100 year time horizon). This equation means that every tonne of CH_4 emitted is equivalent of 25 tonnes of CO_2 emissions.

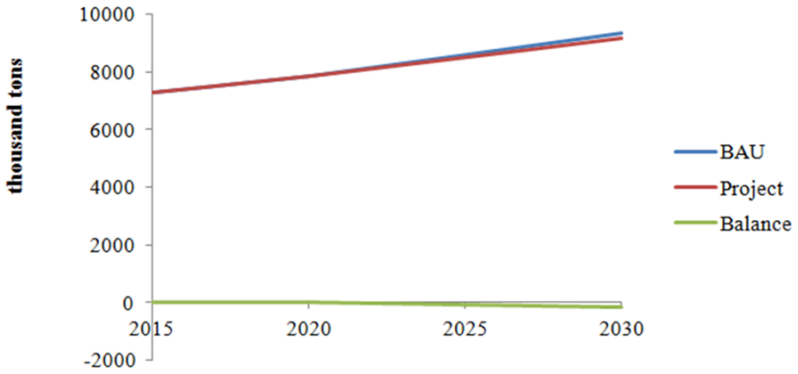

Fig. 2: Assumed changes of CO_2 emission in Hungarian transportation sector till 2030
Source: Fogarassy et al. (2015)

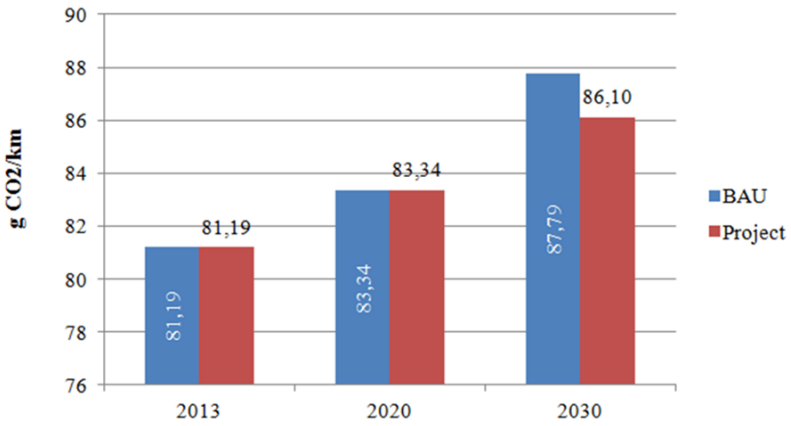

Fig. 3: Assumed changes of CO_2 emission per kilometer in Hungarian transportation sector till 2030
Source: Fogarassy et al. (2015)

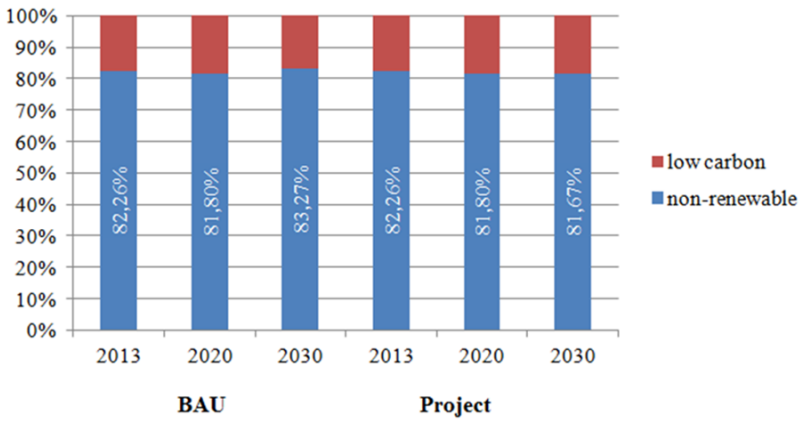

Fig. 4: Changes of rate of low-carbon technology in transportation sector till 2030
Source: Fogarassy et al. (2015)

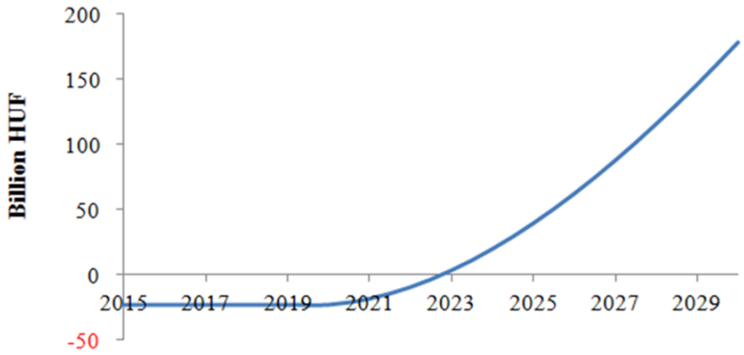

Fig. 5: Present value of extra income in cost-benefit analysis of the transportation project till 2030
Source: Fogarassy et al. (2015)

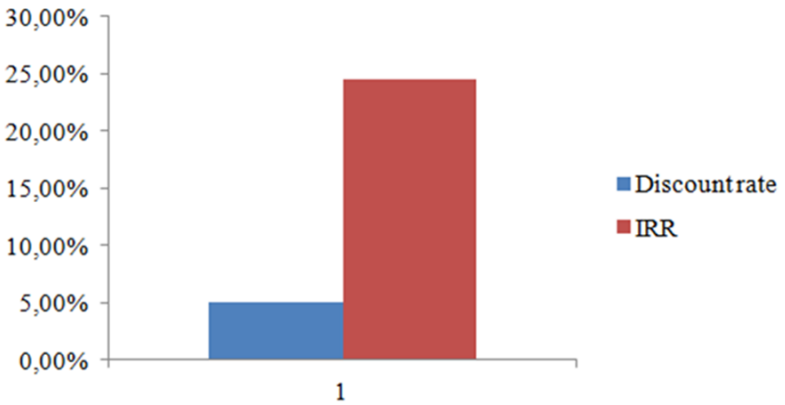

Fig. 6: Internal return rate of transportation project
Source: Fogarassy et al. (2015)

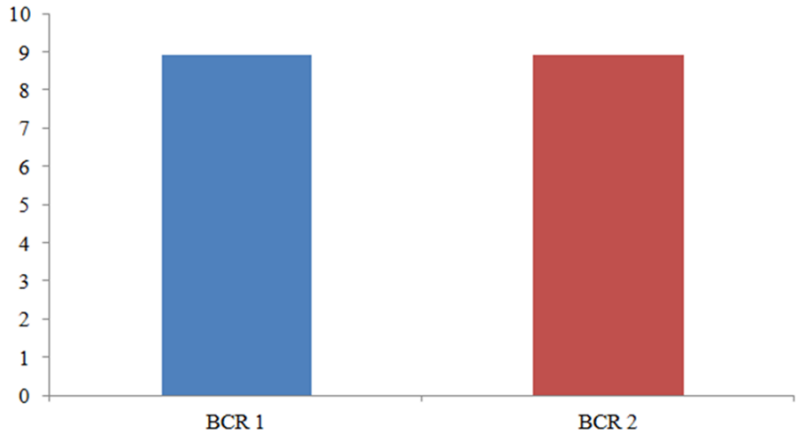

Fig. 7: BCR indicators of transportation project
Source: Fogarassy et al. (2015)

project cannot be conducted below −10% in any cases.

BCR_1 (Fig. 7) shows the total income compared to the investment cost in ratio. In case of a value above 1 a project is financially viable, between the value of 1 and 0.5 it is up to further consideration and under 0.5 the investment is not feasible. BCR_2 demonstrates that how many times the investment will show a return until 2030. According to Fig. 7 the transportation project is investable.

The high value of financial indicators came from the pilot type of the presented transportation project. It means that with low investment we can reach high income. We can see that the environmental value of the project is not significant but it is worth to be extended to the whole sector. This case indicated an example for the assessment of the financial and environmental aspects of a project. In the next chapter we elaborate on how to merge the business and the social attitudes into the described CBA model.

3.2 Methods for overcoming the resistance to change

The modified CBA equation (1) estimated only the economic factors. In vain the model shows that the project is viable if the person who will operate has resistance to change (Illés et al., 2012). The forms of resistance may be variable: fear of losing status quo or power; distrust, misunderstanding, hard learning, different circumstances, self-doubt, negative feelings about changes, uncertainty, pursuit of risk etc. Overcoming the resistance on strategic level is the key factor of success regarding long-term decisions. In the strategic decision we must calculate with those elements which play an important role in the success of change during the implementation. We may use various models to estimate the success of change. In this paper we attempt to modify the change equation model (2) by Cameron and Green (2012) and Beckhard and Harris (1987) with the CBA model. The change equation is based on the following context:

$$\text{Dissatisfaction} \times \text{Desirability} \times \\ \times \text{Practicality} > \text{Resistance to Change}$$

Change equation model:

$$C = (A + B + D) > X, \tag{2}$$

where C = chance to success of change; A = level of dissatisfaction with the status quo; B = desirability of the proposed change or end state; D = practicality of the change (minimal risk and disruption); X = cost of changing.

4 RESULTS

We attempt to define a model which is able to aggregate the modified CBA model (1) and the change equation model (2) in one equation. Our model is able to calculate with the economic and ecological factors of the project and the human aspect of the decision making process together (3).

Modified change equation model by CBA:

$$C = \left(\pm A_1 \pm A_2 \pm \mathrm{IE} \pm \mathrm{GHG_i} + \right. \\ \left. + (\mathrm{AS} - \mathrm{AC})\right)_{\mathrm{pv}} > (\mathrm{IC} - \mathrm{DI})_{\mathrm{pv}}, \tag{3}$$

where C = chance to success of change; A_1 = social deadweight loss; A_2 = lost caused by short-term corporate/individual vision; IC = the additional investment cost of the equipment to be purchased (EUR); DI = possible support and discounts (EUR); AS = the additional sales revenue resulting from the additional yield or increase in quality attributed to using the given technology (EUR/year); AC = the balance of the given technology's additional costs and its possible savings (EUR/year); IE = the indirect economic impacts (environmental effects, effects on society) of using the given technology and the value of GHG reduction (EUR/year); $\mathrm{GHG_i}$ = the indirect effects on emissions of using the given technology, based on the value of the decrease in GHGs as per the EU ETS quota forecast (EUR/year); pv = present value.

The first result of this paper is the combination of the CBA model and the change equation. The other result is that we separated factor "A" (level of dissatisfaction with the status quo) to factor "A_1" meaning social level and factor "A_2" meaning project level which both make the long-term resistance to the current situation. In factor "A_2" we figure a case when a producer exploits the resources in spirit of short-term benefits. These decisions of the producer result in degradation of the environment and as a consequence the producer will lose yield in long-term (Loum and Fogarassy, 2015).

The combination of the two equations makes a good example for examination models of the environmentally friendly or low-carbon projects. It shows that environmental initiatives will always contain "soft-factors" which reflect the social and/or corporate way of thinking.

5 DISCUSSION AND CONCLUSION

From and external point of view the environmental protection may look like some civil organisations putting pressure on the decision makers who make legislation for industrial producers. Nowadays this picture is a lot more blurred because preserving the environment requires efforts from the side of society as well as it does from business stakeholders. Moreover, the climate policy of the EU includes more and more sectors, for example transport and buildings. In case of these sectors it is obvious that the involvement of society is quite significant in order to reach the future goals. Concerning the results of this paper it is very well expressed that despite the endeavours, not all the important indicators of environmental projects can be monetarized or quantified. There are always going to be measures like social and corporate behaviour to influence the expected outcome without showing exact values.

That is the reason why the offered equation aims to operate with the amount of losses generated by these behavioural aspects. The applicability though faces two major obstacles. One comes from the theoretical nature of the equation which requires future analyses to earn practical credibility. The second segment is the attitude of the examined stakeholders which vary in different countries. The difference in their environmental consciousness can be observed as the product of wage-level disparities in the case of the several nations. While in Western European countries raising social awareness of an environmental or social problem could be enough to change the way how people think and act towards that matter, in case of Central and Eastern Europe policy makers need to build a radical legislation framework in order to gain the same results.

The present study is based on the personal perception of the authors that the discipline of environmental sustainability cannot be distributed among market and social stakeholders without regards to economic benefits. The firms and the society will not show serious participation in environmental protection actions until their personal advantages will be proven. The distribution of Smart Metering systems is a good example for this. The essence of these devices is to track the energy consumption of households. Due to this system the residents could pay their bills according to their actual monthly consumption – like in the case of phone bills – instead of the common flat-rate scheme. The advantage of this metering system is the correct measurement which helps the costumers to plan their consumption more accurately. After a successful nation-wide Smart Metering project in Italy, the attitude of customers apparently changed. People from society used their household appliances less, started to operate with alternative solutions and changed the time of use. The reason for this phenomenon was that they were finally able to see the exact cost of their energy waste.

The success of the projects goes together with appropriate business and social attitude. However, it is necessary to make demonstration/pilot projects to evolve this attitude. So

the final question is: where to start this process? Which comes first, the egg or the chicken? The answer – based on the Italian example – is that top-down solutions are necessary to start this circulation. Later on the society and the business sector will show their need for clean environment and make own efforts if they are able to see the financial advantages of it.

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EXAMINING YOUNG PEOPLE'S ATTITUDE TOWARD SPECIAL DOMESTIC ITEMS IN HUNGARY

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ABSTRACT

In our study we have examined the awareness and attitudes of young people (18–24 years) in Hungary toward a special selection of items: as several countries in the world, Hungary also has its own list of domestic products, places and historical heritages, which are called 'hungaricums'. These items could be defined as the core elements of patriotism, thus they are able to induce strong ethnocentric behavior. Our aim was to differentiate the emotional attitudes by gender. To achieve that, we have designed an online survey in order to get a basic understanding about the young people's attitude toward the hungaricums and the gender differences in this age group.

We have found that the hungaricums are known in this age group, but most of them has a really small spontaneous awareness. Based on the opinion of the respondents the most typical hungaricum is the schnapps ('pálinka'), and the Ilcsi natural cosmetics are the less typical to our country. By analyzing the gender differences with using ANOVA method we could conclude that the evaluation of the females is significantly higher in eight cases. Based on this evaluation we grouped the hungaricums with using the MDS method, and our results show that there are also some differences between the males and females.

This study is the first step of a complex neuromarketing study, where we examined the visual representation of the hungaricums in an fMRI machine. Further extension of the research project is to check the attention and interest with the usage of an eye tracking device.

KEY WORDS

consumer ethnocentrism, gender difference, consumer behaviour

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1 INTRODUCTION

The concept of ethnocentrism was developed by Sumner in 1906 (in Shimp, 1984): "it was originally conceptualized as a purely sociological concept that distinguished between in-groups (those groups with which an individual identifies) and out-groups (those regarded as antithetical to the in-groups). Shimp states that 'consumer ethnocentrism' is designed to capture individual consumer cognitions and emotions as they relate to product offerings from other countries."

The concept has object-based beliefs and attitudes (perceptions of product quality, value, etc.), which stands in the center of our study.

Consumers with strong ethnocentrism consider the consumption of foreign products dangerous, because it threatens the domestic economy, e.g. it could cause unemployment. The non-ethnocentric consumers can make more realistic quality-based judgments of foreign products, thus they prefer the foreign products more frequently (Malota and Berács, 2007; Zeugner-Roth et al., 2015).

Shimp and Sharma (1987) with the use of CETSCALE (consumer ethnocentrism scale, a worldwide accepted measurement tool) proved that strong ethnocentrism negatively correlated with consumer's beliefs, attitudes, and purchase intentions toward foreign-made products (Shimp and Sharma, 1987). They also state that older individuals should manifest particularly strong ethnocentric tendencies because these individuals are especially threatened.

This study is the first step of a neuromarketing research project, aiming to discover young people (18–24 years old) awareness and attitudes toward a special selection of items: as several countries in the world, Hungary also has its own list of domestic products, places and historical heritages, which are called 'hungaricums'. Thus, the purpose of this study was to identify the youth's attitudes towards hungaricums, and to discover the gender differences within.

2 LITERATURE REVIEW

The connection between different (foreign) products and high emotional involvement was discovered by Crawford and Lamb (1981). They said this involvement is particularly strong when the foreign products threaten the security of domestic economy and job security. Shimp and Sharma (1987) have had similar conclusions. Many other researches have focused on the connections between consumers' ethnocentrism and purchase intentions: Bilkey and Nes (1982), Yelkur et al. (2006), Vida and Reardon (2008), Nguyen et al. (2008), Evanshitzky et al. (2008), Poturak (2013), Siamagka and Balabanis (2015).

According to Herche (1992), consumer ethnocentrism can serve as a reliable predictor of consumers' preferences to buy domestically produced goods instead of foreign ones. These ethnocentric tendencies are better predictors of purchase behavior than demographic or marketing mix variables.

Herche (1994) also found that ethnocentric consumers tend to reject people, symbols and values that are culturally different, while inner cultural objects will become recipients of pride and attachment.

Consumer ethnocentrism means to prefer domestic products while rejecting foreign ones. In this relation Klein and Ettensoe (1999) found about consumer animosity that while consumer ethnocentrism contributes to a consumer's aptness for avoiding foreign products in general, animosity is usually directed towards a certain country (Rose et al., 2009, p. 331).

Regarding to the hungaricums, the official website explains that the national treasures (and the hungaricums within) are values meant to be protected and preserved. They can be

connected to Hungarian creative processes, production cultures, to knowledge, to traditions, landscape and fauna, national history and to every spiritual and material, natural and common value or product (Magyar Értéktár – Hungarikumok gyűjteménye, 2014).

The protection of our national values contributes the shaping of national identity. Wide-range introduction of our national values within Hungary and abroad as well has top priority, in order to strengthen the country brand itself (Baglyas, 2012).

According to the regulation, the hungaricum is a collective name, based on a standardized classing, ranging and record system in order to distinct and highlight values that are the characteristic features of the Hungarian nation, with their uniqueness, specialty and quality.

The list is approved by the Hungaricum Committee. At the time of our research the list had 41 items, but there is an extended list with 106 items, called 'national treasures'.

The legal paragraph XXX/2012 was ratified by the Parliament of Hungary in April, 2012. In October, the Hungaricum Committee was established. The Committee has sixteen members and the President is the Minister of Agriculture. The other members are delegated by different ministers and departments. Their main objective is to set up the list of the National Values and Collection of Hungaricums (Varga and Kemény, 2015, pp. 29–34).

The process of identification, organization and eventually, the protection have a system called Hungarian National Values Pyramid. The search and collection of values begins in the settlements of Hungary, since the local inhabitants are most likely familiar with them. Local historians, museologists, ethnographists, educators are probably already having a set of their local specialties. These lists are parts of wider, regional selections, which serve as the starting point for the Hungaricum Committee. This Committee has the right to certify a certain value into a hungaricum. The collection had 41 items at the time of the research (Tab. 1).

We believe that hungaricums are the core items of ethnocentrism in Hungary. They could arouse higher emotional connection, thus, higher purchase intent. Our opinion is that stronger, highlighted utilization of hungaricums in any domestic country image campaign could arouse stronger ethnocentric attitudes among the youth in Hungary.

3 METHODOLOGY AND DATA

During our exploratory research we have conducted an online survey among the students of two universities of Hungary. Our aim was to discover the attitudes of young male and female towards hungaricums.

Our online survey had three major parts: in the first part we have asked about the spontaneous and supported notoriety of hungaricums. The second part focused on the attitudes towards the hungaricums, namely to what extent they feel characteristic of Hungary the specific item. The last part consisted of basic demographic data.

We used snowball sampling: an initial group of respondents were selected who were known to possess the desired characteristics of the target population. The initial respondents were asked to identify others who also belong to our target population of interest. Subsequent respondents were selected based on the referrals. By obtaining referrals from referrals, this process has led to a snowballing effect.

Even though probability sampling can be used to select the initial respondents, the final sample is a non-probability sample. The referrals had demographic and psychographic characteristics more similar to the persons referring them than would occur by chance. The main objective of snowball sampling is to estimate characteristics that are rare in the wider population. The major advantage of snowball sampling is that it substantially increases the likelihood of locating the desired characteristic in the population (Malhotra and Birks, 2007, p. 414).

Tab. 1: Categories of hungaricums (2014/Q2)

Category	**Hungaricum**
Agriculture and food industry	Pálinka
	Törkölypálinka
	Csabai sausage or Csabai thick sausage
	Tokaji aszú produced in Tokaji vineyard
	Products from fattened goose
	Gyulai sausage or Gyulai paired sausage
	Hungarian grey cattle meat
	Kalocsa paprika spice
	Pick salami
	Hungarian acacia
	Hungarian acacia honey
	Herz Classic salami
	Makó onion
Health and lifestyle	Béres Drops and Béres Drops Extra
	Ilcsi natural cosmetics
Industrial and Technical solutions	Kürt data recovery
	Zsolnay porcelain and ceramics
Cultural heritage	Traditional dance house as a transmitter by heredity
	Busójárás from Mohács
	Hunting with hawks
	Matyó folk art
	Budapest – Banks of Danube, Buda Castle District, Andrássy street
	Hollókő village
	The Benedictine arch-abbey of Pannonhalma
	Hortobágy National Park
	The early Christian tombs of Pécs
	Lake Fertő – Neusiedlersee
	Tokaj wine region
	Herend Porcelain
	Hungarian operetta
	Kassai horse archery
	Lacework of Halas
	Folk art of Kalocsa
	100-member Gypsy Orchestra
	Intellectual heritage of Count István Széchenyi
	Zsolnay Cultural District
	Classic Hungarian music
Sport	The life-work of Ferenc Puskás
Natural environment	Aggtelek Karst
Tourism and entertainment	Lamb stew of Karcag
	Gundel Heritage

Source: Magyar Értéktár (2014)

During the two weeks of data collection we have reached 132 respondents (38% response rate). The majority of them are women (95), lives in the capital (48) and only 15 of them lives in a village (Tab. 2).

Tab. 2: The characteristics of the sample

	Respondents	%
Gender		
Male	37	28%
Female	95	72%
Type of settlement		
Capital	48	36%
County seat	32	24%
Other city	32	24%
Village	20	15%

4 EVALUATION

The first part of our survey was about the spontaneous and supported notoriety of hungaricums. Based on our results, the strongest spontaneous notoriety belongs to the pálinka (87 mentions), followed by Kalocsa paprika spice (70 mentions) and Tokaji aszú wine (56 mentions). There were some incorrect mentioning as well: the Unicum schnapps (33), the túró rudi dessert (20) and the Rubik's cube (20) have the highest numbers.

With the comparison of spontaneous and supported notoriety we have discovered that most of the hungaricums have high supported notoriety, but the spontaneous mentioning rate is low. The highest difference between the two value can be found in the cases of Béres Drops/Béres Drops Extra (Spon. Aw. = 10 person, Supp. Aw. = 129 person, Diff = 119 person) and the Aggtelek Karst (Spon. Aw. = 2, Supp. Aw. = 121, Diff = 119). The detailed results are presented in Tab. 3.

The expressiveness of hungaricums was measured on a scale from 1 to 5, where 1 meant it is not characterizing Hungary, 5 meant it is strongly characterizing it. The results are similar to the results of spontaneous mentions: the most typical hungaricums are the pálinka (average = 4.77, std. deviation = 0.76) and the Tokaji aszú produced in Tokaji vineyard (average = 4.70, std. deviation = 0.71). The least typical items (their average is below 3) are the Ilcsi Natural cosmetics and (average = 2.46, std. deviation = 1.24), KÜRT data saving (average = 2.56, std. deviation = 1.21) and the early Christian tombs of Pécs (average = 2.99, std. deviation = 1.19). It is important to note that notoriety and expressiveness are not correlating.

4.1 Gender characteristics

Our current study is an exploratory research, in order to provide a start-up point for our neuromarketing research project by discovering the youth's attitudes towards hungaricums. The revelation of gender differences is a popular approach in the field of neuromarketing, which also stands in the focus of our current research.

During our examination of gender differences, our first step was to discover the differences in supported recognitions. There is a significant difference between male and female in the case of five hungaricums (Tab. 4), and in each cases females have higher rates. The highest difference can be experienced in case of Ilcsi natural cosmetics: 55 per cent of the female respondents (52 persons) are familiar with this product, but in case of male the rate is only 19 per cent (7 persons). The notoriety of the different items is the same in the following cases: pálinka – 100 per cent, Gyulai sausage – 97 per cent and Hortobágy National Park – 95 per cent. In 24 cases the notoriety is higher among female respondents – from this the five cases presented above are significantly higher – and in 14 cases male respondents reached higher rates, but these results are not differing significantly (Tab. 5).

Tab. 3: Gender differences in spontaneous and supported awareness

Hungaricum	**Spontaneous awareness**	**Supported awareness**	**Diff** $\Delta_{\text{Supp-Spont}}$	**Means** μ	**St. dev.** σ
Pálinka	87	132	45	4.77	0.76
Kalocsa paprika spice	70	128	58	4.40	0.97
Tokaji aszú produced in Tokaji vineyard	56	130	74	4.70	0.71
Pick salami	36	131	95	4.38	0.90
Matyó folk art	23	124	101	4.02	1.11
Hungarian grey cattle meat	23	117	94	4.27	0.93
Herend Porcelain	20	129	109	4.31	0.83
Makó onion	18	125	107	4.42	0.87
Folk art of Kalocsa	18	122	104	3.99	1.12
Lacework of Halas	14	67	53	3.41	1.20
Gyulai sausage or Gyulai paired sausage	13	128	115	4.14	0.99
Zsolnay porcelain and ceramics	13	128	115	4.38	0.86
Hortobágy National Park	11	125	114	4.23	0.99
Béres Drops and Béres Drops Extra	10	129	119	3.61	1.20
Hungarian acacia honey	10	124	114	4.17	1.05
Busójárás from Mohács	10	123	113	3.63	1.11
Csabai sausage or Csabai thick sausage	9	122	113	4.02	1.03
Budapest[a]	8	123	115	4.44	0.94
The life-work of Ferenc Puskás	7	108	101	4.16	1.14
Hungarian acacia	6	108	102	3.42	1.27
Traditional dance house as a transmitter by heredity	6	73	67	3.36	1.24
Gundel Heritage	4	110	106	3.68	1.11
Kassai horse archery	4	37	33	3.18	1.20
Products from fattened goose	3	97	94	3.31	1.16
Aggtelek Karst	2	121	119	3.17	1.19
Törkölypálinka	2	117	115	3.77	0.98
Herz Classic salami	2	117	115	3.74	1.09
Tokaj wine region	2	117	115	3.72	1.17
Hollókő village	2	107	105	3.42	1.20
Hungarian operetta	2	105	103	2.99	1.19
Hunting with hawks	2	70	68	4.50	0.75
The early Christian tombs of Pécs	2	65	63	4.30	1.02
100-member Gypsy Orchestra	1	117	116	3.75	1.19
The Benedictine arch-abbey of Pannonhalma	1	106	105	3.73	1.10
Kürt data recovery	1	39	38	3.01	1.24
Lamb stew of Karcag	1	24	23	2.56	1.21
Classic Hungarian music	0	116	116	3.37	0.94
Lake Fertő – Neusiedlersee	0	95	95	3.68	1.19
Intellectual heritage of Count István Széchenyi	0	92	92	2.46	1.24
Zsolnay Cultural District	0	82	82	4.08	1.11
ILCSI Natural Cosmetics	0	59	59	3.63	1.23

Note: [a]Banks of Danube, Buda Castle District, Andrássy street

Tab. 4: Gender differences in supported awareness (notoriety)

Hungaricum	**Male**		**Female**		**Difference** $\Delta_{\mathbf{M\text{-}F}}$
ILCSI Natural Cosmetics	7	19%	52	55%	36%
Lamb stew of Karcag	8	22%	16	17%	−5%
Kassai horse archery	11	30%	26	27%	−2%
Kürt data recovery	12	32%	27	28%	−4%
Traditional dance house as a transmitter by heredity	14	38%	59	62%	24%
Zsolnay Cultural District	16	43%	66	69%	26%
The early Christian tombs of Pécs	16	43%	49	52%	8%
Lacework of Halas	17	46%	50	53%	7%
Hunting with hawks	21	57%	49	52%	−5%
Lake Fertő – Neusiedlersee	26	70%	69	73%	2%
Hungarian operetta	27	73%	78	82%	9%
Hungarian acacia	28	76%	80	84%	9%
Hollókő village	28	76%	79	83%	7%
The Benedictine arch-abbey of Pannonhalma	28	76%	78	82%	6%
Intellectual heritage of Count István Széchenyi	28	76%	64	67%	−8%
Products from fattened goose	29	78%	68	72%	−7%
Classic Hungarian music	30	81%	86	91%	9%
Busójárás from Mohács	32	86%	91	96%	9%
Folk art of Kalocsa	32	86%	90	95%	8%
100-member Gypsy Orchestra	32	86%	85	89%	3%
Matyó folk art	33	89%	91	96%	7%
The life-work of Ferenc Puskás	33	89%	75	79%	−10%
Zsolnay porcelain and ceramics	34	92%	94	99%	7%
Makó onion	34	92%	91	96%	4%
Hungarian acacia honey	34	92%	90	95%	3%
Budapest[a]	34	92%	89	94%	2%
Csabai sausage or Csabai thick sausage	34	92%	88	93%	1%
Herz Classic salami	34	92%	83	87%	−5%
Tokaj wine region	34	92%	83	87%	−5%
Gundel Heritage	34	92%	76	80%	−12%
Herend Porcelain	35	95%	94	99%	4%
Kalocsa paprika spice	35	95%	93	98%	3%
Hortobágy National Park	35	95%	90	95%	0%
Aggtelek Karst	35	95%	86	91%	−4%
Törkölypálinka	35	95%	82	86%	−8%
Hungarian grey cattle meat	35	95%	82	86%	−8%
Pick salami	36	97%	95	100%	3%
Béres Drops és Béres Drops Extra	36	97%	93	98%	1%
Gyulai sausage or Gyulai paired sausage	36	97%	92	97%	0%
Pálinka	37	100%	95	100%	0%
Tokaji aszú produced in Tokaji vineyard	37	100%	93	98%	−2%

Note: [a]Banks of Danube, Buda Castle District, Andrássy street

Tab. 5: Gender differences in supported awareness (crosstab analysis)

		Male	Female	Difference $\Delta_{M\text{-}F}$	Total	Sig.
Ilcsi Natural cosmetics	Familiar	7 (18.9%)	52 (54.7%)	36%	59 (44.7%)	0.000
	Not familiar	30 (81.1%)	43 (45.3%)		73 (55.3%)	
Zsolnay Cultural District	Familiar	16 (43.2%)	66 (69.5%)	26%	82 (62.1%)	0.005
	Not familiar	21 (56.8%)	29 (30.5%)		50 (37.9%)	
Traditional dance house as a transmitter by heredity	Familiar	14 (37.8%)	59 (62.1%)	24%	73 (55.3%)	0.012
	Not familiar	23 (62.2%)	36 (37.9%)		59 (44.7%)	
Busójárás from Mohács	Familiar	32 (86.5%)	91 (95.8%)	9%	123 (93.2%)	0.057
	Not familiar	5 (13.5%)	4 (4.2%)		9 (6.8%)	
Zsolnay porcelain and ceramics	Familiar	34 (91.9%)	94 (98.9%)	7%	128 (97.0%)	0.034
	Not familiar	3 (8.1%)	1 (1.1%)		4 (3.0%)	

The differences of expressiveness between male and female respondents were also examined. Based on the results of our variance analysis, there are significant differences in case of eight hungaricums. In each case female respondents gave higher evaluations. The biggest difference belongs to traditional dance house as a transmitter by heredity ($\Delta_{\text{F-M}} = 0.73$). According to the responses, we have found that these eight hungaricums expresses Hungary more than the others, therefore they could be interpreted as female value representatives (Tab. 6).

The evaluation by male respondents is higher in the following five cases: products from fattened goose ($\Delta_{\text{F-M}} = 0.169$), Kassai horse archery ($\Delta_{\text{F-M}} = 0.123$), intellectual heritage of Count István Széchenyi ($\Delta_{\text{F-M}} = 0.217$), the life-work of Ferenc Puskás ($\Delta_{\text{F-M}} = 0.079$) and the lamb stew of Karcag ($\Delta_{\text{F-M}} = 0.327$).

4.2 Group possibilities of the Hungaricums

By using the evaluation of male and female we have tried to classify the hungaricums with the multidimensional scaling (MDS) method. In the interest of easier understanding we have applied the two dimensions' solution from the possible classification methods. The data are suitable for the application of the method, since the stress indicators take values around 0.2 ($\text{Stress}_{\text{M}} = 0.156$, $\text{RSQ}_{\text{M}} = 0.90$; $\text{Stress}_{\text{F}} = 0.142$, $\text{RSQ}_{\text{F}} = 0.93$).

In case of two dimensional analysis, one of the axes in both cases (currently the X axis) shows how strongly a hungaricum expresses Hungary. The more it is positioned to the right of the figure, the more expressive it is.

In case of male, the other dimension (Y axis) is interpreted as the tangibility: the higher a certain value is positioned, the less tangible it is (e.g. it is connected to a touristic destination, or to an intellectual heritage). The hungaricums, which are positioned lower, have a more tangible dimension. On the opposite, in case of female the Y axis could be interpreted as the traditional axis: the higher a certain value is positioned, the more traditional it is.

Using the current position of hungaricums, in both cases we have separated them into five groups, by using cluster analysis. These clusters also show that there are well described differences between the genders, which results

Tab. 6: Gender differences in expressiveness (ANOVA analysis)

		N	Average	Std. dev.	Sig.	Difference $\Delta_{\text{M-F}}$
Budapest – Banks of Danube,	Male	37	4.16	1.14	0.035	0.385
Buda Castle District, Andrássy Street	Female	95	4.55	0.83		
	Total	132	4.44	0.94		
Kalocsa paprika spice	Male	37	4.03	1.19	0.005	0.520
	Female	95	4.55	0.83		
	Total	132	4.40	0.97		
Zsolnay porcelain and ceramics	Male	37	4.11	0.99	0.024	0.376
	Female	95	4.48	0.78		
	Total	132	4.38	0.86		
Zsolnay Cultural District	Male	37	3.22	1.32	0.016	0.573
	Female	95	3.79	1.17		
	Total	132	3.63	1.23		
Hungarian acacia honey	Male	37	3.24	1.19	0.012	0.536
	Female	95	3.78	1.04		
	Total	132	3.63	1.11		
Traditional dance house as	Male	37	2.89	1.24	0.003	0.729
a transmitter by heredity	Female	95	3.62	1.22		
	Total	132	3.42	1.27		
Hunting with hawks	Male	37	2.81	1.15	0.028	0.505
	Female	95	3.32	1.18		
	Total	132	3.17	1.19		
ILCSI Natural Cosmetics	Male	37	2.14	1.16	0.058	0.454
	Female	95	2.59	1.25		
	Total	132	2.46	1.24		

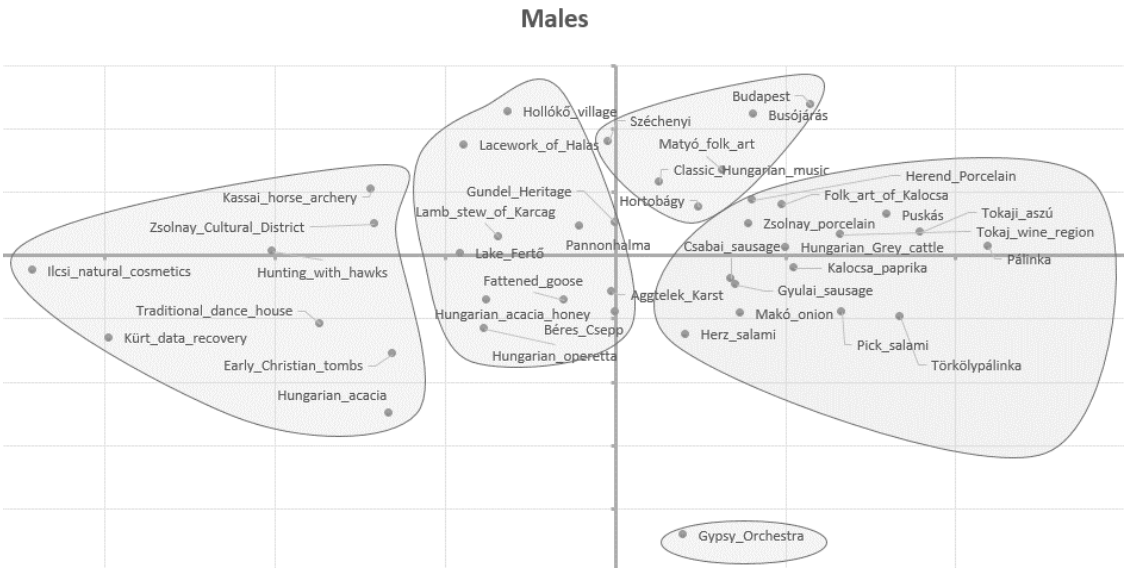

Fig. 1: The groups of hungaricums based on the evaluation of males ($N = 37$ respondents)

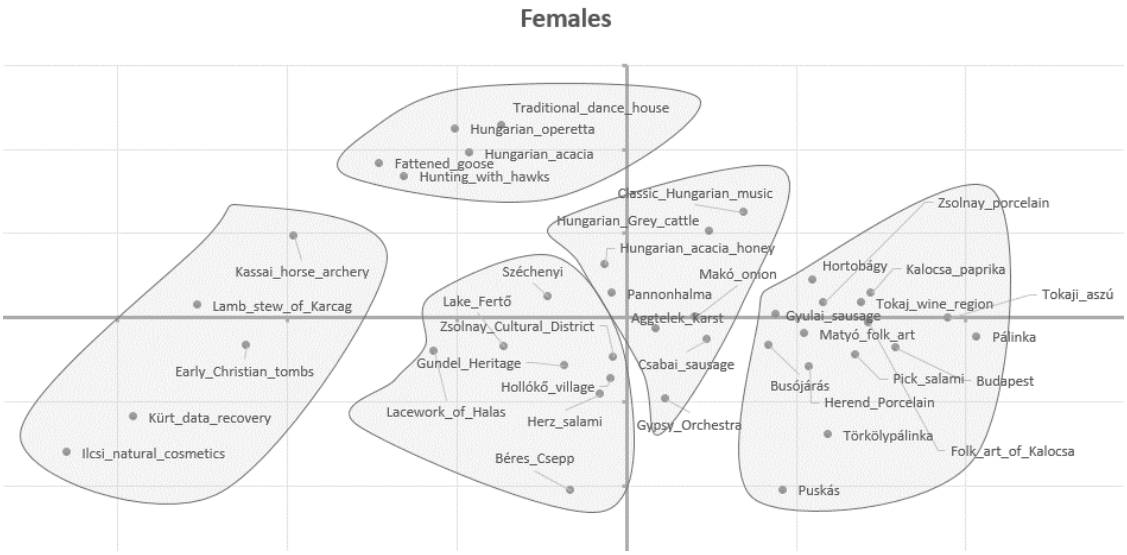

Fig. 2: The groups of hungaricums based on the evaluation of females ($N = 95$ respondents)

provide a solid basis for further analysis in the future (see Fig. 1 and Fig. 2).

The tangible, expressive items such as pálinka (special Hungarian spirit) or Tokaji aszú (traditional Hungarian wine specialty) were the most preferred among both genders. In case of male respondents (see Fig. 1), the agricultural and/or food industrial products were in the most preferred group, which could be a relevant indicator of male preference.

In case of female respondents, their responses could be classified on the traditional values of the hungaricums. Besides some agricultural or food industrial items, they prefer the handicraft products such as porcelain and folk art (see Fig. 2).

5 CONCLUSION, LIMITATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

The familiarity and the preference of the different hungaricums show us that the attitude towards hungaricums are changing. In our sample the young people have a certain preference of tangible products which are more available for them in their everyday life. The more traditional items (such as traditional places, heritages) are less important for them, thus they do not consider them as relevant, expressive items for Hungary. This finding could be a basis for further research on a representative sample to see if it could be utilized for domestic campaigns to strengthen the national values of Hungary.

This research is the first step of a full-scale neuromarketing research. Based on these results, we are going to design our research involving different technical equipment and devices, such as fMRI and eye-tracking camera. The utilized visual stimuli are going to be presented based on the results presented above.

In this study we presented the results of an exploratory research in case of hungaricums on a university student's sample. Based on these results, we can see that there are significant differences in awareness and expressiveness between young male and female. By using MDS method, different groups have also been formed. Based on our results, further neuromarketing research looks to be a relevant method in order to discover the hungaricum-related perceptions and emotions, furthermore the results could help establishing initial hypotheses.

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PERCEPTION OF LOCAL FOOD LABELLING BY GENERATION Z: AN EYE-TRACKING EXPERIMENT

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ABSTRACT

The subject of this research is to reveal the customer's approach towards local food in general and to explore the impact of its labelling on consumer perceptions. The main objective is to find out if an eco-label, a local-label or a bio-label has an impact on consumer behaviour. The following methods were used during the research: eye-tracking technology, in-depth interviews, the A/B testing method, the non-parametric Mann-Whitney test and the non-parametric Kruskal-Wallis test for testing hypotheses. Data were collected from the eye-tracking device in December 2015 and additionally revised for higher validation. In total, the observation contains 121 respondents (63 participants in the reference group – A, and 58 participants in the control group – B). Participants are defined as being from generation Z. It is assumed that the presence of the label on a product has an effect on consumer behaviour. The experiment itself took place at the eye-tracking laboratory of the Faculty of Business and Economics at Mendel University in Brno.

KEY WORDS

consumer behaviour, eye-tracking, local products, labelling

JEL CODES

M300, M310

1 INTRODUCTION

1.1 Local Food

Whereas the Czech Ministry of Agriculture clearly defines the term "local food", no standards exist defining it in the United States. The US market is characterised by one of the biggest demands for alternative food (organic and regional food) among countries. This is the main reason why we mention some data in our study. According to the Czech Ministry of Agriculture, a local food product is one produced in certain region and made from ingredients

FIALA, Jan, TOUFAROVÁ, Ivica, MOKRÝ, Stanislav, and SOUČEK, Martin. 2016. Perception of Local Food Labelling by Generation Z: An Eye-Tracking Experiment. *European Journal of Business Science and Technology,* 2 (2): 152–159. ISSN 2336-6494.

grown in the same region. A local product in the United States has to be grown within the country or neighbouring countries, or within a state (U. S. Department of Agriculture, 2012; Ministerstvo zemědělství ČR, 2016).

Recently, the demand for local (and organic) products has continued to rise as consumers are increasingly interested in a healthy lifestyle. As proof of this, data from 2012 can be referenced. Almost 2 billion Czech crowns were spent on local and organic food in the retail market in the Czech Republic, representing an annual increase of 6.7% (FiBL and IFOAM, 2016). But it is not just a question of the one country. According to National Geographic and GlobeScan (2014), there has been growth in the interest of people in local and organic food in 12 countries since 2012.

A desire to live a healthier lifestyle is not the only factor that has been driving consumers to include local products into their daily menu; there is also a demand for a diverse range of quality food products that consumers are taking into account. Furthermore, it seems that people are taking methods of production and food processing more seriously than ever before (Moudrý and Prugar, 2002).

Purchasing local products has become inseparably associated with responsible consumption, which has an ethical and social background (De Pelsmacker et al., 2005; Harrison et al., 2005).

As already mentioned, there is less supplier exploitation due to the existence of local food, food without chemicals and additives, reduced amounts of packaging, and other positives that local food consumption benefits from (McEachern et al., 2010).

Apart from food quality and the impact on the environment leading consumers to buy local products, there are also other reasonable factors motivating them to do so. According to the COI (2007), these include for instance supporting local farmers and local business, cutting down on pollution and reducing the purchase power of supermarket chains. On the other hand, according to Lithuanian research people do not believe that buying environmentally-friendly products can make a difference to the environment (Kavaliauskė et al., 2013).

Aside from this the Institute of Grocery Distribution (IGD) reported (2005) that many people still do not know of the impact and benefits from buying local products. A lack of awareness of local production, an ignorance of the positives of having a healthy lifestyle and supporting the local environment and business are considered to be the main boundaries preventing potential consumers from buying local food.

1.2 Labelling of Organic Products

According to recent studies, eco-labelling is a significant factor that occurs in promoting sustainable consumption patterns (Horne, 2009). Agenda 21, in connection with the Earth Summit in Rio in 1992, recognised the value of placing local labels as an indisputable factor in promoting the consumption of products that have an obvious positive impact on local environment (Goethe Institution, 2006).

As a great deal of scientific, political and social debate, supported by the mass media, spread the importance of focusing on reducing global warming and "saving" the global climate in general, interest in the value of eco-labelling can be seen as a hope for achieving greater participation in purchasing eco-friendly products by the general public (Horne, 2009).

Research recently conducted around the world has proven the importance of labelling, and resulted in a clear finding. Placing labels (eco, local and bio) definitely plays certain role in marketing communications aimed at consumers with a sense for a sustainable environment and eco-friendly production. Therefore placing labels should be included when influencing the eco-friendly consumer purchase intentions. (Chow et al., 2003; Grankvist et al., 2007; Horne, 2009; Dočekalová and Straková, 2011).

According to Atkinson and Rosenthal (2014) the presence of the eco-label on the product makes the product appear more trustworthy, but it does not lead a consumer to the purchase by itself. Other factors are needed, such as price and taste. The influence on the purchase is indirect. On the other hand, the eco-label's effect, as determined by Sörqvist et al. (2015),

can have a direct influence on the purchase of the product. For some samples (mostly fruit) it was found that respondents were more willing to buy a product with an eco-label because they thought it tasted better.

An assumption was formulated following from the mentioned information that the presence of a label on a product has an impact on consumer behaviour. From this two hypotheses were formulated. Hypothesis #1: There is not a relationship between the presence of the label and percentage Dwell Time of the brand and hypothesis #2: There is not a relationship between the attitude of the respondents to regional products and percentage Dwell Time [%] of the label.

2 METHODOLOGY AND DATA

Two research methods were used to gain trustworthy data. In the first part of the research, the eye-tracking technology was used and in the second part, in-depth interviews with all participants were conducted.

The SMI RED 250 eye-tracker was used in this research and the SMI Experiment Centre software helped us in designing the experiment. SMI BeGaze software and the SPSS programme were additionally used for the analysis, export and appraisal of the collected data. For the experiment a remote eye-tracker was used – it was affixed to the bottom edge of a monitor which had a diagonal size of 22" with a 16:10 aspect ratio. The respondent's viewing distance was about 60 cm.

The research was conducted in December, 2015 and involved 121 respondents (63 participants in the reference group and 58 participants in the control group). The original number was higher, but some respondents had to be eliminated. The reason for this was different eye-handicaps which disrupted the accuracy of the measurements. The age of the respondents was 18–26, making them part of generation Z.

The experiment was designed as an A/B test, where one group of the respondents (group A or the reference group) was shown the modified stimulus and the second group (group B or the control group) the original version. The reference group saw an experiment with chosen labels on products and the control group saw products without labels. The aim was to show the influence of the label on consumers. Original labels were added in the Zoner Callisto graphics programme.

The process of working with eye-tracking technology has its specific features. At the beginning of experiment the researcher has to instruct a participant how to behave during the trial. It is very important for validity of the data. For example the participant cannot look away from the monitor, shake his/her head violently or make similar movements.

When respondents had completed the first part of the research, an in-depth interview could begin. The aim of the second part of the research was to support data from the eye-tracker and fully understand the thinking of the participants. Questions were related to the participant's consumer behaviour and to the factors that have a particular influence on them during the purchase of the mentioned products and their relationship to local labels on products.

In-depth interviews lasted around 15–20 minutes each and the questions were thoroughly prepared in advance. These questions were given to the respondents to answer during interviews and the answers were written down on prepared sheets. As a precaution against the loss of the papers or overhearing of the answers, all the interviews were recorded on a voice recorder.

2.1 Eye-tracking

Eye-tracking technology is actively used as part of the neuromarketing methods for analysing customer behaviour. It is based on the tracking of a respondent's pupils during the presentation of various stimuli. Tracking allows us to get closer to consumer behaviour with objective

Fig. 1: Gherkins – differences between the reference and control groups, Regionální potravina.
Source: Znojmia (2016), Ministerstvo zemědělství ČR (2011)

data uninfluenced by consumers. As a result, in combination with other neuromarketing methods, it is be possible to gain a more complex view of the consumer's psychological processes (Zurawicki, 2010).

Conversely, some restrictions that have to be taken into account when concluding research based on eye-tracking technology are also worth mentioning. On the one hand, we are able to discover the level of label visibility and perceive whether consumers pay attention to certain elements on the internet or on the shelf. Nevertheless not all of this information depicts the actual relationship between the consumer and element in question precisely. Due to this information about eye-tracking technology, an additional research method should be included (Turpault, 2014).

2.2 Products Tested

Eight products were tested during the experiment: apple juice, cream, gherkins, flour, a children's snack (Hamánek), mead, paprika and yogurt.

The chosen products were photographed and the label of the regional product was added. The primary aim of the research was to find out if labels have some influence on consumer behaviour. Fig. 1 shows the original package of the tested product (left) and the edited one (right). In this case, the local label: Regional Food (Regionální potravina) was used and it was placed next to the description of the product (see Fig. 1 right).

2.3 Statistical Testing

Because the output from the eye-tracker differs from a normal distribution, non-parametric tests were used – the Mann-Whitney U test for hypothesis #1 and the Kruskal-Wallis test for hypothesis #2.

Some authors say that a non-parametric test has less explanatory power than the parametric ones. The other option is to normalise the data and use a parametric test, such as the t-test. But for the purpose of this paper non-parametric tests were used. For hypothesis #1 the Mann-Whitney U test was chosen, as the equivalent of the parametric t-test. Hypothesis #1 was formulated to find the differences between the reference and control groups. One issue was that the number of participants was not same across the groups. The Mann-Whitney U test was used because of the comparison of two different groups and the possibility to use it for data without an assumed normal distribution. The null hypothesis is that distribution of the independent variable is same across categories. The significance level of the alpha is 0.05. As a result, if the significance level is

lower than 0.05, than we can say that there are differences between the groups (reference and control group), as was assumed (Field, 2009).

For hypothesis #2 the Kruskal-Wallis test was used. In this case the objective was not to find differences between control and reference groups, but to find differences between four smaller groups in the reference group according to their attitude to the eco, bio and local-labels. As in hypothesis #1 the groups have different numbers of respondents. The groups were ranked from 1 to 4 depending on their attitude to the mentioned labels:

- 'I believe them, they present quality and eco-friendly production' = 4;
- 'I perceive them, they play an important role when I am deciding in the shop' = 3;
- 'I do not have an opinion on them, I have neutral attitude' = 2;
- 'They have negative influence on me, they dissuade me from purchasing' = 1.

If the significance level is lower than 0.05, there are differences between the groups from 1 to 4 in the reference group (Field, 2009).

3 RESULTS

Two hypotheses were formulated for statistical testing. To verify the relationship between the presence of the label (Regional Food) and the time (Dwell Time [%]) of observation of the brand of the product hypothesis #1 was used.

Hypothesis #1: There is not a relationship between the presence of the label and the percentage Dwell Time of the brand.

Percentage Dwell Time was used because all participants had the chance to watch the picture for as long as they wanted. The hypothesis was tested for every product individually. The non-parametric Mann-Whitney U test was chosen for testing. The confirmation of the null hypothesis in this case means that the Dwell Time [%] of the brand is the same in the reference and control groups and the presence of the label has no effect on the dwell time of the brand.

Hypothesis #1 retained for all researched products. Cream was the closest to significance level with the value 0.084, followed by mead with a value 0.230. The rest of the products did not event get close. According to these results we can say that consumers do not become more interested in the brand of the product just because of the Regional Food label placed on it. The biggest disagreement with the hypothesis was measured in flour with a value 0.864.

Within the experiment the respondents were asked to rank their attitude toward products with Regional Food labelling. To verify the existence of a relationship between the attitude to regional products and attention to this label *Hypothesis #2* was formulated: *There is not a relationship between the attitude of respondents to regional products and percentage Dwell Time [%] of the label.*

Tab. 1: Results of testing hypothesis #1 (from SPSS)

Name of product	Mann-Whitney U test	Conclusion
Apple juice	0.468	The null hypothesis is retained.
Cream	0.084	The null hypothesis is retained.
Gherkins	0.725	The null hypothesis is retained.
Flour	0.864	The null hypothesis is retained.
Hamánek	0.564	The null hypothesis is retained.
Mead	0.230	The null hypothesis is retained.
Paprika	0.593	The null hypothesis is retained.
Yogurt	0.267	The null hypothesis is retained.

Tab. 2: Results of testing hypothesis #2 (from SPSS)

Name of product	Kruskal-Wallis test	Conclusion
Apple juice	0.440	The null hypothesis is retained.
Cream	0.969	The null hypothesis is retained.
Gherkins	0.133	The null hypothesis is retained.
Flour	0.673	The null hypothesis is retained.
Hamánek	0.373	The null hypothesis is retained.
Mead	0.469	The null hypothesis is retained.
Paprika	0.136	The null hypothesis is retained.
Yogurt	0.029	The null hypothesis is rejected.

Fig. 2: Heatmaps of paprika – differences between the reference and control groups (output from SMI BeGaze)

In this case the non-parametric Kruskal-Wallis test was chosen. The verification of the null hypothesis for this test means that the Dwell Time [%] of the label is the same in the reference and control groups and the respondent's attitude to regional food labelling has no effect on it.

The null hypothesis was rejected only in the case of the yogurt stimulus, as you can see from Tab. 2. There we can say that participants who care about the origin of the products did watch the label longer than those who do not recognise the mentioned labels on products. For the rest of the products, the null hypothesis is retained. Participants who perceive eco-labels as being better did not focus on labels on the chosen products any longer than those who do not.

Within the experiment, heatmaps of eye movement were also revisited. The heatmap shows places on the product that participants looked at most.

The difference between the tested groups is apparent in Fig. 2. The control group (on the right) without the label spent more time on the description of the product and on the brand. The reference group (on the left) placed their focus more on the stimulus including the added label.

Within this paper only the results of heatmaps for the paprika stimulus are provided, but the results are valid for all the tested products.

4 CONCLUSION

Eye-tracking technology brings us a relatively new interesting way of looking at consumers' habits when purchasing.

It was found during the research in all cases that the presence of the mentioned labels on products has no influence on the Dwell Time [%] of the brand. Respondents showed no greater interest in the brand of the products just because of the presence of the label, as was first thought. There are probably other factors that should be taken into account.

On the other hand, participants who have a positive relationship to labels of origin are focusing more on these labels on a package of the yogurt than on other products which were tested. This could be a consequence of the difference in the attractiveness of the label in comparison with the rest of the products.

There are probably differences between labels on different types of food or different colours of package. The yogurt was the most successful from this selection. The labels on other products were not so attractive for respondents.

The results from heat maps show that participants did notice the labels, but in the final result it has only a small or zero effect on their behaviour as consumers.

There is a chance that the measurement was distorted by the age of the respondents (18–26). Participants at this age are not economically active in all cases, so the selection between variants of products can be made by their parents. This could be an impulse to continue in the experiment with different age categories.

We can find a very similar conclusion in other research also realised with help of eye-tracking technology. According to a study focused on perception of wine labels (Mokrý et al., 2016) the presence of a sticker or awards had a greater degree of observation than the other monitored attributes. Furthermore, the presence of an award/sticker also, as in our study, did not automatically translate into a better perception or nor lead to higher Dwell Time.

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STEREOSCOPIC ANALYSIS AND DEPTH MAP CREATION

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ABSTRACT

This contribution is focused on the use of the stereoscopic image for the purpose of depth map creation. Further, methods for calibration of the camera(s) are discussed. A stereoscopic head was constructed for the purpose of creating a stereoscopic image. Two Basler acA1600-20uc industrial cameras with Computar M2514-MP2 lenses were used for constructing this head. Furthermore, the algorithm for obtaining the depth map is described. The programming language C# and EmguCV library were used for the implementation of the algorithm. The algorithm consists of 4 parts. The calibration of the camera(s) and image acquisition is solved as first. Calibration of the camera(s) is solved by detection of intersections on the chessboard. Further, methods for the purpose of obtaining the depth map are described. Finally the implemented algorithm is tested.

KEY WORDS

stereoscopic image, depth map, EmguCV, Basler

JEL CODES

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1 INTRODUCTION

Today, robotic assistants are at the forefront of scientific research. Robotic assistants are not only used in the industrial field, but are increasingly used in the home. Therefore, these assistants must be able to manipulate with objects of everyday use. For these purposes, robotic assistants must be able to detect different objects in the scene and subsequently manipulate with them.

Currently there exist many approaches to the detection of an in an image and subsequent manipulation. These approaches differ especially in the technology used for image acquisition and in the data storage format. Approaches based

upon a stereoscopic image or storing data in RGB-D format are used especially in practice. Each approach brings various problems, e.g. the image quality and the sensor calibration. These problems have to be addressed before creating the stereoscopic image. The depth map can be used for the detection of objects, manipulation sequence and obstacles in the scene, which is necessary for manipulation with objects.

The image quality and calibration of the camera(s) are decidedly possible problems when a stereoscopic image is used. Light conditions affect image quality in most cases. Digital noise is produced especially in low light conditions and extreme oversaturation can be caused by direct sunlight. Therefore, it is necessary to use a polarizing filter or to use subtle image smoothing algorithms. The calibration of the camera(s) is the most important step when working with a stereoscopic image. A perfect parallel type of stereoscopic head is almost impossible to achieve. Therefore, calibration of the camera(s) is necessary. Deformation of the depth map is the next possible problem. This deformation can be detected when the depth map is obtained.

The main goal of this contribution is the creation of a configurable stereoscopic head, the subsequent acquisition of the stereoscopic image, obtaining the depth map and finding the right values of the key parameters of the depth map.

2 THEORETICAL FRAMEWORK/CALCULATION

Two basic approaches exist for the purpose of obtaining the stereoscopic image. These approaches differ especially in the orientation of the cameras. These approaches are shown in Fig. 1. The ideal approach (Fig. 1a) is almost unattainable in practice. Cameras are mounted perfectly parallel and the image is not distorted in this approach. Therefore, a conventional approach (Fig. 1b) can be often found in practice. The image is distorted by using some lens and cameras are not mounted parallel in this approach. The image must be calibrated for the purpose of firstly compensating the distortion. The OpenCV library or Matlab has an integrated calibration tool. Many experts are currently focused on the process of calibration of the camera(s). A 3D image can be created after the calibration process. (National Instruments, 2016)

Sun et al. (2011) deal with calibration of the camera(s). These authors are focused on the calibration of the camera(s) with a large field of view. The conventional model of cameras was used to obtain of the stereoscopic image. Each camera is modelled as a pinhole. Radial distortion can be seen on the lenses of the cameras which are used in this model. All calculations are performed by using rotation or transformation matrices. It is necessary to firstly obtain the distortion. Further, a linear model must be obtained. This model is obtained by using a non-linear optimization method. This method minimizes linearity between key points in the image. Further, the image is converted by using vanishing points to a 1D space (three key points in 1D space are obtained from one key point in 2D space). The intrinsic and extrinsic parameters of the cameras are detected by this conversion. The obtained image in 1D space is affected by digital noise. Therefore, this image is smoothed by using a Lavenberg-Marquart algorithm. When the intrinsic and extrinsic parameters are detected, the rotation and transformation matrices are then calculated. The distortion of the cameras is removed by using these matrices. Cao and Foroosh (2006) also use calibration of the camera(s) in 1D space.

An alternative approach to calibration of the camera(s) uses a pinhole as the model of the cameras. The rotation and transformation matrices are used to the conversion of 3D coordinates from the coordinates system of the cameras to the general coordinates system. The Lavenberg-Marquardt, Extend Kalman Filter and Bard-Deming algorithms were combined with the above matrices and were then used to obtain the camera parameters. The Bard-

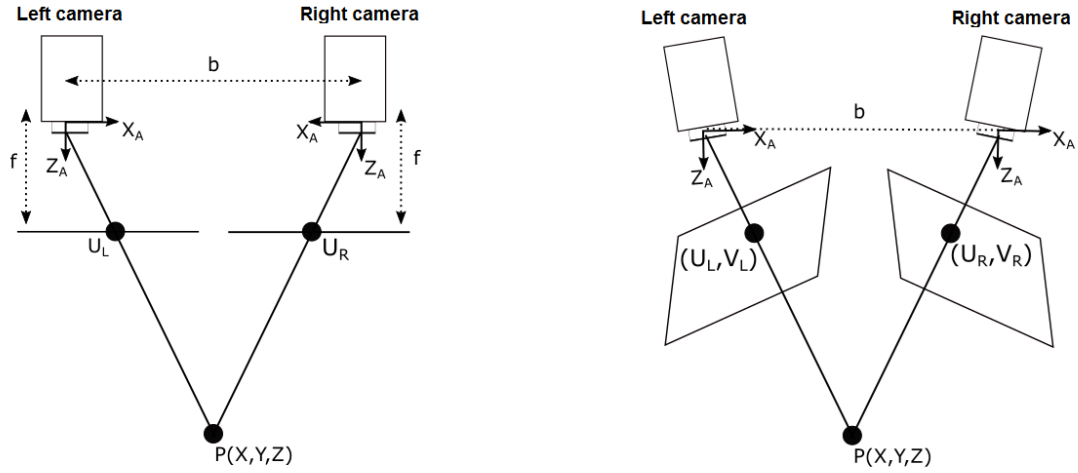


Fig. 1: The ideal (left) a conventional (right) approaches for the purpose of obtaining the stereoscopic image (National Instruments, 2016)

Deming method achieved the best result. However, this method uses a lot of memory and is time-consuming. The method of global nonlinear minimalization was performed in a multi-view context. The Sorensen method was used for the first estimation of the intrinsic parameters. Sub-pixels were extracted from the image. An interpolation of these sub-pixels is used for the optimalization of the calibration accuracy. A grid is used for the calibration. Intersections are detected on the grid. The calibration of the pictures is performed in greyscale (Devy et al., 1997). Chen et al. (2012a) solve this problematic similarly to these authors.

Lindner et al. (2010) develop an alternative approach, which uses detection of the chessboard for the purpose of camera(s) calibration. Chessboard detection is also used by Chen et al. (2012b), de la Escalera and Armingol (2010), Fathi and Brilakis (2016), Prokos et al. (2012), Bennett and Lasenby (2014). Placht et al. (2014) use the OpenCV library for the purpose of image processing. Chu et al. (2013) also deal with camera(s) calibration by using a chessboard pattern and he uses Matlab for the purpose of image processing. Laureano et al. (2015) are also focused on camera(s) calibration by using a chessboard pattern and these authors use the Matlab image database for the testing process.

Kolomazník et al. (2013) deal with the approach towards obtaining a depth map. This approach uses the BoofCV library for the purpose of image processing. The methods SURF fast Hessian and Canny edge are used in this approach. Kamencay et al. (2012) develop an alternative approach, which uses a modified Sum of Absolute Difference (SAD) algorithm to obtain the depth map. George and George (2014) and Gu et al. (2014) use the OpenCV library for camera(s) calibration and obtaining the depth map. Wang et al. (2017) developed a similar approach and this author uses the Matlab toolbox for camera(s) calibration and the OpenCv library for obtaining the depth map. The use of the OpenCV library for the purpose of calibration and obtaining the depth map is described in Dröppelmann et al. (2010). Revuelta Sanz et al. (2011) use PCI (pseudo-color image) for matching process and segmentation of objects in the scene.

If cameras are properly calibrated, it is possible to obtain the stereoscopic image or the depth map. There exist many toolboxes for obtaining the stereoscopic image, e.g. OpenCV, BoofCV, EmguCV or MatlabCV. These toolboxes are related to the programming language of the user's choice. The toolbox OpenCV is related to the programming language C++. The toolbox BoofCV is related to the programming

language Java. The toolbox EmguCV is related to the programming language C#. Various methods can be used to obtain the depth map. These methods differ according to the type of algorithm which is used to compare of the image. These methods are the Block-Matching (BM) method, the Graph-Cut (GC) method and the Semi-Global Block-Matching (SGBM) method. The SGBM method uses the semi-global block-matching algorithm for computing stereo correspondence. The BM method uses the block-matching algorithm for computing stereo correspondence. The GC method uses the graph-cut algorithm for computing stereo correspondence. When a method is used it is then necessary to set up its key parameters. These parameters affect the quality of the depth map. The key parameters are published in Rambhia (2013) and these are the key parameters:

- `minDisparity` – minimum possible disparity value;
- `numDisparities` – maximum disparity minus minimum disparity (this parameter must be divisible by 16);
- `SADWindowSize` – matched block size (it must be an odd number ≥ 1);
- `disp12MaxDiff` – maximum allowed difference (in integer pixel units) in the left-right disparity check;
- `preFilterCap` – truncation value for the pre-filtered image pixels;
- `uniquenessRatio` – margin in percentage by which the best (minimum) computed cost function value should "win" the second best value to consider the found match correct (normally, a value within the 5–15 range is good enough);
- `speckleWindowSize` – maximum size of smooth disparity regions to consider their noise speckles and invalidate;
- `speckleRange` – maximum disparity variation within each connected component.

3 METHODOLOGY AND DATA

A stereoscopic head was constructed for the purpose of creating a stereoscopic image as the first step. This stereoscopic head was constructed by using two Basler acA1600-20uc industrial cameras with Computar M2514-MP2 lenses and is shown in Fig. 2. A frame rate of 20 fps, resolution 1624×1234 and chip size 1/1.8" are the key parameters of these cameras. A focal length 25 mm and optical size 2/3 are the key parameters of these lenses.

The programming language C# was used for developing this solution. The EmguCV library was used for the purpose of image processing. The designed algorithm is shown in Fig. 3. This algorithm consists of 4 parts. The first part is the acquisition of the image. The key camera properties are set up in the process of initialization of the camera. The digital noise, brightness and shutter mode are these properties. These properties are set up for the purpose of obtaining a noiseless image. Only one image is acquired from both cameras, which means that the cameras do not operate as a stream. The obtained data is converted to PNG format in the process of image acquisition. Furthermore, images are slightly smoothed by using the bilateral filter. Further, images are converted to the image in greyscale.

Camera calibration is next part of this solution. A chessboard detection in the acquired image is used for purpose of camera calibration. The detection is performed 10 times at different positions of the chessboard. Intersections are detected on the chessboard and the resulting lines are subsequently drawn. The detection of lines is performed by using EmguCV functions. The functions `FindChessboardCorners` and `FindCornerSubPix` were used for this purpose.

The detection of intrinsic and extrinsic camera parameters is performed in another part. The detection is performed again by using EmguCV functions. The functions `StereoCalibrate` and `cvStereoRectify` were used for this purpose.

The depth map is obtained in the last part. The key properties of the depth map, which

Fig. 2: The stereoscopic head

are discussed in Chapter 2, are firstly set up. Further, the depth map is obtained by using the SGBM method. This method uses a modified Hirschmuller algorithm HH08. The depth map is reprojected to the 3D space in the final step.

4 RESULTS

The process of implementation has been examined in the previous chapter. Several problems have been found in the implementation of the depth map. The first problem was the format of data acquired by the Basler camera. The camera captures the scene as raw data. Therefore, the conversion to PNG format has been made using a storage sequence. The resolution of the image was another problem. Calculation of the depth map insists that the resolution of 1624×1234 is too long.

Therefore, the obtained image was scaled to the resolution of 800×600. A GUI was developed for testing purposes. This GUI allows rendering the obtained image and the depth map. Furthermore, it allows setting parameters of the depth map, which were discussed in Chapter 2. Objects of various shapes, e.g. cups or cones, were used for the purpose of testing the process. The testing process was realized in several lighting conditions. Methods for obtaining the depth map were tested in the first step. The Block-Matching method (Fig. 4a) and the Semi-Global Block-Matching method (Fig. 4b) were tested in this step. The SGBM method was evaluated as the best. The quality of the depth map was tested in the next step. The results of the testing process are shown in Fig. 5. The quality of the depth map was tested in a special cage with LED lighting, which is placed in the laboratory of intelligent systems, as the first step. The testing process in the special cage with LED was performed with a special photo background (Fig. 5a–5c) and without it (Fig. 5d–5f). The quality of the depth map was also tested in normal lighting conditions and this result is shown in Fig. 5g–5i. The quality of the depth map was evaluated as acceptable.

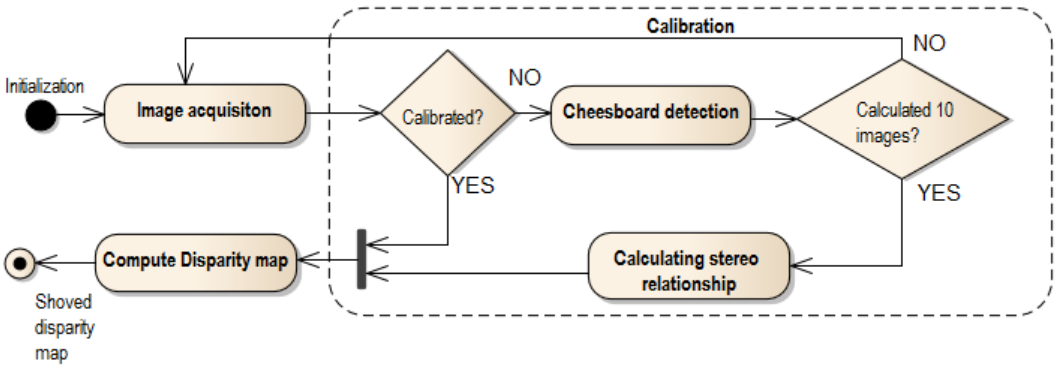
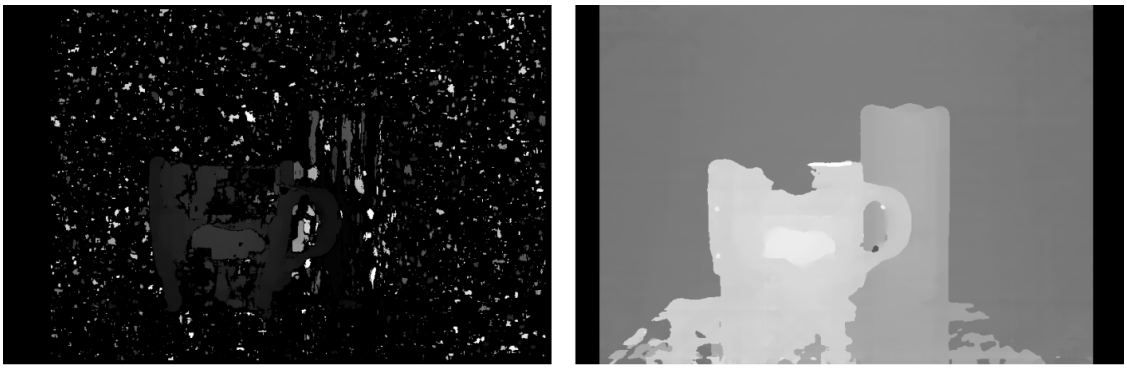


Fig. 3: Outline of the designed algorithm for image processing



a) b)

Fig. 4: The result of methods for obtaining the depth map

Some shortcomings were revealed in the testing process. The deformation of the depth map is the biggest shortcoming of this solution. The lighting conditions probably affect deformations of the depth map, because it may cause oversaturation of some parts in the image or digital noise may be produced. The deformation of edges and digital noise in the depth map are these kinds of deformations. Therefore, further research will be focused on removing these deformations. Furthermore, further problems are included with the lighting conditions. The global setup of key parameters does not exist for different lighting conditions. Therefore, the key parameters must be reset at the change of lighting conditions. The final depth map is shown in Fig. 6 as the result of author's work.

5 DISCUSSION AND CONCLUSIONS

This article deals with the use of stereoscopic images for the purpose of creating a depth map and with the associated problems. The image quality and camera calibration need to be addressed when working with stereoscopic images. These problems are gradually examined in Section 1. The stereoscopic head was constructed for the purpose of obtaining of the stereoscopic image. Furthermore, the algorithm for camera calibration and the creation of the depth map was implemented. The programming language C# was used for developing this algorithm. The use of the programming language C# allows control of the Katana 300s robotic arm. The

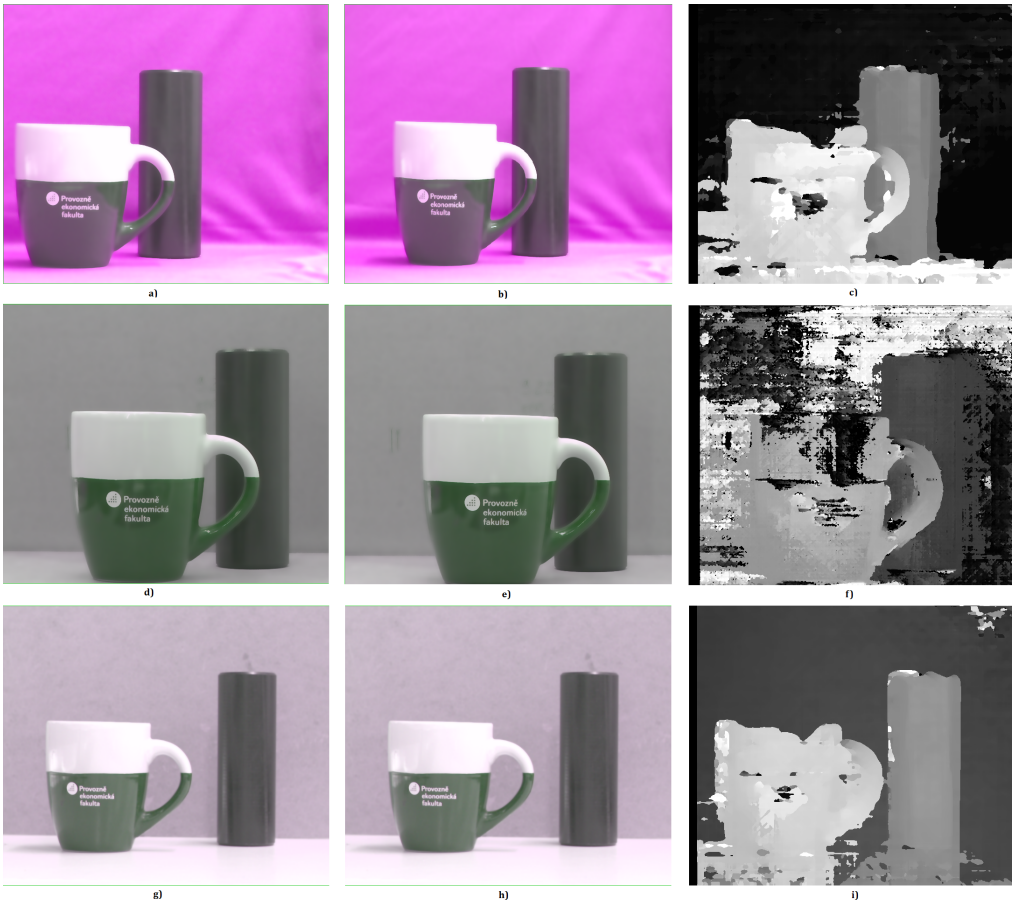


Fig. 5: Testing of the depth map quality

Fig. 6: Final depth map

problem with the image quality was solved by using a bilateral filter and setting key properties for the camera. Furthermore, the implemented solution was tested.

The result of the developed solution was also compared with another solution in the EmguCV tutorial (Emgu CV, 2012). A human head is included in the depth map in the EmguCV tutorial and some everyday objects are included in author's depth map. The comparison of these solutions evaluates author's solution as more usable in normal conditions. The depth map of the EmguCV tutorial is better in an ideal setting and conditions.

This solution includes some shortcomings, which are discussed above in the Results chapter. These shortcomings will be removed in the future. The use of the depth map includes some benefits. The detection of obstacles in a scene is the first benefit. The detection of the object manipulation sequence or detection of distance of each object are further benefits.

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