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Geoinformation Methodology of Agricultural Land Evaluation for Agricultural Economic Growth

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Abstract

The formation of an economically developed management system for the country's agro-industrial complex cannot be considered only from the point of view of a separate science. Land resources are the source of profit, which is involved in almost all sectors of society. Land preservation and improvement is required to ensure an economic security and competitiveness of each region of the Russian Federation). The dynamics of changes in the areas of Svetloyarsky district of the Volgograd region in the context of municipalities is analyzed. The actual deviation of the area of Privolzhsky rural settlement amounts to 2,3 % of the statistical data. The boundaries and areas of the used plots of arable land in the Raigorod settlement do not coincide with the data of the state cadastral registration, the discrepancy of only one land plot is 422,44 hectares. By implementing GIS-technologies, the data were obtained for 2355 arable land plots, whereof the irrigated land area amounts to 52138 hectares, instead of the potentially possible 19455 hectares, that exceeds the settlement's capabilities by 2,7 times according to the statistical data.

Keywords

GIS-technology, land quality, monitoring, tax, evaluation, cost, management, registration.

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Introduction

Land resources are not only a mean of getting products and raw materials for manufacturing, but also a natural resource on which depend ecological, social, recreational and cultural conditions of each region. Efficiency of agricultural land management especially during the period of land transformations is a guarantee of sustainable formation of all subjects of land relations.

The land management system provides for the consideration of legal, political, organizational, economic, environmental and social conditions of the state development. And it is impossible to consider the land management only as a separate branch of the state, because in the modern conditions of the agro-industrial complex development the land acts as an object both of legal relations and real estate, which forms a taxable base, collection of land payments, attraction of investments in the development of municipalities and regions (Borkhunov and Sagaidak, 2011; Kazankov, 2010).

The purpose of the research is to assess the spatial layout of the non-irrigated and irrigated arable land in the territory under study, give an assessment with the qualitative characteristics of each of them, identify discrepancies in the cadastral registration and actual use of land, create a local geo-information system for the regional characteristics of the distribution and the use of irrigated land.

The purpose of research is to determine the significance of modern geoinformation methods for identifying quality and quantity indicators of land, allowing to get relevant and reliable information in a short time that significantly effects the development of the economic sector of a particular region.

The land fund of the Volgograd region is strategically important due to the unique natural and geographical conditions, opportunities to get various types of agricultural products (Denisova and Silova, 2019). The region belongs to the most developed territories, and further expansion of agricultural land area is almost impossible. With the total area of 11287.0 thousand hectares,

almost 82% accounts for agricultural land, of which 63 % is arable land, 21,5 % is pastures, the rest of the land is less than 20.0 %.

However, the most current issue of the region is deterioration of the soil quality of agricultural land, due to natural, agricultural zoning and high anthropogenic impact (plowing, irrigation, etc.) (Maler, 1990).

Improving land quality, preservation, prevention of degradation and desertification is a priority task of the state at all levels of government – the state (municipal) and private.

Materials and methods

Among the existing methods of assessment on land degradation and preservation of land quality the most interesting are those that provide a forecast of changes which occur on agricultural land, with a real variation of external and internal factors that determine such changes.

Modern land quality research methods are based on aerospace research methods in conjunction with geoinformation technologies and computer modeling.

For this purpose, geoinformation and local data sources are used, the electronic space maps are taken to display the general condition and the location of the research object (Tsifrovaya baza dannykh vysot and Tsentr nauchnykh dannykh Sentinels, 2018). These maps are based on digital topographic model of satellite imagery in a GIS environment in the form of thematic map by the QGIS 3.12 program.

Ground remote sensing data are represented by various survey methods, types of aircrafts, geolocation accuracy and resolution of the obtained image. Currently, there are freely available bitmap images with a pixel size of 1 cm (unmanned aerial vehicles), 30 cm (color-synthesized space images of World View 4 satellite), 10 m (multispectral space images in separate channels of the optical range of Sentinel 2 satellite), the use of the last mentioned ones provides the possibility of assessing the agricultural land use. The preservation of soil fertility, the identification of degradation processes, their dynamics is a necessary requirement for improving the efficiency and sustainability of land use.

Nowadays satellite imagery is the most important source of objective information about the research objects (Lidin, 2018 and Roy, 2014). The most accessible for research is satellite imagery from the satellites: Sentinel 2, Landsat-8 or Landsat-7 and others located on GIS services for free use and allow carrying out the full range of research in order to obtain information about condition, quality and agricultural land use (Erol, 2005). The maps are developed based on digital topographic model of space images corresponding to research objects in the GIS environment in the form of thematic raster, vector and attribute layers (Amin, 2012).

Soil mapping was carried out by the QGIS 3.12 program sequentially overlaying several high-resolution mapping layers and raster images on each other. The research consisted of several stages. The first stage was to overlay contours on the space image obtained by digital relief model (according to SRTM). Further, the boundaries of administrative regions were overlaid on the obtained map scheme. The next stage was to overlay thematic layers (agricultural land, terrain, soil contours, field contours). This approach allows carrying out full range of researches to get information about conditions, quality and agricultural land use (Denisova, 2021).

Results and discussions

The issue of preserving and improving the quality of land is relevant for all municipalities of the Volgograd region and especially for areas with a high anthropogenic load due to the close location of the administrative center – Volgograd.

The differentiation of the Volgograd region into three land-assessment areas clarified Svetloyarsky district to the third one, with a medium -meter soil point – 50, reflecting the smallest fertility (Table 1).

The favorable geographic location and the developed transport infrastructure of the region provide favorable conditions for industrial cooperation, allow the sale of products of the agro-industrial sector to the northern and southern regions of Russia. The municipal district has 1 urban and 9 rural settlements.

The dynamics of the area changes of municipal settlements shows the significant deviations both upwards and downwards (Table 2). Continuous erosion, the transfer of agricultural land to other categories, in particular to the category of land settlements, agricultural land transactions lead to significant changes in the structure of the land fund.

The main problem of agricultural land is the availability of alkali soil and salt complexes of 62.7%, as well as salinization of soils of 30.5 %.

№ Land-assessment area	Land-assessment plot area		Cadastral value		Geometric mean soil rating
	ths. ha	%	ths. rub/ha	%	
I	2595.5	28.1	28899	61.5	85
II	1688.8	18.3	11821	25.1	62
III	4959.3	53.6	6299	13.4	50
Total	9243.6	100	47019	100	62

Source: own processing

Table 1: Weighted average cadastral value for land-assessment areas.

Name of municipal settlement	Area (ha)	Area (ha)	Area (ha)
	1942	1963	2015
Svetloyarskoe	45168.23	45173.07	39442.0
Bolshechapurnikovskoe	15802.26	15806.55	16263.0
Dubroovrazhnoe	19959.93	19956.56	19510.0
Kirovskoe	18300.12	18294.63	15080.2
Narimanovskoe	42999.89	43004.85	43023.0
Privolzhskoe	39224.98	39235.16	38365.1
Privolnenskoe	40848.5	40845.73	40860.0
Raigorodskoe	26580.46	26586.82	27246.0
Tsatsynskoe	50948.00	50960.13	51718.0
Chervlenovskoe	26961.53	26970.75	26993.0
Total	326793.90	326844.25	318500.3

Source: research findings

Table 2: Summary of municipal settlements areas of Svetloyarsky district.

Unfortunately, registration of quantity and quality changes (erosion, deflation, overvoltage, wipping, salinization, salmon, stony and others) is done through collecting and processing the statistical data that do not reflect the current land condition and use.

Such researches were carried out in the Volgograd region in 2005 as a part of the first stage of cadastral valuation of agricultural land.

The cadastral valuation included two main stages:

- assessment of landowners' agricultural land by several factors: soil fertility, technological properties and location;
- valuation of landowners' agricultural land by land rent and cadastral value.

However, such researches are not precise and reliable, as they present the land conditions of 2004.

GIS-technologies allow to survey large areas in a shorter time, to get reliable information about use of land plots, their areas, cultivated products, the presence of trees, shrubbery and forest vegetation, as well as to identify whether the fields are covered with crops or not Bazzi (2019).

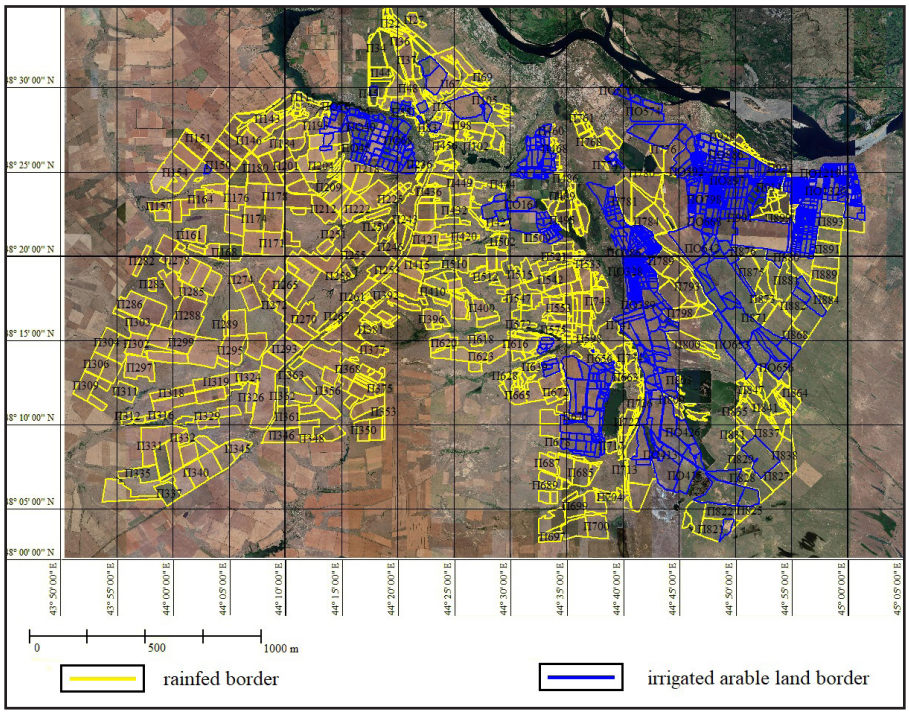
Carrying out of systematic cartographic tracking of the processes caused by the human economic activity allows to create thematic cards of dynamics and forecast these modifications (Papaskiri, 2013).

The use of remote sensing techniques for land registration in the territory of Svetloyarsky district made it possible to examine agricultural land on the area of 253640.0 hectares or 79.6 %.

Having implemented GIS technologies with aerospace research methods at assessment of the territory the boundaries and the plots of the used non-irrigated and irrigated land were clarified, as well as the individual characteristics of each one (an angle of the slope, exposition, height difference and others) were defined. The picture 1 presents the use of irrigated and non-irrigated arable land.

To obtain this electronic space map, the images of satellite Sentinel 2 were used dated 08.07.2020 ID:L1C_T38UMU_A026344-2020-07-08 and ID: L1C –T38UNU-A026344-20200708.

The main advantages of implementing space imageries and digital data obtained during remote sensing are as follows: they cover extensive and hard-to-reach territories in a single moment



Source: Authors

Figure 1: Space map image of irrigated and non-irrigated arable land in Svetloyarsky district of the Volgograd region.

of time, have the resolution of the appropriate characteristics of the applied equipment, give an integrated image of all elements of the earth's surface allowing determine their structure and communication, and also conduct any seasonal space monitoring of agricultural systems, in other words to fix the state of objects at different points in time and trace the dynamics of their changes.

This approach of registration the quantity and the quality of land, namely irrigated and non-irrigated is innovative, as the researches with application of GIS technologies in the territory of the Volgograd region were not conducted yet.

With the help of the current research methods the boundaries of 2.355 plots of arable land in Svetloyarsky distrikt were clarified, of which 1.424 land plots were irrigated and 931 ones were non-irrigated. The area of non-irrigated land amounts to 139540.0 hectares, and the irrigated one is 52138.0 hectares.

The main issue of the district land use is an uncontrolled irrigation which leads to a shallow contour of land, indented boundaries, and a loss of soil fertility. Irrigated land is a prerequisite for getting high stable yields in the Volgograd region, and it is simply vital for some municipalities.

In Svetloyarsky municipal district for the period from 2009 to 2016 the area of irrigated land changed from 1555 hectares to 5282 hectares, it means that it increases of 3,727 hectares. With the help of irrigation grow grain, fodder and industrial crops, vegetables, melons, perennial plantings in irrigated area of 3450 hectares. The picture 1 shows the use of non-irrigated and irrigated arable land.

According to the data of Federal State Budgetary Institution "Upravlenie "Volgogradmeliovodkhoz" there were 9557 hectares of regularly irrigated land in the territory of the surveyed area in 2016. But according to the statistics data, the region's capabilities amount to 19455 hectares, but the geoinformation research indicates that actual use of irrigable areas had been 2,7 times more, instead of 19455 hectares were used 52138 hectares.

Conclusion

Modern methods admit obtaining spatial data about condition and main characteristics of arable land plots. Both allocation and mapping of plots for arable land as well as specifying their present condition during the survey are important for the Volgograd region. Thus, these methods allow to increase the efficiency of land management.

Application of remote research methods of agricultural land in combination with geoinformation technologies make it possible

to determine not only the spatial location of areas that are subject to agricultural production, but also to establish the nature, level and application features, as well as to differentiate into irrigated and non-irrigated land.

This differentiation allows drawing up a steady mechanism for economic land management aimed at implementing the land policy of the state, ensuring the rights of landowners and land users, establishing socially just land payments, promoting rational and effective land use, imposing sanctions for deterioration of the ecological condition of land plots, protecting land from damage, illegal seizure, unuse and others Eremchenko (2011), Khlystun (2019).

The total area of land to be recorded within the borders of Svetloyarsky district is 282955,24 hectares. Agricultural land accounting based on the geo-information study in view of several municipal settlements of the district provided an opportunity to identify the discrepancies in the areas of land, the list of irrigated land and the arrangements for using.

In Privolzhskoe municipal district the discrepancies were revealed in the area of the settlement itself. According to the results of the study, its area decreased by 2,3 % (1071 ha) in comparison with the statistical data.

In Raigorodskoe rural settlement, the plots used for agricultural production were identified, but they haven't passed the state cadastral registration. According to the results of the space mapping of Svetloyarsky district, the area of the used land amounts to 181,28 hectares with reference to the cadastral unit 34:26:100601. But in compliance with the Federal Service for State Registration, Cadastre and Cartography only 33,02 hectares of land are registered. Referring to the cadastral unit 34:26:120203, the irrigated land plot (PO411) within the actual boundaries of 96,9 hectares is used and a plot of non-irrigated land P817 of 650,29 hectares is used, however, only arable land is subject to registration within the area of ZU: 2221 - 168.75 hectares and ZU: 121-156.0 hectares. Indeed, the discrepancy between the used and registered areas is 422.44 hectares. The areas of the used arable land and registered ones in Chervlenovsky rural settlement have significant discrepancies (Savu and Raboj, 2014).

The methods of conducting such agricultural land studies are particularly relevant to keeping accounting for land resources, their legal use, the formation of regional tax base, which includes land tax; rental fee; market price; loan price; compensation for land taken; compensation for land conservation; payments for improving land quality and soil fertility; fines for environmental damage; taxation in civil land turnover and others Lidin (2018).

Proposed solutions:

- to monitor, account and observe the quantitative and qualitative changes in land resources in the view of each municipal settlement by the modern geoinformation technologies;
- to differentiate land into irrigated and non-irrigated with clarification of actual boundaries and their use;
- to carry out a state cadastral registration of irrigated land and fill in data in the real estate register;
- to legislate the concept of "irrigated land" in order to specify the necessary set of characteristics (degree of wetting, soil texture, slope, fertility and others);
- to double the cadastral value of irrigated land and to use the existing tax base as follows: 0.3 % for non-irrigated land; 1.5 % for irrigated one.

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Climate Change and Sustainability in Czech Wheat Production

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Abstract

The paper deals with the analysis of Czech wheat production and its determinants. We use the Just and Pope (1979) stochastic production function to estimate the effects of economic and weather variables, together with technological progress and climate change, on wheat yield in the Czech regions in the period 1961–2018. The results suggest that both economic and environmental factors play important roles in the wheat yield function. The output/input price ratio has a positive effect on the wheat yield. The effects of temperature and precipitation are month-specific and highly non-linear. Technological change also has a positive effect on yield, whereas climate change has a rather negative effect on wheat yield.

Keywords

Cereals, production, yield, weather, precipitation, economic loss.

Hálová, P., Mach, J., Čechura, L. and Slaboch, J. (2021) “Climate Change and Sustainability in Czech Wheat Production", *AGRIS on-line Papers in Economics and Informatics*, Vol. 13, No. 4, pp. 9-18. ISSN 1804-1930. DOI 10.7160/aol.2021.130402.

Introduction

The world’s population is expected to exceed 9 billion people in 2050 (Alexandratos and Bruinsma, 2012). Thus, it is essential that the problem of ensuring global food security is addressed in the near future. A sufficient amount of food for the entire population depends greatly on the sustainable production of crops and livestock. Beddington et al. (2012) pointed to the current threat of global climate change, which requires major local and global interventions in current patterns of food production, distribution and consumption to be made/implemented. Investment, innovation and joint efforts will be needed to secure the situation of the world's most vulnerable populations. There is a need to build a stable global food system that adapts to climate change, ensures food security, minimizes greenhouse gas emissions and, at the same time, is in line with sustainable development. A significant increase in investments in sustainable agriculture, including the improvement of supporting infrastructure and the restoration of ecosystems, is an essential and necessary part of long-term economic development. The sooner these investments are made, the greater the benefits. The scientific community plays a key role in meeting the global challenges of moving the world into a safe operating space, where agriculture can meet global food-supply needs while reducing greenhouse gas emissions at the same time.

In general, climate change typically has a negative impact on the agricultural sector. However, for example, for northern European countries, rising temperatures have a positive effect on crop yields per hectare, especially for wheat or corn (King et al., 2018; Morel et al., 2021Sub-Saharan Africa (Hoffman et al., 2018, Challinor et al., 2015) and South Asia (Khanal et al., 2018) appear to be the most vulnerable areas. However, this fact is valid not only for the least developed and developing countries, but also for the developed countries. Numerous studies confirm that increasing temperatures, along with longer and recurrent dry periods / periods of drought, have a negative impact worldwide on yields of primary crops, namely wheat, corn, and rice (Knox et al., 2012), but also groundnuts and other crops (Khanal et al., 2018).

Numerous studies investigating the effects of weather changes have been done in recent years. Robertson et al. (2007) described the impact of precipitation on the scattering of US crop yields. He found that the models depend on the precipitation in terms of correlation and root mean square error. The effects of year-on-year variability and trends in temperature, solar radiation and rainfall in the years 1961–2003 were investigated by Chen et al. (2013), in particular for wheat and maize yields in the double-cropping system in Beijing and Zhengzhou. He examined the relative contributions of individual climate variables separately. The Agricultural Production Systems Simulator

(APSIM) was used to study crop yields under a set of generated climate scenarios. The results showed that the warming trend did not have a significant effect on the wheat yield in both localities, however it had a significant negative impact on the maize yield in Beijing. Lobell et al. (2007) analysed the relationship between crop yield and three climatic variables (precipitation, maximum and minimum temperature) for 12 major California crops between 1980 and 2003. The environmental variables, most important for each crop, were used in regression model for yield. Relatively simple models using only 2-3 variables explained more than two-thirds of the observed yield variance of the majority of crops. The results show that crop infection, pollination, and dormancy may represent important mechanisms by which climate affects crop yield.

De Wit et al. (2005) expressed the effect of precipitation and radiation uncertainty on the results of a local crop yield simulation and on a regional scale (NUTS1 regions). Two experiments were performed, simulating crop yields for winter wheat and maize for grain, using the Crop Growth Monitoring System (CGMS) for the year 2000 with different precipitation and radiation inputs. The experiments suggest that the uncertainty in precipitation and radiation translates into considerable uncertainty in the crop yield at the 50 × 50 km grid level. Then, the yield statistics from EUROSTAT and the output of the CGMS model for maize in the period 1990–1999 were used to develop yield models for France and Germany. These models showed that the uncertainty of radiation and precipitation in CGMS has little effect on the prediction of CGMS yield at the national level.

Many authors are concerned not only with quantification of climate influences but also with the impact of technical and economic factors on the yield of main crops in a sown area (acreage). Early studies addressed mainly the effects of temperature, precipitation, and technological progress, represented by a linear or quadratic trend for crop yield. It was found that, in principle, there is a positive effect of precipitation and a negative relationship between temperature and yields. A comprehensive meta-analysis predicting the effects of climate change on wheat yield was presented by Wilcox and Makowski (2014). In terms of methodology, the available publications pursue two directions. The first group of studies uses experiments and measures, among other things, the effects of CO2 increases on crop yields (Amthor, 2001) directly. The second group is based on the application of regression analysis to all types of underlying data, from cross-sectional surveys through time series to panel data. Articles based on cross-sectional data obtained through a questionnaire survey also often address the influence of farmers' decision-making for adopting climate change adaptation strategies (Khanal et al., 2018, Füssel, 2007). Omitting this aspect can also lead to overestimated results.

Analysis by Hoffman et al. (2018) demonstrates that although improvements in technology have a positive effect on crop yields, warmer and drier climates have a negative effect. For instance, maize shows that there is an increase in yields of up to 13 kg/ha, but climate change can reduce current production by up to 10 kg/ha. The volatility of yields, dynamics of plant growth and time development are typical characteristics of crop modelling. This approach uses the stochastic production functions in accordance with assumptions about the random component (Just and Pope, 1979). Most articles provide results concerning the effects of future climate change on crop yields by using crop models and climate change scenarios. Weather data (temperature, precipitation) are the explanatory variables and are considered direct factors, but genetic improvements in the form of adoption of new varieties, soil characteristics, greater application of fertilizers, management practices, and indicators of adaptation to changed conditions are also considered (Qiao et al., 2018; Challinor et al., 2015).

However, only a few studies deal with the impact of climate change on primary agricultural production in terms of crop area. Other indirect factors that should not be neglected in the models are discussed here. Input prices, output prices, crop rotation and biological or agronomic factors are important determinants (Hendricks et al., 2014). More recent studies also take into account risk spreading, land constraint and the multiple output profit function of agriculture (Weersink et al., 2010). Omitting these variables, especially crop prices, can distort the effects of climate change on their yields by 9% (corn) - 15% (soybeans), see Miao et al. (2016). Studies typically differ in the way they measure climate variables, as well as in the level of data aggregation. The situation described above can be appropriately captured using panel-based models. Their advantage is the ability to estimate the linear and nonlinear influence of air temperature and the interaction between precipitation and temperature. All these are in line

with other factors, including input, output prices and agronomic factors.

A common approach to study the climate change effects on crop yields is to use statistical models. These models are based on historical yields and some simplified weather measurements, such as average temperature during the growing season and precipitation. There are several strengths and weaknesses of this approach. For example, Lobell and Burke (2010) used a perfect model approach to examine the ability of statistical models to predict yield responses to changes in average temperature and precipitation, as simulated by a crop-process-based model. Then, the Crop Environment Resource Synthesis (CERES)-Maize model was used to simulate the historical variability of maize yields at nearly 200 sites in Sub-Saharan Africa with different scenarios. Three types of statistical model (time series, panel, and cross-disciplinary models) were then tested for simulated historical variability and used to predict responses to future climate change. The results suggest that statistical models, compared to CERES-Maize, are a useful, albeit imperfect, tool for designing future yield responses, with higher utility on a wider spatial scale. It is on these broader scales that climate projections are the most accessible and reliable, and it is therefore likely that statistical models will continue to play an important role in predicting the future impacts of climate change.

The pronounced effects of climate change on Czech agriculture in recent years have stimulated research activities in this area. For example, Čechura et al. (2020) studied the impact of climate change on cereal production in Czech regions. Čechura et al. (2015) related the effects of climate change to the total factor productivity (TFP) growth in Czech agriculture. The authors concluded that some effects are systemic, i.e. they affect all sectors, but they also identified idiosyncratic factors, especially in animal production. Moreover, Halova et al. (2015) provide a broader perspective, in relation to the production of public goods in Czech agriculture (water quality and availability, agricultural land biodiversity, flood resistance, soil functionality, air quality, climate stability, etc.).

In the Czech Republic, wheat production dominates crop production and, as such, represents one of the most important agricultural outputs of the country. From a total sowing area of 2.5 million ha, cereals account for 56%. The largest share is held by wheat, at 62%. Barley accounts for 23%, corn 6%, oats almost 3% and rye less than 2%. However, the structure of cereal production has been changing considerably from a long-term perspective. At the beginning of the 20th century, rye with 35% and oats with 30% dominated cereal production. Wheat was cultivated on less than 20% of the sowing area. A steady increase in wheat on the cost of rye and oat production was experienced up to the 1970s. The reasons for these changes were not only the requirements for sufficient quantities of food supply, together with an emphasis on the profitability of the sector through higher yields, but also changes in consumer preferences. Currently, the highly important problem of crop cultivation is climate change. In this respect, pronounced extreme variations in daily temperature and changes in the distribution of precipitation, in particular, have negative effects.

The aim of the paper is to quantify the impact of economic and environmental variables, as well as the impact of climate change, on wheat yields in the Czech Republic using the stochastic production function, and to evaluate how technological progress may contribute to sustainable wheat production in the Czech Republic. The estimate of the production function is based on panel data representing the average wheat yields in individual regions of the Czech Republic for the period 1961–2018. The long panel dataset allows us to distinguish between the effects of employed variables, and to separate the impact of climate change. In this respect, the paper aims to fill the gap in empirical literature on the assessment of the environmental dimension of Czech wheat production, as well as the impact of climate change.

The paper is organized as follows. The next section describes the data and methods. Then the results are presented. The final section provides concluding remarks and a discussion of the results.

Materials and methods

The yield function specification is based on the Just and Pope (1979) stochastic production function:

$$\boldsymbol{y} = \boldsymbol{f}(\boldsymbol{X}) + \boldsymbol{h}(\boldsymbol{X})^{\frac{1}{2}}\boldsymbol{\varepsilon} \qquad (1)$$

where $h(\boldsymbol{X})^{\frac{1}{2}}$ is a function of regressors in $\boldsymbol{X}$, $\boldsymbol{y}$ represents the yield and $\boldsymbol{\varepsilon}$ stands for residual term which is assumed to be i.i.d. $\boldsymbol{N}(\boldsymbol{0}, \boldsymbol{\sigma_\varepsilon^2})$. There are at least two advantages of the Just and Pope specification (1) (i.e. with $h(\boldsymbol{X})^{\frac{1}{2}}$ term) over a standard approach. First, in the latter case, the risk of production is not considered. That is, if we assume the risk aversion, which is the typical

farm characteristic, the risk effect is incorrectly estimated. Second, the standard approach is typically characterized by the presence of heteroscedasticity. As a result, it makes problems in hypothesis testing about the importance of regressors, and it may decrease the efficiency of the model estimate (Just and Pope, 1979).

The estimation procedure of (1) consists of three steps. In the first step, y is regressed on $\boldsymbol{X}$ using ordinary least square (OLS) method. The second step uses the squared residual from the first step in the regression on $\boldsymbol{X}$ using OLS. In the third step, y is regressed on $\boldsymbol{X}$ and the square root of the predictions from the second step.

The functional form of the model (1) in this study is specified as a Taylor approximation of the second order in the environmental variables. That is, we use the Taylor approximation of the second order to approximate the nonlinear relationship between wheat yield and temperature/precipitation in the respective month. In the case of the price index and moisture, we assume a linear relationship with wheat yield. Moreover, the technological change and climate change effects are captured using the trend variable (t). In the latter case, we use trend variable in combination with temperature and precipitation variables, in order to capture the changes in the first-order parameters due to the effects of climate change. That is, we can write our model as:

$$\boldsymbol{y = \alpha' z + \beta' x + \gamma' x^2 + \delta' c + h(X)^{\frac{1}{2}}\varepsilon} \qquad (2)$$

where $\boldsymbol{\alpha, \beta, \gamma, \delta}$ are vectors of parameters to be estimated. $\boldsymbol{z, x}$ and $\boldsymbol{c}$ are vectors of regressors.

The vectors of regressors $\boldsymbol{z, x}$ and $\boldsymbol{c}$ consist of the following variables (variables are logarithmically transformed and normalized by their mean):

$\boldsymbol{z}$:

- ***P_index_ratio - (lPP)*** - a ratio of wheat price index over composite price input index.
- ***Moisture – (lMo)*** – average of precipitation from November to March.

$\boldsymbol{x}$:

- ***Monthly temperatures - (lTM4,…,lTM7)*** – average monthly temperatures from April to July.
- ***Monthly precipitation - (lSM4,…, lSM7)*** – average monthly precipitation from April to July.

$\boldsymbol{c}$:

- ***Climate change variables – (lT4_t,… lT7_t, lS4_t,…, lS7_t)*** – average monthly temperatures and precipitation in combination with the time vector.
- ***Time vector – (t and t_2)*** – a proxy for technological change.

The study uses panel data representing the average wheat yields, price indices, monthly temperatures and precipitation in individual regions of the Czech Republic for the period 1961–2018. The source of the data is the Czech Statistical Office (www.czso.cz) and the Czech Hydrometeorological Institute (www.chmi.cz). The basic statistical characteristics of the variables are provided in the Appendix.

In our empirical application, we exploit the properties of the long panel dataset, i.e. small N and large T, and we use the fixed effects model estimator. In particular, Pesaran (2015) shows that there is no difference between the fixed or random effects model estimator when N is small and T large.

SW GRETL was used to estimate model (2).

Results and discussion

Table 1 provides a parameter estimate of the yield function in a Just and Pope specification. The estimate displays an overall good fit. In particular, the estimate is consistent with economic and agronomical assumptions. Then, the majority of fitted parameters are significant even at a 1% significance level. The variability of yield is well explained by the regressors (LSDV R2 = 0.87), and the assumptions regarding the residual term are met by the estimate as well.

Variable	Coefficient	Standard Deviation	p-value
const	5.697	1.784	0.002
lPP	0.651	0.067	0.000
lT4	-0.051	0.087	0.559
lT5	-0.989	0.113	0.000
lT6	2.644	0.853	0.002
lT7	-0.799	0.125	0.000
lT4_2	3.932	1.725	0.023
lT5_2	-6.053	2.330	0.010
lT6_2	0.621	0.204	0.002
lT7_2	-12.841	3.331	0.000

Source: author's own calculation

Table 1: Estimated parameters of the stochastic production function (to be continued).

Variable	Coefficient	Standard Deviation	p-value
lMo	0.023	0.019	0.244
lS4	-0.002	0.010	0.810
lS5	0.040	0.011	0.000
lS6	-0.067	0.012	0.000
lS7	-0.066	0.010	0.000
lS4_2	-0.028	0.014	0.044
lS5_2	-0.093	0.024	0.000
lS6_2	-0.232	0.038	0.000
lS7_2	-0.032	0.017	0.065
lT4_t	0.009	0.006	0.134
lT5_t	-0.063	0.009	0.000
lT6_t	0.004	0.002	0.050
lT7_t	0.037	0.010	0.000
lMo_t	0.004	0.001	0.000
lS4_t	0.000	0.001	0.570
lS5_t	-0.002	0.001	0.002
lS6_t	-0.001	0.001	0.409
lS7_t	0.002	0.001	0.000
t	0.040	0.008	0.000
t_2	0.000	0.000	0.000

Source: author's own calculation

Table 1: Estimated parameters of the stochastic production function (continuation).

Since variables were logarithmically transformed and normalized by their means, the first-order parameters can be interpreted as elasticities when evaluated on sample means. That is, a particular first-order parameter provides information on the percentage change in wheat yield in a reaction to a 1% change in the respective explanatory variable evaluated on the sample mean. In this respect, the parameter on price index (lPP) shows that a 1% change in the ratio of wheat output and composite input price indices results in a 0.651% change in wheat yield. This positive effect of the price index is consistent with the economic expectation concerning the effect of price on the yield. Hendricks (2014) makes similar conclusions. In particular, an increase in the wheat index over the composite input index stimulates farmers to increase the allocation of a higher portion of quality land in the production of wheat, resulting in a higher wheat yield, on average.

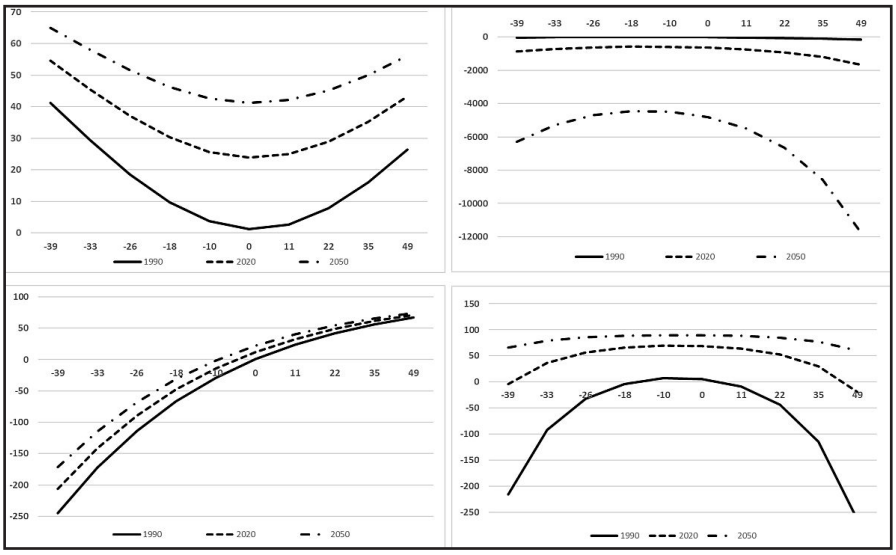
Temperature shows the greatest impact on wheat yield. The first-order parameters suggest that temperature has a negative effect in April, May and July, and a positive effect in June (with respect to the mean).It is in accordance with King et al.(2018) and Morel et al (2021). The second-order parameter reinforces the negative effect in May and July, as well as the positive effect in June. In particular, high nonlinearity is pronounced in May and July. It holds that the higher the temperatures (above-average temperatures) are in May and July, the higher wheat yield losses we can expect. On the other hand, the second-order parameter in April changes the negative effect to a positive one, with higher temperatures above the average.

The temperature effects for different months and different years are depicted in Figures 1a, b, c, d. In addition, the figures capture the estimated climate change effect. That is, the model estimate shows that the first-order parameters are changing over time (see parameters on lT4_t, …, lT7_t). Whereas the parameters in April, June and July are going up, the negative effect in May is more and more pronounced. Since we can associate these parameter changes with the effects of climate change, Figures 1a,b,c,d demonstrate how these climate change effects determine the changes in wheat yield over time. In particular, we can observe the differences between the years 1990, 2020 and 2050 according to our estimates.

Moisture shows a positive, but not a significant effect on wheat yield. However, the minor increase in the positive effect due to climate change is significant, even at the 1% significance level. The estimated effect of precipitation is negative in April, June and July, and there is a positive effect in May. The second-order parameters suggest that the higher precipitation is above the average in April, June and July, the greater is the negative effect on wheat yield. On the other hand, the positive effect of precipitation in May deteriorates with an increase in temperatures above the average.

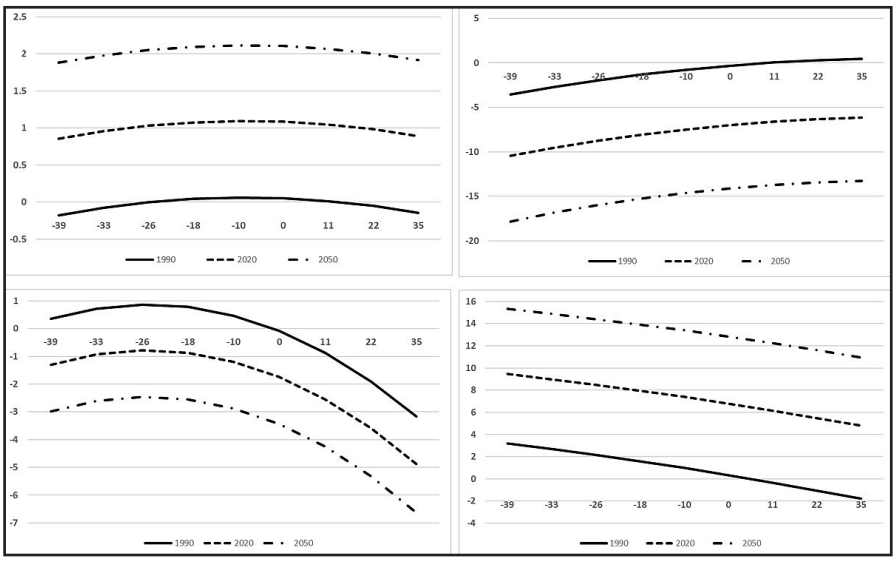
The climate change effect (lS4_t, …, lS7_t) is significant in May and July. We can observe a decrease in the positive effect of May, and a decrease in the negative effect of July (as far as the first-order parameters are concerned). Figures 2a, b, c, d demonstrate how the climate-change effects on precipitation determine the changes in wheat yield over time.

Finally, we estimated the positive effect of technological change. That is, we can observe that advances in R&D positively contributed to wheat yield. The effect accounts for, on average, a 0.04% increase per year. Then, we found significant heterogeneity among the Czech regions.



Note: a) April, b) May, c) June, d) July
Legend: x-axis - % change in temperature with respect to the mean of the respective month; y-axis - % change in the wheat yield with respect to the sample mean.
Source: author's own calculation

Figure 1a, b, c, d: Climate change effect on the changes in yield – temperatures.



Note: a) April, b) May, c) June, d) July
Legend: x-axis - % change in temperature with respect to the mean of the respective month; y-axis - % change in the wheat yield with respect to the sample mean.
Source: author's own calculation

Figure 2a, b, c, d: Climate change effect on the changes in yield – precipitation.

In particular, the fixed effects suggest that yield differences between the Czech regions are another important characteristic of Czech wheat production.

Conclusion

The aim of this study was to demonstrate and quantify the effects of economic and environmental factors, as well as climate change, on the yields of wheat grown in the Czech Republic. The study uses panel data constructed for individual regions of the Czech Republic for the period 1961–2018. Wheat yields are explained by price index, monthly temperatures in the period of growth, precipitation, moisture, climate change and technological change. A stochastic production function was applied to model the effects of selected variables.

The largest and most positive effect (2.644%), by far, is evident for temperature in June, which is still supported by the second-order parameter.

On the other hand, a significant negative effect is evident for higher temperatures in May and July. This finding is also reinforced by the second-order parameter and is in line with the appropriate conditions for growing this type of cereal. The second most important variable is the price index, which has a positive effect (0.651%). From an economic point of view, it is also expected that favorable output prices motivate farmers to produce more.

Another significant determinant is the precipitation in individual months. It is obvious that it has a positive effect in the spring months, contrary to the time of grain ripening and harvesting. It has the largest positive effect in May (0.04%) and the highest negative effect in June (0.06%). The fourth most important variable is climate change, which confirms the negative impact of high temperatures in May. On the contrary, warming in the summer months has a positive effect.

In the evaluation of the influence of selected factors, technological progress is next in line; its positive effect is confirmed by an elasticity of 0.04%. The last positive, although statistically insignificant effect, was demonstrated for the variable moisture.

The results show that climate change, in the form of higher temperatures and uncertain precipitation, brings the need for agronomic and technological change. In particular, it is necessary to grow more resistant wheat species on suitable soils, in order to ensure efficient and sustainable production of this essential commodity.

With these results, this study is important for future agricultural policy-making. The results point to the possible impact of climate change, which may be positive for some cultivated crops and negative for others. Wheat is the most cultivated cereal in the Czech Republic. An important task is therefore to draw the attention of agricultural entities to potential changes in yields with regard to the evaluated variables so that they have enough time to choose an appropriate adaptation strategy.

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Appendix

Variable	Number of observations	Mean	Standard Deviation
Wheat yield	784	4.28	1.13
Wheat price index	784	0.75	0.35
Composite input index	784	0.70	0.37
Average temperature - April	784	7.64	1.73
Average temperature - May	784	12.56	1.63
Average temperature - June	784	15.72	1.44
Average temperature - July	784	17.42	1.77
Moisture	784	44.77	13.70
Average precipitation - April	784	43.25	20.23
Average precipitation - May	784	71.89	32.06
Average precipitation - June	784	81.99	30.08
Average precipitation - July	784	85.68	43.00

Source: author's own calculation

Table A1: Descriptive statistics of model variables.

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Analysis of Calculation Methods Currently Practised at V4 Agricultural Holdings

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Abstract

This paper assesses calculation methods in the Visegrad 4 countries (Czech Republic, Hungary, Poland and Slovakia) and, based thereon, recommends and considers activity-based costing (ABC) in the agricultural sector, while evaluating manager knowledge of ABC as an appropriate alternative to outdated, "conventional" methods of calculating costs that are used in practice.

It was found that a majority of agricultural holdings in the V4 are currently using conventional cost calculation methods and the most frequent reason for their failure to incorporate ABC is low awareness among managers.

Farms and agricultural holdings that have introduced ABC and utilise it to assign their costs evaluate its benefits highly positively, in particular, ABC's more accurate identification of costs, mainly overheads; more effective cost management and the accuracy of price estimates.

From this analysis and assessment, introduction of ABC is recommended for companies in order to obtain the different benefits associated with the method. Successfully implementing ABC leads to a number of advantages, especially in the inevitable decision-making agricultural holdings face about high overhead costs. From the information obtained, managers at agricultural holdings have little information, in most cases, about ABC as an appropriate alternative to the outdated "conventional" cost estimate methods practised today. It is therefore important to work on raising managers' awareness of new approaches to costing by publishing scientific articles with specific examples from practice, pointing out the advantage of the ABC method, especially with high overheads, which are almost the rule in agricultural holdings.

Keywords

Activity Based Costing method, cost calculation, agricultural holdings.

JEL: M21, M41, Q14

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Introduction

Most agricultural holding managers know nothing about the significance of calculating costs. In strategic management and decision-making, only companies with advanced managements responsibly devoted to strategy and visualising further development are making such calculations. They comprise about 30% of agricultural holdings operating in Slovakia. From an economic point of view, these are considered above-average businesses. However, most farms are still using traditional cost accounting methods to address overhead.

Such economic cost management in the agricultural sector is associated with input price growth, falling production, increased competition, the macroeconomic environment and an unfavourable market situation. Agricultural costs are also influenced by natural factors such as climate, location, high in-house consumption, circulating assets and the nature of property, plant and equipment in agriculture.

Internal costs are more substantially influenced by how the holdings are managed than from external factors. But this requires managers to pay more attention to costs and emphasise cost-effectiveness in their spending. It also requires a change in attitude among managers at different agricultural holdings, still often grounded in previous practices and traditional farm management methods. They fail to pay enough attention to internal management, where such focus could ultimately lead to cost reductions.

In today's environment, it is critical to seek out ways to optimise costs and identify problem areas, where an activity-based cost management model can be applied to ensure long-term competiveness. Activity-based management (ABM) includes activity-based costing (ABC), activity-based planning (ABP), activity-based budgeting (ABB) and activity-based accounting (ABA). These are so-called "AB" techniques.

In the 1980's much criticisms were raised regarding the ability of traditional cost accounting to provide relevant, timely, and accurate information to the management. During that period, ABC has emerged as one of the management accounting tools that recognizes such concern. Since then ABC has gained its popularity and has received substantial attention from various parties including the academicians, practitioners, and industries. ABC has also been studied from various perspectives for quite some time in many countries. Literatures are enriched with studies that have argued that the adoption of ABC benefits organizations. Unfortunately, studies have also found that the level of ABC adoption is still considered low. Many organizations still use the traditional cost accounting methods in dealing with overhead costs. (Maelah and Ibrahim, 2007). The implementation of ABC could improve firms both financial performance and nonfinancial performance (Fei and Isa, 2011).

Large scale agricultural enterprises that depend heavily on capital investments require rational allocation of the available resources and efficient utilization of the existing production technology. The accurate and reliable computation of cost per unit of product is crucial for the evaluation of the economic performance of the enterprises and the investigation of the optimal allocation of the production factors in different activities. The concept of Activity Based Costing methodology, which is of great importance in the system of cost accounting, allows the allocation of indirect costs to specific activities and individual products, overcoming the drawbacks of the traditional method of cost accounting (Koutouzidou et al., 2015).

In order to solve problems with the allocation of indirect costs, it is appropriate to use the approach it supports a structured decision making process – ABC approach. ABC is a methodology developed to face the increasing level of fixed costs in the modern companies (Cooper and Kaplan, 1988), (Johnson and Kaplan, 1987). Allocation of fixed costs to products is complex and ABC "measures costs and performances of activities, resources and cost objects, assigns resources to activities and activities to cost objects based on their use, and recognizes causal relationships of cost drivers to activities" (Dierks and Cokins, 2000).

Given the highly competitive environment in which the Agribusiness is inserted, there is a growing need for professional management of rural properties, which requires the use of methods that assist decision making. In this context, it is noticed that cost management is an essential tool for the administration of rural enterprises. (Sampaio et al., 2011).

Because of the ongoing income pressure in agriculture, the analysis of services and costs at farm activity level is gaining in importance. The advantage of the ABC approach would be to achieve a wider impact. This would encourage cost awareness on farms, which could ultimately improve income. (Gazzarin and Lips, 2018). The agricultural companies need to deepen the effective use of the appropriate techniques for the strategic management of costs of the processes and activities to meet the different demands of the agribusiness economic system, which is situated in an environment of new perspectives and challenges arising from the reshaping of markets and the continuous improvement of competitiveness. (da Silva et al., 2019) Facing increasingly competitive market demands, agricultural producers must act as managers of their property, knowing the strengths and bottlenecks in production systems. In this perspective, there is a methodology activity-based costing system (ABC), a cost management tool, used when there is a mix of products, to determine the unit costs of production (Araújo et al., 2019).

The method Activity Based Costing is an instrument to better assignment of costs to activities. The method is appropriate for manufacturing corporations, distribution centres, agriculture, but also for the field of services, especially in the hospitality. The method has advantages and benefits for whole range of companies without difference to branch classification. (Dejnega, 2011), (Dalci et al., 2010). ABC has capability to calculate the overhead cost more precisely and generate the information that contributes to improving the overall production activity (Gholami et al., 2019).

ABC demonstrates how significant cost-saving opportunities can be identified in the business and offers a first step in a change in cost management thinking (Schulze et al, 2012). The ABC cost model could be the most

appropriate tool to manage resources and provide the information needed to achieve the strategic objectives set out by the institution (enterprise), since it would allow to know at all times what is done and how it is done, since the implementation of the it implies the definition of the main activities developed in the institution, how they are being carried out and the cost of their realization. Information would be available on the effectiveness and efficiency of the activities (Del-Río Sánchez et al., 2019). ABC model is a model of cost management system has been developed that takes into account certain directions of information flows between the elements of the organizational structure of cost management at all stages, making possible the effective impact on the use of resources (Perevozova et al., 2019). Accounting approach known as ABC model allows for decisions toward a company's sustainability by acting on both the amount and kind of a company's product that should be managed, as well as on the effective increase of a specific company's activity or process (Neto et al., 2018).

An ABC system is based on the idea that products make use of certain general activities developed inside the company and these activities require some resources to be done. It means that, first, the cost of the resources are allocated to the activities and, then, the costs of activities are allocated to the products (costs objects) using specific activity drivers for each activity. In this way, it is possible to assign overheads to products in a more accurate and precise way. This logic enables managers to have a deeper control on how products or services, brands, customers, channels of distribution, or facilities consume resources and generate costs. Furthermore, this logic fosters the understanding of patterns of resource consumption at the micro level. Managers can have access to a deeper level of information that enables corrective actions directed to the enhancement of revenues, profitability and cost reduction. ABC prevents some distortions related to product cost information that arise from traditional accounting systems where the overheads (indirect costs) are arbitrarily attributed, usually in proportion to an activity's direct cost. Traditional systems create higher distortions when there are sophisticated production structures, with a wide range of products or services that require the assignment of large amount of general costs (Carli and Canavari, 2013).

Arora and Raju (2018) found in their study a number of employees and the percentage of overheads as significant company characteristic factors for the implementation of the ABC system. More adequate pricing decisions, better overhead cost allocation, and more accurate product cost were found as the motives for the implementation of the ABC system. The major challenges faced during the adoption process of the ABC system are selecting cost drivers, high cost of ABC, data collection difficulties, and uncertainty of ABC benefits. Costly to switch to ABC, easy to track cost, satisfied with current system, and uncertainty of ABC benefits were found as the main causes for non-adoption of ABC. The study recommended the implementation of the ABC system to get the various benefits associated with it.

Elhamma (2015) found in his study that the management accounting system based on ABC method results in a better performance for enterprises that have adopted it. Finally, they demonstrated that the firms operating in an uncertain and dynamic environment have an interest to adopt this new method of the management accounting, but the firms operating in a certain and stable environment are indifferent between adopting and not adopting this method.

The activity-based costing (ABC) systems emerged as a management accounting innovation in the mid-1980´s in response to dissatisfaction with traditional management accounting techniques and heightened international competition. Although ABC provides many advantages for managerial decision making, ABC tends to be outdated due to its limitations and is substituted by the time-driven activity-based costing (TDABC) systems. TDABC requires estimates of only two parameters: how much it costs per time unit of capacity to supply resources to activities and how much time it takes to perform each activity. TDABC allows incorporation of variation in the time demands made by different types of processes and consequently the representation of all possible combinations of activities that a process performs (Park et al., 2019).

Allain and Laurin (2018) argue that managers should be aware that designing and implementing a cost system that can simultaneously be used in both controlling and enabling ways is a very difficult, if not an insurmountable challenge.

Activity-based costing (ABC) looks like a great way to manage a company's limited resources. But executives who have tried to implement ABC in their organizations on any significant scale have often abandoned the attempt in the face of rising costs and employee irritation. They should try again, because a new approach

sidesteps the difficulties associated with large-scale ABC implementation, write Kaplan, and Anderson (2004) about an innovated ABC method - about the Time-driven activity-based costing. In the revised model, managers estimate the resource demands imposed by each transaction, product, or customer, rather than relying on time-consuming and costly employee surveys. This method is simpler since it requires, for each group of resources, estimates of only two parameters: how much it costs per time unit to supply resources to the business's activities (the total overhead expenditure of a department divided by the total number of minutes of employee time available) and how much time it takes to carry out one unit of each kind of activity (as estimated or observed by the manager). This approach also overcomes a serious technical problem associated with employee surveys: the fact that, when asked to estimate time spent on activities, employees invariably report percentages that add up to 100. Under the new system, managers take into account time that is idle or unused. Armed with the data, managers then construct time equations, a new feature that enables the model to reflect the complexity of real-world operati and activity characteristics cause processing times to vary. This Tool Kit uses concrete examples to demonstrate how managers can obtain meaningful cost and profitability information, quickly and inexpensively. Rather than endlessly updating and maintaining ABC data, they can now spend their time addressing the deficiencies the model reveals: inefficient processes, unprofitable products and customers, and excess capacity.

Materials and methods

Based on the above ascertained facts, the aim of the paper is to evaluate the calculation methods used by agricultural holdings in the Visegrad 4 countries (Czech Republic, Hungary, Poland and Slovakia) and therefrom recommend and consider activity-based costing in the agricultural sector, while evaluating knowledge managers have of ABC as an appropriate alternative to outdated, "conventional" methods of calculating costs that are used in practice.

In order to reach this objective, the following research questions and hypotheses were set:

Research questions:

What other calculation methods are agricultural holdings in the Visegrad 4 countries (Czech Republic, Hungary, Poland and Slovakia) presently using?

What percentage of agricultural holdings knows ABC and what percentage of them in each V4 country is actually utilising it compared to the others?

What are the advantages and weaknesses of practising ABC among agricultural holdings in the V4 (why has it not been successful in some farms and why are other farms refusing to introduce it)?

Hypotheses:

Hypothesis 1: Most agricultural holdings in the V4 are currently using "conventional" methods to calculate costs.

Hypothesis 2: The most common reason for agricultural holdings in the V4 not using ABC is low awareness of the method among managers.

Hypothesis 3: There are differences among the countries in the various types of calculation methods used.

Hypothesis 4: ABC's assessment as time consuming varies depending on the country where the agricultural holding is located.

Hypothesis 5: Management's doubts about ABC's benefits vary depending on the country where the agricultural holding is located.

The hypotheses were verified using the significance test for a proportion, the Wilcoxon signed-rank test, the Chi-square test of independence, and the Kruskal-Wallis one-way analysis of variance.

Questionnaires were used to capture data, with replies received from a total 98 agricultural holdings. The questionnaire was sent out and the data collected in the period January-April 2020. All subjects in the analyzed set of companies are trading companies – limited liabilty company, joint stock company, cooperative. Entities of natural persons are not included in the file. Likewise, all agricultural entities in the analyzed group perform mixed crops and livestock production (classification of production focus according to FADN). In terms of the size of enterprises, the file includes almost all economic size classes according to FADN (II.-XIII.), which for the purposes of research in the article are divided into sizes according to two criteria - according to the number of employees and according to the area of agricultural land in ha.

The number of holdings in the four countries and their size are shown in Tables 1 and Table 2.

Company size by number of employees	CZ		HU		PL		SK		Together	
	N	%	N	%	N	%	N	%	N	%
Microenterprise (up to 10 employees)	9	37.5%	6	28.6%	7	30.4%	6	20.0%	28	28.6%
Small company (11 - 50 employees)	8	33.3%	10	47.6%	10	43.5%	12	40.0%	40	40.8%
Medium company (51 - 250 employees)	6	25.0%	5	23.8%	5	21.7%	11	36.7%	27	27.6%
Big company (over 250 employees)	1	4.2%	0	0.0%	1	4.3%	1	3.3%	3	3.1%
Together	24	100.0	21	100.0	23	100.0	30	100.0	98	100.0

Source: own processing

Table 1: Numbers of holdings and their size by number of employees in V4 countries.

Company size by area of land	CZ		HU		PL		SK		Together	
	N	%	N	%	N	%	N	%	N	%
Less than 500 ha	8	33.3%	6	28.6%	7	30.4%	10	33.3%	31	31.6%
501-1000 ha	6	25.0%	6	28.6%	5	21.7%	7	23.3%	24	24.5%
10001-1500 ha	5	20.8%	6	28.6%	7	30.4%	7	23.3%	25	25.5%
1501-2000 ha	2	8.3%	2	9.5%	1	4.3%	4	13.3%	9	9.2%
More than 2,000 ha	3	12.5%	1	4.8%	3	13.0%	2	6.7%	9	9.2%
Together	24	100.0	21	100.0	23	100.0	30	100.0	98	100.0

Source: own processing

Table 2: Numbers of holdings and their size by area of agricultural land in V4 countries.

The questionnaire contained the items below:

1. Size of the holding, according to the number of people employed there and its measured land area.
2. Other calculation methods currently used to estimate the holding's costs.
3. Thoughts about changing the methods presently utilised and what new method was being contemplated.
4. Awareness of activity-based costing.
5. How long activity-based costing had been used and if the holding was using it.
6. What benefits activity-based costing had bought the holding.
7. Whether activity-based costing had met expectations.
8. Why the holding was not using activity-based costing.
9. If the holding had tried activity-based costing and was no longer using it, why it had not been successful there.

The results for questions 6-9 are rated on a scale: 4 - definitely yes, 3 - rather yes, 2 - rather no, 1 - definitely no, 0 - I don't know, I can't express myself.

Results and discussion

1. Analysing the calculation methods used

Table 3 shows the methods the holdings used to estimate agricultural costs, by country. The most popular calculation method currently practised by them is mark-up, considered to be the conventional method. It is used by most holdings in all 4 countries. According to our findings, only 6% of holdings are considering a change in the currently used calculation method. Just over 30% currently use the ABC method.

Table 4 describes overall ABC awareness among agricultural holdings. It was mentioned the most among all the holdings which were contacted and had replied to the questionnaires (by more than 31%) that they knew about the method, but had elected not to utilise it. What is striking is that 28% of the farms surveyed had not even known about ABC.

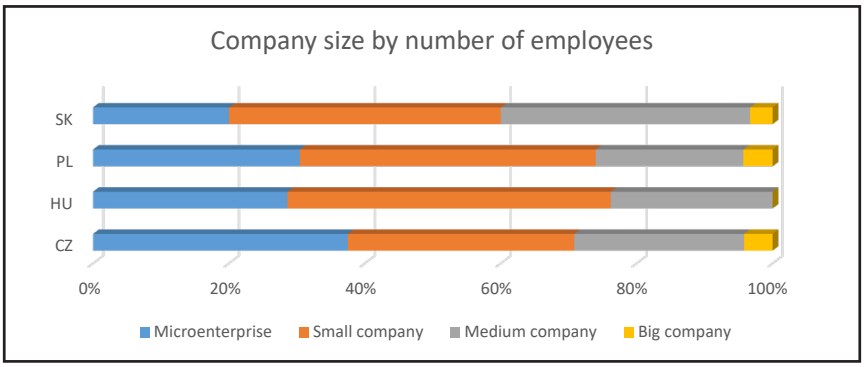
Table 5 shows how long the agricultural holdings had used ABC to estimate costs. The question was only answered by those practising it at the time when they replied to the questionnaire. Table 6 summarises the farms whose expectations were met after they had implemented ABC.

Calculation methods used	CZ		HU		PL		SK		Together	
	N	%	N	%	N	%	N	%	N	%
Mark-up calculation	12	50.0%	11	52.4%	15	65.2%	13	43.3%	51	52.0%
Calculation of combined outputs	3	12.5%	0	0.0%	0	0.0%	5	16.7%	8	8.2%
Calculation of variable costs	0	0.0%	2	9.5%	0	0.0%	1	3.3%	3	3.1%
Process calculation (ABC)	9	37.5%	8	38.1%	8	34.8%	11	36.7%	36	36.7%
Together	24	100.0	21	100.0	23	100.0	30	100.0	98	100.0

Thinking about change	CZ		HU		PL		SK		Together	
	N	%	N	%	N	%	N	%	N	%
Yes	1	4.2%	2	9.5%	1	4.3%	2	6.7%	6	6.1%
No	23	95.8%	19	90.5%	22	95.7%	28	93.3%	92	93.9%
Together	24	100.0	21	100.0	23	100.0	30	100.0	98	100.0

Source: own processing

Table 3: Use of calculation methods in agricultural holdings.



Source: own research

Figure 1: Use of calculation methods in agricultural holdings.

Attitudes to the ABC method	CZ		HU		PL		SK		Together	
	N	%	N	%	N	%	N	%	N	%
We did not meet, we do not know	6	25.0%	6	28.6%	6	26.1%	10	33.3%	28	28.6%
We know, we don't use it	7	29.2%	7	33.3%	9	39.1%	8	26.7%	31	31.6%
We are introducing ABC	5	20.8%	4	19.0%	2	8.7%	4	13.3%	15	15.3%
We use	4	16.7%	4	19.0%	6	26.1%	7	23.3%	21	21.4%
We tried, unsuccessfully	2	8.3%	0	0.0%	0	0.0%	1	3.3%	3	3.1%
Together	24	100.0	21	100.0	23	100.0	30	100.0	98	100.0

Source: own processing

Table 4: Attitudes towards the Activity Based Costing method by country.

Length of use of the ABC	CZ		HU		PL		SK		Together	
	mean	102.00	78.00	78.00	92.57	87.43	N	%	N	%
standard deviation	12.00	20.78	43.43	39.63	33.54	4.3%	2	6.7%	6	6.1%
N	4	4	6	7	21	95.7%	28	93.3%	92	93.9%
Together	24	100.0	21	100.0	23	100.0	30	100.0	98	100.0

Source: own processing

Table 5: Length of use of the ABC method in months.

Meeting the expectations	CZ		HU		PL		SK		Together	
	mean	3.50	3.25	3.17	3.43	3.33	N	%	N	%
standard deviation	0.58	0.96	0.41	0.53	0.58	4.3%	2	6.7%	6	6.1%
N	4	4	6	7	21	95.7%	28	93.3%	92	93.9%
Together	24	100.0	21	100.0	23	100.0	30	100.0	98	100.0

Source: own processing

Table 6: Meeting the expectations of using the ABC method.

The respondents that had already introduced ABC into their estimation of costs were asked to evaluate the benefits on a four-point scale. Twenty-one agricultural holdings responded to the question. Possible reasons were arranged in descending order by the average of the scores (Table 7).

As is evident in Table 7, respondents appreciated the more accurate identification of costs, especially of overheads. Here the mean score of 3.95 was virtually the maximum value possible, reached in all countries except for the Czech Republic, where the average was only 3.75.

The managers also highly appreciated the accuracy of the calculated price estimates. In the Czech Republic and Slovakia, the scores averaged the maximum 4.00, while in Poland it was 3.50 and in Hungary 3.00. Across all countries, the mean was 3.67.

More effective cost management was rated as an advantage of ABC, receiving the third highest mean score of 3.57, with recognition of the fair value of activities and true costs particularly cited as a reason. This factor was particularly appreciated extremely highly by respondents in Slovakia (4.00), while it was still significant in the other countries: 3.50 in the Czech Republic, 3.33 in Poland and 3.25 in Hungary.

Ranked fourth among the benefits, from their replies to the questionnaires, was ABC's ability to clarify the economic efficiency of activities. The mean score of 3.48 is just slightly lower than the next highest benefit rated. Managers in the Czech Republic mainly cited this factor. The variance of replies from respondents in other countries was greater, but overall they still gave a positive opinion (Poland: 3.50, Slovakia: 3.29 and Hungary 3.25).

As with the previous factor, the respondents also evaluated the quality and effectiveness of monthly final calculations, scoring an average of 3.48 across all countries. Czech respondents again unanimously rated this factor with the highest possible score of 4.00, while agricultural holdings responding in Hungary (3.50), Poland (3.33) and Slovakia (3.25) gave positive evaluations, but the variance between opinions was greater.

When evaluating the cost analysis of activities, respondents within the countries rarely agreed. While all holdings in the Czech Republic and Hungary evaluated it with the maximum possible score of 4.00, all of the respondents in Poland and Slovakia scored it only slightly positive (3.00), and so the mean across all four countries was only 3.38.

Monthly customer and product evaluations were rated even lower as a benefit among the agricultural holdings responding to the questionnaire, with scores averaging 3.29. All of the respondents in the Czech Republic again rated them the maximum 4.00, while respondents in Poland (3.50) and Slovakia (3.00) appreciated them less and the 2.75 average among Hungarian holdings was the lowest score.

Respondents were even more sceptical about the remaining two possible benefits. The possibility ABC provides of performance-based compensation according to real economic benefits only scored an average of 2.86, where responding agricultural holdings in the Czech Republic again rated it the highest (3.50), followed by Slovakia (3.00), Hungary (2.75) and the lowest by Poland (2.33).

Respondents considered product and customer portfolio optimisation to be the least significant advantage of ABC. The overall mean here was 2.62, where it was rated highest by farms in the Czech Republic (3.50) and lowest in Hungary (2.75). The perception of portfolio optimisation found in Poland (mean of 2.33) and Slovakia (2.29) was practically indecisive because of the variance in responses.

Agricultural holdings responding that they did not use ABC were also asked to provide reasons for their decision. Table 8 shows their answers, broken down by country. Again the reasons are arranged in descending order.

All of them agreed that they were not aware of the method, which was reflected in all of the V4

Benefits of implementing ABC		CZ	HU	PL	SK	Together
	Number	4	4	6	7	21
More accurate identification of costs, especially of overheads	**mean**	**3.75**	**4**	**4**	**4**	**3.95**
	stand. deviation	0.5	0	0	0	0.22
Accuracy of the calculated price estimates	**mean**	**4**	**3**	**3.5**	**4**	**3.67**
	stand. deviation	0	0	0.55	0	0.48
More effective cost management (fair valuation of activities and cost objects)	**mean**	**3.5**	**3.25**	**3.33**	**4**	**3.57**
	stand. deviation	0.58	0.5	0.52	0	0.51
Transparency of economic efficiency of activities, targeted distribution of overheads for specific business activities	**mean**	**4**	**3.25**	**3.5**	**3.29**	**3.48**
	stand. deviation	0	0.5	0.55	0.49	0.51
Process calculations - better monthly final calculations of products and evaluation of their efficiency	**mean**	**4**	**3.5**	**3.33**	**3.29**	**3.48**
	tand. deviation	0	0.58	0.52	0.49	0.51
Cost analysis of activities	**mean**	**4**	**4**	**3**	**3**	**3.38**
	stand. deviation	0	0	0	0	0.5
Monthly evaluation of profit and economic value added by customers and products	**mean**	**4**	**2.75**	**3.5**	**3**	**3.29**
	stand. deviation	0	0.5	0.55	0	0.56
Performance-based compensation according to real economic benefit	**mean**	**3.5**	**2.75**	**2.33**	**3**	**2.86**
	stand. deviation	0.58	0.5	0.52	0	0.57
Product and customer portfolio optimisation	**mean**	**3.5**	**2.75**	**2.33**	**2.29**	**2.62**
	tand. deviation	0.58	0.5	0.52	0.49	0.67

Source: own processing

Table 7: Benefits of implementing ABC.

Reasons for not using ABC		CZ	HU	PL	SK	Together
	Number	6	6	9	10	31
Not aware of the method ABC	**mean**	**4.00**	**4.00**	**4.00**	**4.00**	**4.00**
	stand. deviation	0.00	0.00	0.00	0.00	0.00
Management's doubts about ABC's benefits	**mean**	**3.00**	**4.00**	**4.00**	**3.88**	**3.74**
	stand. deviation	0.00	0.00	0.00	0.35	0.44
Assumption that implementation would be time-consuming	**mean**	**3.00**	**4.00**	**3.78**	**4.00**	**3.71**
	stand. deviation	0.00	0.00	0.44	0.00	0.46
ABC is unsuitable for their agricultural holdings	**mean**	**3.29**	**4.00**	**3.56**	**3.50**	**3.58**
	stand. deviation	0.49	0.00	0.53	0.53	0.50
Resistance to change from staff employed	**mean**	**2.43**	**1.86**	**2.56**	**2.63**	**2.39**
	stand. deviation	0.98	1.07	1.13	0.52	0.95

Source: own processing

Table 8: Reasons for not using ABC.

countries equally with the maximum score of 4.00.

Respondents likewise agreed more or less on management's doubts about ABC's benefits for the agricultural holding, with a mean score of 3.74 among them. All of the respondents in Hungary and Poland fully agreed (4.00), while most in Slovakia (3.88) and the Czech Republic (3.00) somewhat agreed.

Another common determinant for using ABC is the assumption that implementation would be time-consuming (mean score of 3.71 across all countries). All of the respondents in Hungary and Slovakia were especially convinced (4.00), while respondents in Poland (3.78) and the Czech Republic (3.00) were less convinced.

Even though the respondents admitted their ignorance of ABC, they also evaluated it as unsuitable for their agricultural holdings. The mean score of 3.58 indicates a high level of agreement among them. All of the respondents from Hungary agreed with the statement (4.00), while there was slight overall agreement expressed

by respondents from Poland (3.56), Slovakia (3.50) and the Czech Republic (3.29).

Resistance to change from staff employed at the agricultural holdings was not considered a significant reason for the failure to introduce ABC. The mean score of 2.39 generally indicates a neutral opinion. Respondents in Slovakia (2.63), Poland (2.56) and the Czech Republic (2.43) share this view a bit more than respondents in Hungary, whose responding agricultural holdings in general rather disagreed with this reason for not implementing ABC (1.86).

Respondents from agricultural holdings whose implementation of ABC had been unsuccessful were asked about the reasons for the lack of success. As only three farms had mentioned it, their responses were not broken down by country - see Table 9.

Reasons for failure	Number	3
Difficulty of project implementing	**mean**	**4.00**
	stand. deviation	0.00
Long time required for implementation	**mean**	**3.33**
	stand. deviation	0.58
Management doubts about project benefits	**mean**	**3.00**
	stand. deviation	0.00
No cooperation from interested staff	**mean**	**2.33**
	stand. deviation	0.58
Problems setting up a change in cost tracking	**mean**	**2.33**
	stand. deviation	0.58

Source: own processing

Table 9: Reasons for failure of the ABC.

The findings indicated the most common reason for failure, where all three agreed, was the challenge of implementing it (4.00). This was followed by the long time required for implementation (3.33) and management doubts about its benefits (3.00). Staff not cooperating (2.33) and difficulties setting up changes in cost monitoring were considered by the responding agricultural holdings to be less compelling reasons for the implementation of ABC to have failed.

2. Assessment of the hypotheses

Hypothesis 1: Most agricultural holdings in the V4 are currently using “conventional" methods to calculate costs.

The hypothesis aims to verify whether the percentage of agricultural holdings using conventional calculation methods is greater than 50%. Therefore, it was verified using the significance test for a proportion. The variable is the calculation method the agricultural holding uses to estimate costs, determined through the second reply to the questionnaire.

Null hypothesis: The proportion of agricultural holdings in the V4 countries using “conventional” methods to estimate costs is ***equal*** *to 0.5.*

Alternative hypothesis: The proportion of agricultural holdings in the V4 countries using “conventional” methods to estimate costs is ***greater than*** *0.5.*

N	Event	Sample p	95% Lower Bound for p
98	59	0.602	0.514

Source: own processing

Table 10 Assessment of the hypothesis 1.

Test

Null hypothesis H_0: p = 0.5

Alternative hypothesis H_1: p > 0.5

P-Value
0.027

Results indicate use of “conventional” calculation methods by 60.2% of the respondents in the V4, where the p-value of the test is calculated as 0.027, less than the significance level of 0.05. Therefore, the null hypothesis is rejected and the validity of the alternative hypothesis is accepted. Because the proportion is greater than 0.5, **Hypothesis 1 is confirmed.**

Hypothesis 2: The most common reason for agricultural holdings in the V4 not using ABC is low awareness of the method among managers.

The hypothesis aims to compare the intensity of the reason for not using the ABC method to estimate costs. This is ascertained from replies to Item 8 from the questionnaire. Therefore, the Wilcoxon signed-rank test was used to verify the intensity of ignorance as the reason for not using ABC for cost estimates paired with the second most common reason.

Null hypothesis: The difference between not using the ABC test because of ignorance and due to other reasons is **zero**.

Alternative hypothesis: The difference between not using the ABC test because of ignorance and due to other reasons is **greater than zero**.

Sample	N	Median
comparison of reasons for not using ABC	31	0

Source: own processing

Table 11: Assessment of the hypothesis 2.

Null hypothesis $H_0: \eta = 0$

Alternative hypothesis $H_1: \eta > 0$

Sample	N for Test	Wilcoxon Statistic	P-Value
comparison of reasons for not using ABC	8	36	0.007

Eight responding agricultural holdings replied that the most common reason for not using the ABC method was because they did not know about it. The other 23 respondents claimed ignorance to be the reason as often as management's doubts about the benefits from using this method. The p-value of the test is 0.007. This value again lies below the level of significance so the null hypothesis is once more rejected and the validity of the alternative hypothesis is accepted. **Hypothesis 2 is confirmed.**

Hypothesis 3: There are differences among the countries in the various types of calculation methods used.

Hypothesis 3 aims to verify the correlation between two nominal variables - country and calculation method used to estimate costs. The Chi-square test of independence is therefore used to verify it.

Null hypothesis: The various type of calculation methods used is not dependent on the country where the agriculture holding is located.

Alternative hypothesis: The various type of calculation methods used is dependent on the country where the agriculture holding is located.

Because variable costs and combined outputs are not very often calculated, these groups were merged prior to the calculation for the test. (Table 12).

Chi-Square Test

	Chi-Square	DF	P-Value
Pearson	5.991	6	0.424

The first table indicates the absolute and relative frequencies for the calculation of variable costs and combined outputs to vary for each country. These are 12.5% for the Czech Republic, 9.52% for Hungary and 20% for Slovakia, with no calculation in Poland.

Frequencies for calculating the mark-up likewise differ: 50.00% for the Czech Republic, 52.38% for Hungary, 65.22% for Poland and 43.33% for Slovakia. However, the percentage of ABC costing is approximately the same: 37.50% for the Czech Republic, 38.10% for Hungary, 34.78% for Poland and 36.67% for Slovakia. Nonetheless, the calculated p-value for testing of 0.424 is relatively high, meaning the described differences are not statistically significant and rather due either to random influences or a low number of respondents. Because the null hypothesis cannot be rejected, it has to be accepted. **Hypothesis 3 is not confirmed.**

Hypothesis 4: ABC's assessment as time consuming varies depending on the country where the agricultural holding is located.

Hypothesis 4 presumes a relationship between the nominal and ordinal variables, so the Kruskal-Wallis test was used to verify it. The sorting variable is the agricultural holding respondent's country and the ordinal variable the analysis of the amount of time required from the eighth item in the questionnaire.

Null hypothesis: Median amount of time required to implement ABC is high and equal in all four countries.

Alternative hypothesis: Median amount of time required to implement ABC is high and varies depending on the country where the agricultural holding is located.

	CZ	HU	PL	SK	All
Calculation of variable costs	3	2	0	6	11
+ Calculation of combined outputs	12.50	9.52	0	20.00	11.22
Mark-up calculation	12	11	15	13	51
	50.00	52.38	65.22	43.33	52.04
Process calculation ABC	9	8	8	11	36
	37.50	38.10	34.78	36.67	36.73
All	24	21	23	30	98

Note: Rows -Calculation methods; Columns - Country
Source: own research

Table 12: Assessment of the hypothesis 3.

Country	N	Median	Mean Rank	Z-Value
CZ	7	3	5.0	-3.64
HU	7	4	20.5	1.49
PL	9	4	17.1	0.41
SK	8	4	20.5	1.63
Overall	31		16.0	

Source: own research

Table 13: Assessment of the hypothesis 4.

Test

Null hypothesis H_0: All medians are equal

Alternative hypothesis H_1: At least one median is different

Method	DF	H-Value	P-Value
Adjusted for ties	3	22.69	0.000

The table makes clear that the medians (4) are the same in three of the four countries. It only varies (3) in the group of respondents from the Czech Republic. The p-value of the test equals nil, so the null hypothesis is rejected and the validity of the alternative hypothesis is accepted. The assessment by different agriculturists of the time consumed to implement ABC significantly varies in the Czech Republic from the remaining countries (z-value = -3.64), so **Hypothesis 4 is confirmed**.

Hypothesis 5: Management's doubts about ABC's benefits vary depending on the country where the agricultural holding is located.

The fifth hypothesis was verified in the same way as the fourth hypothesis. The level of doubt among managers ascertained in the eighth question was compared across the four countries.

Null hypothesis: Median level of management doubts about the benefits of ABC is the same across the four countries.

Alternative hypothesis: Median level of management doubts about ABC's benefits varies depending on the country where the agricultural holding is located.

Country	N	Median	Mean Rank	Z-Value
CZ	7	3	4.5	-3.80
HU	7	4	20.0	1.32
PL	9	4	20.0	1.57
SK	8	4	18.1	0.74
Overall	31		16.0	

Source: own research

Table 14: Assessment of the hypothesis 5.

Test

Null hypothesis H_0: All medians are equal

Alternative hypothesis H_1: At least one median is different

Method	DF	H-Value	P-Value
Adjusted for ties	3	25.58	0.000

The results were very similar to those from the preceding hypothesis. Here the median was also the same in three of the four countries (4) and only among the group of respondents from the Czech Republic did it vary (3). The test's p-value equals nil so again the alternative hypothesis applies. Significantly less doubt was expressed by agriculturalists in the Czech Republic (z-value = -3.80), so **Hypothesis 5 is confirmed**.

Conclusion

The analysis revealed the mark-up method to be the most commonly used in agriculture for estimating costs, which was used in 52% of the agricultural holdings analysed, most commonly in Poland (65%). It is quite surprising to find almost 94% of the companies satisfied with this method and not intending to switch away from it.

The analysis also showed low awareness of ABC, with up to 28% of agricultural holdings expressing no knowledge about it, while 31% of the farms acquainted with the method are not using it. Even though the respondents admitted their ignorance of ABC, they also assessed it as unsuitable for their agricultural holdings. 3% of the holdings had tried ABC, but it proved unsuccessful for them.

Agricultural holdings that had implemented ABC and were using it appreciated the more accurate identification of costs, especially of overheads. This advantage achieved the highest possible score among all the V4 countries, except for the Czech Republic. Managers also highly appreciated the accuracy of price estimates, especially in the Czech Republic and Slovakia. Respondents to a questionnaire cited more effective cost management, especially the recognition of the fair value of activities and true cost, as ABC's third biggest advantage. This factor was assessed quite highly especially among respondents from Slovakia and also significantly in the remaining V4 countries. Ranked fourth among the benefits, from their replies to the questionnaires, was ABC's ability to clarify the economic efficiency of activities. Managers in the Czech Republic

mainly cited this factor. The quality and efficiency of final monthly calculations received the maximum possible score from the Czech respondents. Nevertheless, agricultural holdings in the other V4 countries likewise considered the benefit to be very important. Respondents considered product and customer portfolio optimisation to be the least significant advantage of ABC.

The most common reason for agricultural holdings not using ABC to estimate costs was unawareness of the method, but another major reason was that their managements doubted the benefit. Respondents in Hungary and Poland were especially convinced thereof, while a majority of respondents in Slovakia and the Czech Republic accordingly agreed. Another important factor in not using ABC is the large amount of time envisaged to be consumed in implementing it. Respondents in Hungary and Poland particularly cited this factor. Resistance to change from staff employed at the agricultural holdings was not considered a significant reason for the failure to introduce ABC. Even though the respondents admitted their ignorance of ABC, they also evaluated it as unsuitable for their agricultural holdings.

The significance test for a proportion confirmed the first hypothesis that most agricultural holdings in the V4 are currently using "conventional" methods to calculate costs. The test results indicated 60.2% of V4 country respondents using "conventional" calculation methods, while the Wilcoxon signed-rank test confirmed the second hypothesis that the most common reason for V4 agricultural holdings not to use ABC was low awareness among managers of the method. The third hypothesis presumed that there were differences among the countries in the various types of calculation methods used to estimate costs. But the Chi-square test of independence did not confirm this hypothesis. The percentage of agricultural holdings that used activity-based costing for estimation was about the same, in the range of 34-38%, in all four countries. Time consumed to implement ABC was found to vary depending on the country where the agricultural holding is located. The Krusal-Wallis test found the assessment by agriculturists in the Czech Republic of the time required for ABC to significantly vary from those in the remaining V4 countries. When ascertaining management doubts about the benefits of ABC, it was found that the perspective taken by the agricultural holdings also varied depending on the country where the agricultural holding is located. Significantly less doubt was expressed by agriculturalists in the Czech Republic.

The observed different results in individual countries can be explained mainly by different information and awareness of managers, willingness to change, efforts to improve a certain situation, different levels of competition, or the general trend of using specific methods in a given country.

From the information obtained, managers at agricultural holdings have little information, in most cases, about ABC as an appropriate alternative to the outdated "conventional" cost estimate methods practised today. Simultaneously, the benefits are visible, especially for agricultural enterprises, for it to become a powerful tool for improving processes as well as products and services. There are benefits for agriculture mainly because ABC is more suitable than traditional methods for integrating the high overhead costs agricultural holdings undoubtedly have. It is these high overhead costs that should signal to the holding's management the need for changing the methods which have been so far used to estimate costs, for accurate estimates of costs and for fair valuation of activities and true costing. ABC allows for more efficient cost management and more accurate price calculations. If an agricultural holding is aware of its internal processes and sub-activities, better budgets can be prepared, the economic performance of its departments can be more accurately measured and the holding can become cost effective. These benefits far exceed the limitations ABC undoubtedly has. Managers are also aware of them, but should not be discouraged because the businesses that have implemented ABC and are using it have evaluated the benefits highly positively, in particular, ABC's more accurate identification of costs, mainly overheads, as well as the advantages of more effective cost management and the accuracy of price estimates.

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INSPIRE Hackathons and SmartAfriHub – Roadmap for Addressing the Agriculture Data Challenges in Africa

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Abstract

Digital farming holds enormous potential for agricultural development, and giving farmers the tools to boost productivity and profitability. Although the benefits of digitalization are numerous, farmers feel they are not the ones benefiting from the value of data collected on their farms. Several issues were identified as factors restricting farmers from benefiting from data-driven agriculture. From the farmers' perspective, there is a distinct lack of awareness of the issues surrounding farm data, and the complexity of these issues. This feeds into the imbalance that exists between individual farmers and larger agribusinesses wherein the former lack enough resources to address and analyse the significance of data, and so cannot take advantage of the value in it. There is also limited legislation for the generation, flow, exchange and use of data; where legislation does exist, it is not well understood by farmer organisations. From a policy perspective, moreover, there is very little guidance as to which agricultural data can be considered personal data, and therefore protected by privacy laws. This paper analyses the interactions and effects of the 5 Concepts: Open Agricultural Data, Open-Source Software, Citizen Science, privacy and legal and ethical issues that are assumed to advance the digitalization of African Food System (AFS and the enabling Digital Innovation Hub (DIH) - SmartAfriHub (https://www.smartafrihub.com/home).

Keywords

Africa Smart Agriculture, Open Data, Open-Source Software, Citizen Science.

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Introduction

The African Development Bank released a report in April 2020 which stated that Africa has 65% of the world's remaining uncultivated arable land, an abundance of freshwater and about 300 days of sunshine each year. More than 60% of Africa's working population is engaged in agriculture, and the soil across most of the continent is rich and fertile. Yet despite that potential, the continent as a whole continues to import much of its food ($64.5 billion in 2017) and many regions continue to suffer annual famines with around five million Africans dying every year from hunger and over a quarter of the population classified as severely food insecure in 2016 (African Development Bank, 2020). The problems of food security are growing with growing population and also with climatic changes (Heidhues et al., 2004; Ngcamu, B. S., and Chari, F., 2020; Rosina et al., 2019; Govender et al., 2017; Thompson et al., 2010). The food security is influencing different age groups (Mkhize, M. and Sibanda, M., 2020; Bishwajit et al., 2020). These problems are increasing now in relation to COVID 19 pandemy (Paganini et al., 2020).

To increase efficiency and productivity and thus

hopefully reduce hunger and reliance on imports, many African countries are now looking for new technologies (Jha et al., 2020) to data collection and analysis for solutions and creating a new demand and market by doing so (Ahmed et al., 2009). Many now see the use of data identifying the areas offering the most lucrative prospects as the way to move forward. Coupled with simpler smartphones to be used in situ, data scientists can analyze data from satellite imagery and records of climate and weather patterns to help focus on those initially promising areas (Henriques and Kock, 2012; Batchelor et al., 2014).

A "Zero Hunger", one of the 17 Sustainable Development Goals (Nilsson et al., 2016) that were adopted by all 191 United Nations Member States, is a goal that aims at ending hunger (Mbow, 2020), achieving food security and improved nutrition and promoting sustainable agriculture by 2030. African Food System (AFS) is a central driver of sustainable development. AFS link diverse interlocked issues and uncertainty incorporating social economy (poverty, accessibility, equity), security, technology (innovation), nutrition (health and welfare), local/traditional cuisine preservation (culture at large), rural desertification vs urbanization, employment, circularity and sustainability, climate action (de-carbonization, emissions, bio economy, blue growth), and more (Mbow, 2020; FCRN, 2015).

AFS currently are a cornerstone of human development recently referred to as "the global standard for sustainability" and framed in "The European Green Deal" that encompasses global trade, working life, schooling spheres, public health, and companies and consumers links across all sectors of the AFS (Communication from The Commission to The European Parliament, 2019).

The United Nations Food and Agriculture Organisation (UN-FAO) conceptual approach to structured sustainable AFS outlined by the food system wheel framework calls for the activation and engagement of all actors and stakeholders of the food system (FAO, 2018).

Digitization is under way with a variety of benefits regarding AFS needs, from production to waste management, also incorporating food security, ecosystem services, economy and social inclusion (Ndung'u and Signé, 2020). AFS are propelled by the emerging possibilities of Information and Communication Technologies (ICT) technologies that are turning AFS into big data systems which are significantly and increasingly impacting the food supply chain (Lynd and Woods, 2011) at a global scale.

The ability to learn from evidence in the real-time via data collection can make sustainable processes that are responsive, proactive and predictive. Intelligent usage of data enhances the ability to achieve a high-performance level regarding quality, delivery, cost, safety and environmental sustainability in the food value chain. The analysis of complex and dynamic AFS leads to rapidly expanding data requirements. (May et al., 2007)

There are a number of challenges that Africa's agricultural sector faces (Middelberg, 2013). As far as development of uncultivated land is concerned, many areas have poor or no transport links. There may be little in the way of communications, little credit to buy the machinery and seed stock needed to cultivate the land, issues with property rights, endemic corruption at local and national levels, a lack of access to technology, and various other issues. Another major problem that faces the sector, and also another that technology may offer a solution to, is that many African agricultural products are subject to the overuse of pesticides (or the use of banned pesticides). This means that they do not pass the stringent standards of target markets such as the European Union (AfricaMe-Team, 2020).

These days, public authorities as well as other institutions and organizations produce large amounts of data and information. The Open Government Data (OGD) initiative (Bello et al., 2016), a set of policies that promotes transparency, accountability, collaboration and participation by making data accessible to all, has emerged (Afful-Dadzie, E. and Afful-Dadzie, A., 2017). However, there are countries where there are barriers to adoption of this initiative: "While much of the research has remained confined to unraveling the theoretical and conceptual dimensions of OGD, empirical investigations are visibly lacking, especially in African context. Using a qualitative research methodology, they analyzed the responses received from relevant stakeholders-representatives from public and private sector-regarding their views about the OGD initiative in Tanzania. The findings showed that the OGD initiative in Tanzania is in an emerging stage and there are barriers (organizational, social, legal and technical) toward instituting a robust OGD initiative in the country. Further, we find that there is inertia among the governments in terms of publishing data sets." (Donald Shao and Saxena, 2019).

According to Afful-Dadzie, E. and Afful-Dadzie, A. (2017), OGD continues to receive considerable traction around the world. In particular, there have been a growing number of OGD establishments in the developed world, sparking expectations of similar trends in growing democracies. In their result using conjoint analysis, the result indicates that media practitioners ascribe to the selected set of OGD attributes in anticipation of a more functional OGD in their respective countries. Using conjoint analysis, the result indicates that media practitioners put a premium on 'metadata' and 'data format' respectively in order of importance. Results from the review also reveal that features of current OGD web portals in Africa are not consistent with the desired preferences of users.

A number of other issues identified were factors restricting farmers from equally benefiting from using and sharing of agricultural data. From the farmers' perspective, there is a distinct lack of awareness of the issues surrounding data, and the complexity of these issues. This feeds into the imbalance that exists between individual farmers and larger agribusinesses wherein the former lack sufficient resources to address and analyze the significance of data, and so cannot take advantage of the value in it. There is also limited legislation for the generation, flow, exchange and use of data; where legislation does exist, it is not well understood by farmer organizations. From a policy perspective, moreover, there is very little guidance as to which agricultural data can be considered personal data, and therefore protected by privacy laws (Addison, 2018).

One of the more important pillars of the digital transformation effort is the activity to develop a network of Digital Innovation Hubs (DIHs) (Rissola and Sörvik, 2018; Klerkx, 2019). DIHs could be defined as non-profit co-working spaces where common users, technologists, scientists, hackers, web developers share their ideas and transform them into real values.

The aim of our research was to use hackathon to build community of African Stakeholders, explore the concepts of Open Agricultural Data, Open-Source Software and Hardware, Citizen Science i.e., multi-actor, participatory and volunteer cooperation, privacy and legal and ethical issues, and the enabling Digital Innovation Hub (DIH) named SmartAfriHub, and foresight their effect on AFS developers and practitioners' readiness to uptake digital- and sustainability driven solutions.

Materials and methods

The INSPIRE Hackathon Concept

Main instruments for collecting information for this study were two INSPIRE Hackathons organised in 2019 and 2020 as Nairobi (Nairobi INSPIRE Hackathon, 2019) and Kampala Hackathons (Anand, 2020), (Kampala INSPIRE Hackathon, 2020). The INSPIRE hackathon concept was born as a means to support sustainability and implementation of results of the European Commission Research Framework Program FP7 and H2020 (Bye et al., 2018), (Bye et al., 2017), (Kollwitz, 2019). The initial idea was mainly to focus on the sustainability of the datasets Open Land Use (Mildorf et al., 2014), Smart Point of Interest (Čerba and Mildorf, 2016) and Open Transport Map (Jedlička et al., 2016) coming from SDI4Apps (Charvat et al., 2014a), Open Transport Net (Jedlička et al., 2015) and FOODIE (Charvat et al., 2014b) projects. In cooperation with citizens observatories projects CITI-SENSE, CobWeb (Higgins et al., 2016), Ground Truth 2.0, LandSense (Moorthy et al., 2017). We started to build the concept of combination Voluntary Geographic Data Initiatives (Harris et al., 2012), (Charvát et al., 2011), (Charvát et al., 2013) and citizens observatories (Higgins et al., 2016).

The intention was also to bring together different project communities to facilitate the transfer of technology and knowledge between projects and, where appropriate, to organizations and companies (Directive 2007/2/Ec, 2007). Since 2016, over fifteen hackathons have been organized by the Plan4All association. The network of supporters, co-organisers, and active hackers is steadily growing. Open data and open source, interoperability, support for Copernicus, INSPIRE and GEO (2020 - 2022 GEO Work Programme, 2020) remain the common themes of the events, despite variations in areas of expertise, perspectives, and technical abilities. The Hackathons themselves spark many interesting ideas, with the results from one often forming the basis for the next hackathon. INSPIRE events are open to everyone interested, serving as a platform for international expert collaboration, training, and capacity building (Bye et al., 2018).

INSPIRE hackathons in Africa, (Nairobi (2019) and Kampala (2020) provide the research setting - Living Lab to assess the 5 Concepts and their interplay. The concept of the INSPIRE Hackathon

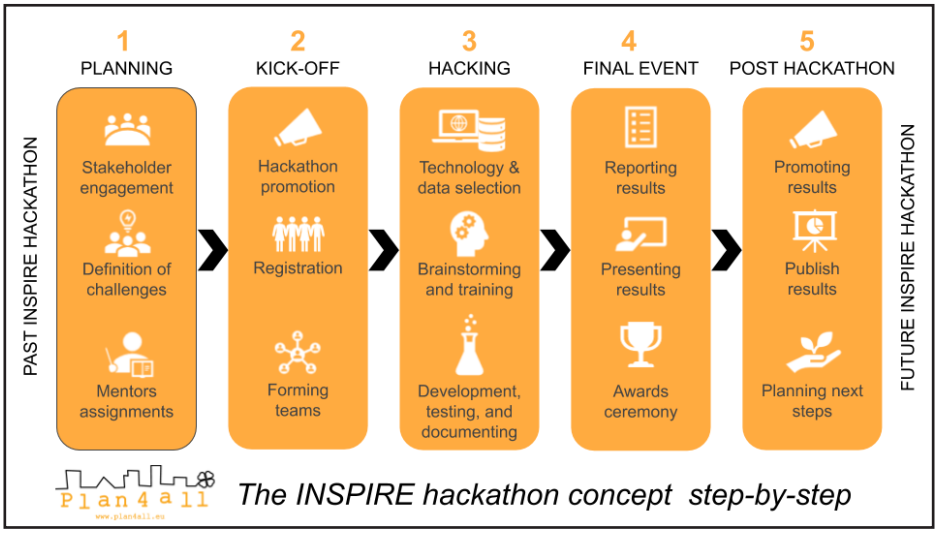
(Figure 1) differs from traditional hackathons in that it is not just a multi-day event, but it is a continuous process that has been designed to be effective using the results obtained from previous hackathons. This means that challenges are defined to follow the results of previous hackathons with the aim at enriching those previous innovation actions. INSPIRE Hackathons are several months lasting virtual events. The overall INSPIRE hackathon process consists of 5 main stages, whereby data is being collected during the so called "hacking" stage and made available during the post-hackathon stage.

The goal of the Kampala and Nairobi INSPIRE Hackathon was to build and strengthen the partnership between various EU projects and African communities. African hackathons attracted nearly 500 participants representing 70 countries. Nairobi and Kampala hackathons were organized around 19 challenge teams. Precipitated by the COVID-19 pandemic, the Kampala INSPIRE Hackathon was organised as a fully virtual event which succeeded well. These hackathons formed a unique social space that is multi-actor, open and participatory. The participation is based on ethical and volunteer cooperation to solve challenges on digital transformation in the field of Food Systems. The series of 2 hackathons shape a Living Lab that provides a testbed to analyse 5 Concepts: Open Data, Open Source Software, Citizen Science i.e. multi-actor, participatory and volunteer cooperation, privacy and legal and ethical issues, and the enabling Digital Innovation Hub (DIH) named SmartAfriHub.

Open Agriculture Data

Open Agricultural data - data that anyone can find, access, use or share, reuse - can help shape solutions by enabling more efficient and effective decision-making at multiple levels across various agricultural food systems, fostering innovation via new services and data driven applications, and driving organizational change through transparency (Charvát et al., 2014b; Musker and Schaap, 2018; Clark et al., 2020; Kamilaris et al., 2017). For Open Agricultural data to act as a road map for digital transformation in Africa, it must be FAIR (Findable, Accessible, Interoperable and Reusable) (Wong et al., 2019). A wide range of specific off-farm and on-farm Agricultural Data is needed across the food value chain to help farmers and actors in making data-driven operational decisions to optimize yield and boost revenue while minimizing expenses, chances of crop failure, and environmental impact.

However, the majority of smallholder farmers in Africa are often the one who are significantly more affected by unfair data sharing, packaging, unequal or insufficient key information and data (McCullough et al., 2008). While this gap in information is most acutely and directly felt in terms of farm activities, markets and price, it is also equally pervasive in the planning, production and postharvest management aspects of smallholder agriculture. All these factors have pushed their lives with agriculture as an occupation of gamble especially for key questions like; What produce can I grow where I live? When should I



Source: own processing

Figure 1: The general concept of the INSPIRE Hackathon: Showing how events feed into each other as part of an ongoing process that defines the INSPIRE concept.

sow/plant/harvest/market it? How should I sow/ plant/ harvest/market it? How to minimize food waste? among many. An example of an SMS crop seasonal forecast alert extracted from the Uganda Weather Information Dissemination System (WIDS) as of 23rd July 2019 for Mukono district presents advice on the appropriate farming activities they can carry out in the January-March season. However, the information is poorly arranged and too abstract for the farmers to unpack.

Data Privacy and legal and ethical issues

Smart farming contributes to exponential income growth, enhanced decision making, better services and products, as well as greater agricultural efficiency, productivity and profitability. However, it is well known that whoever controls farm data has the power and means to create the most relevant agricultural services and products, which in turn also capture insights for the development of more lucrative innovations.

Nowadays, numerous agricultural technology providers are entering the market, focusing on aggregating farmers' data. But many farmers, especially smallholders, do not benefit from the sharing and exchange of this data, which leaves them feeling disempowered. There are two key challenges that need to be overcome for smallholders to truly benefit: first, they need to be provided with better access to relevant data and services; second, they need greater awareness on the topic of personal data to ensure that any information they share does not weaken their position.

While laws and regulations that govern personal data (such as The European General Data Protection Regulation or GDPR) are becoming increasingly common, there is a lack of legislation covering the collection, sharing and use of data in agriculture. A lack of transparency around issues of data ownership, better control of access to and use of data, data rights, privacy, security and whether farm data should be considered 'personal' or not, are some of the data challenges faced by all agricultural stakeholders, but farmers in particular. Moreover, data transactions are currently governed by contracts and licensing agreements, but the terms of these contracts and agreements are complex, which leaves smallholder farmers with very little negotiating power and it is obvious that a lack of trust dominates these relationships.

Up until now, ethical considerations were often side-lined because gathering more data was seen as necessary, and concerns about how data might be abused or misused were only subsequently considered. However, with the increase of big data in smart farming, it is more essential than ever to focus on the ethical aspects of data governance (access, control, consent) and practices. This will provide valuable insights into how data is being collected and used, and for what purposes, how to bridge the digital divide, and how to create transparency in order to build trust between stakeholders.

To ensure that the benefits of the digital revolution in agriculture reach everyone involved, especially farmers, there is a need to identify sustainable ways to support data sharing among various stakeholders (Zampati, 2019).

Citizen Science to support multi-actor and participatory approach

Citizen Science (Khaldoon et al., 2020), (Dehnen-Schmutz et al., 2016), (Ryan et al., 2018) is the collection and analysis of data relating to the natural world by members of the general public, typically as part of a collaborative project with professional scientists. It is the practice of public participation and collaboration in scientific research to increase scientific knowledge. Through citizen science as SmartAfriHub framework, innovators analyze problems, generate ideas, build prototypes, test and share working prototypes that contribute to data collection, use, monitoring and evaluation of processes and programs. Usually, this participation is done as an unpaid volunteer.

Open-Source Software and Hardware

Open-Source Software (Tonnang et al., 2020; Charvát, 2009; Charvát and Krivanek, 2010) is the type of computer software in which the source code is released under a license in which the copyright holder grants users the rights to use, study, change and distribute the software to anyone and for any purpose, it refers to something people can modify and share because its design is publicly accessible. Examples of Open source software packages include; QGIS, GIS, Open streetmap, Python etc. These could be used to design data driven mobile apps like ChatBots, Crop monitoring softwares using geospatial datasets etc. Open source software and hardware are the driving forces of the SmarAfriHub towards creating data driven solutions for the farmers.

WhatsUp as potential tools for African Citizens Science

According to the Global Digital Report, there were 192 million social media users in Africa in 2018. Nearly 90% of those users were mobile-only. The most popular application in Africa was WhatsApp. WhatsApp provides access to online communication particularly to those rural area inhabitants where there is no traditional telephone infrastructure. For many, WhatsApp is the first app they download into their mobile and the one they use most.

INSPIRE Hackathon is digital-oriented. In the European context, the hackathon organisation team uses the newest and advanced technologies e.g. webinars, platforms, video conferences to facilitate communication. In the African context, the hackathon participants' communication was possible almost only by using Whatsapp.

WhatsApp group SmartAfriHub has reached 50 members' level, mainly agricultural experts from Africa. During the INSPIRE Hackathons, the facilitated and free-format WhatsApp communication formed the glue which kept participants along the process. Already in early stages in addition to hackathon team mentors, several active colleagues from different African countries took responsibility to initiate, administer and facilitate the communication and debate. It was remarkable that the atmosphere of communication was respectful and polite aiming to share knowledge and find solutions to problems of African agriculture.

The broad view on Citizens Science concept includes e.g. generation of any theory or hypothesis, research, scientific data collection, and/or data analysis in which the public (individuals or communities) participates. African Citizens Science movements' first step is to connect people with each other, facilitate their communication, and empower them to work together for Africa society and for themselves

SmartAgriHub Digital Innovation Hub

Building on and complementing the various national initiatives for digitising domains, the European Commission acts to trigger further investments in the digitisation of domains and support the creation of better framework conditions for the digital transformation. One of the most important pillars of the digital transformation effort is the activity to develop a network of Digital Innovation Hubs (DIH).

The INSPIRE hackathon can be generally defined as a collaborative event for developers, researchers, designers and others interested in open data, volunteered geographic information and citizen observatories. In the SmartAfriHub, INSPIRE hackathons are the tools used with the idea to bring together different project communities to facilitate transfer of technology and knowledge between the projects, and eventually also to organizations and companies.

SmartAfriHub is a Digital Innovation Hub that connects people to digital information and services in Africa. DIH integrates African agriculture and climate community members, and beyond, to the knowledge bases e.g., Blog, Forum, Science Shop, WIKI. DIH provides different types of Open Source Softwares and demo applications, where farmers, developers and researchers can cooperate, test different API for new solutions and also provide common experiments upon geospatial information and agriculture. The SmartAgriHub is developed in cooperation with 3 European companies - Plan4All, Wirelessinfo, Club of Ossiach - with the intention of supporting and furthering smart and sustainable agriculture in Africa. We reused the concept, which was already validated in some European projects (Ulman et al., 2020).

Results and discussion

Can Hackathon stimulate cooperation of African stakeholders?

Both African INSPIRE Hackathons introduced concepts of Citizen Science and multi-actor and participatory approaches. The INSPIRE Hackathon teams were formed by a multi-actor and participatory approach on a voluntary basis. Teams encompass different disciplines, experiences, nationalities and skills that complement each other and enrich the communication and extend the potential solutions. The innovation pattern of hackathon teams applied a multi-actor and participatory approach. All phases of the innovation pattern; ideation, building, piloting and reflecting, were carried out together, aimed at a maximum participation by using available digital and collaborative tools e.g. teleconferences, social media (e.g., Facebook, Linkedin, Twitter and WhatsApp) and shared work spaces in cloud services. SmartAfriHub is the center of communication.

Regarding smart and sustainable agriculture development the key factors were; the data, know-how and skills, and applications to form data to information. All three are needed. Regarding

data, the procedure can be either top-down i.e., Open Data provided by government, authorities or companies, or bottom-up which means that small-scale data sets can be collected by regular citizens, researchers, practitioners, and share the data set via the internet. The latter approach was applied often in the concept of Citizen Science. INSPIRE Hackathon team members were encouraged to look into and carry out data collection in order to test how to collect data and how to exploit the collected data at various Open Source Softwares. Though there was not much available data, the participants assigned were able to gather data on country based for analysis (Kampala INSPIRE Hackathon, 2020).

The most important result is that we demonstrate sustainability of such an approach and also the large interest of African communities about such types of Hackathons. It was demonstrated by 3 facts:

1. From 230 participants on the first Hackathon 170 participated also in the second year.
2. After Kampala Hackathon, was organised COVID 19 INSPIRE Hackathon (COVID-19 INSPIRE Hackathon, 2020), which was primarily not focused on Africa, but there were two teams (namely *Developing a blockchain technology to enhance tracking and tracing of food items throughout the value chain to ensure food security in Africa and Digitalization of indigenous knowledge in African agriculture for fostering food security*) organised by African communities participating in previous Hackathons and there teams were managed by African mentors and reached excellent results.
3. African participants of Nairobi Hackathon organised a self-sustainable and open WhatsUp community of 50 members. It operates continuously with a support of 5 administrators and several active members. The members use it as a channel to exchange knowledge, advertise events, connect to experts and reach out African smart agriculture practitioners.

What are the main problems of African Agriculture in this period and What are solutions, for which African communities are looking for? How could sustainability of African Agriculture be supported?

During Hackathons were discussed important challenges for African Agriculture and on the base of community feedback in different teams we select a number of priority topics. It was done through questionnaires, face to face communication and also during discussion on the final ceremony on the Nairobi Hackathon. The main priorities of African communities for sustainable agriculture and food security were detected: Needs to build Rural commodity exchange hub. Production and productivity - To tackle this issue, we really need to restart almost everything, African agriculture needs to change. And with the issue of climate change this has to be taken as a priority, Market failure - The responsibilities are shared, at the farmers' level, buyers' level and institutions. It is important to build trust among all stakeholders, High transaction cost - the main issue here is information asymmetry. It is important to make a platform that will give correct information about what is happening. All stakeholders need to know exact information of what farmers are producing in a given village in Africa. The platform needs to inform farmers about the need on the market, It is important to build sampling plots from different agro-climatic zones in Africa and monitor their growth using earth observation techniques together with ancillary data like weather data and biophysical data, There is a need for establishing crop growth scenarios under different weather events that could help in projecting future yields which is very critical in the planning operations and budgeting by state agencies and county governments, To build systems for prediction of disease susceptibility of crops using the temporal crop dynamics from earth observation data. Using historical data of crop disease and connecting them with features extracted from earth observation data for generating alert of probable crop disease, To provide a combination of agent-based models of human activities and how these contribute to food (in) security and a dynamic change in the environment as captured by big earth observation data, To develop accurate monitoring crop phenology to aid the application of farm inputs like fertilizers, irrigation and farm management, To provide assessment of hydrological flows through a combination of field observations and output from satellite image analysis workflows, Provide augmenting weather and climate monitoring through the use of affordable in-situ weather sensors and remote sensed weather estimates

Some topics coming from the Nairobi Hackathon were already implemented during Kampala Hackathon and during COVID 19 INSPIRE Hackathon.

A key problem for extension and adoption of ICT

services in Agriculture supporting its sustainability was identified as a financial problem and it was discussed that there is a need to identify financial sources for building African ICT for Agriculture infrastructure.

What is the situation with Ethic, Data Privacy, Open Data and Open Software and Hardware, and how can African community benefit from them?

This topic was discussed mainly during Kampala Hackathon as part of Challenge 9: Ethical and legal aspects of open data affecting farmers. As results of the work and discussion were recognised next facts: There is an emerging need to enhance the ethical and legal frameworks in agriculture. The rise of digitalisation in agriculture is not only a technical issue, but it also has social, ethical and legal implications. Since the world of agriculture is quite diverse, it consists of different types of agricultural methods and farming realities. In order to maximize their potential, it is important that digital solutions are designed with a view to the farming communities' needs. This is especially true in African countries with very low literacy levels and limited knowledge of digital technologies, yet where the highest untapped agricultural potential remains. Farmers have concerns about issues around data ownership, access, and control, security, and privacy. Data asymmetries and imbalances as well as monopolies are quite present/dominant in the agricultural sector, these data asymmetries arise when smallholder farmers with rather limited resources reveal their most personal farm data to gain access to benefits of technology, while those who can transform the collected data into useful information reveal little to nothing about the back-end processes or how or where the information will be kept or used. Therefore, there is a need to address the question of the balance between the cost of introducing the technology versus the expected benefits for the farmers (Kritikos, 2017), Mostly in developing countries smallholder farmers are not harnessing the power of data and must overcome challenges and risks to ensure that investments benefit them. Farmers need to feel and be engaged in the decision process of how collectors will use their data. They also need assurances of their privacy and control, they seek transparency and trust in their interactions with providers, they would like to receive benefits of their data and to have access to relevant data, Codes of conduct in agriculture, voluntary guidelines, sets of principles on how to transparently govern farm data are a recent thing. These Codes have started to emerge to fill the legislative void and to set common standards for data sharing contracts: codes provide principles that the signatories/subscribers/members agree to apply in their contracts. Farm data is an example of such sensitive data flows. Farm data flows go from the farm to many other actors (extensionists/advisory service providers/agri-tech companies, farmers' associations, financial service providers, government...) and then – aggregated and combined and in the form of services – back to the farm. Such flows potentially open up data that should only be shared with specific actors at specific conditions or should be anonymised in order not to harm the farmer's interests and privacy. This is especially true in the case of smallholder farmers whose farm data often coincides with household data and personal data and who are in the weakest position to negotiate their data rights. We have also considered what such a code should cover to better empower farmers with more equitable data flows. We tried to draw some conclusions on commonalities and differences between the existing codes, guidelines and regulations, in order to then extract and recommend the essential aspects and points for a general, scalable and further customizable code of conduct template that best addresses the needs of the farmer, An interesting point from our farmer-oriented perspective is that, the existing farm data codes do not have farmers or farmers' organisations as their primary target audience – not to mention smallholder farmers – but rather the agribusinesses and agri-tech companies that work with farmers and use their data. Codes are an instrument for these companies to ensure data sharing by gaining the trust of farmers through transparent documentation of good practices. So, while being prepared by bodies that represent also farmers (so far, big farmers' associations of developed countries) and indirectly raising farmers' awareness of their data rights, they are not written primarily for farmers and, so far, surely not for smallholder farmers. Therefore, from our perspective, during the Kampala INSPIRE Hackathon we have used another approach to our review of the current landscape from a further practical purpose: providing the conceptual basis for general scalable guidelines for associations of smallholder farmers in developing countries on how to use/adjust/negotiate/set up a farmer-centered farm data sharing code.

Developed SmartAfriHub platform and Open Source Softwares

SmartAfriHub is a one of the Digital Innovation Hubs developed during Nairobi INSPIRE

Hackathon 2019 and Kampala INSPIRE Hackathon 2020 - The intention was to support and further smart and sustainable agriculture and connect people to digital information and services in Africa. SmarAfrihub also integrates African agriculture and climate community members, and beyond, to the knowledge bases e.g., Blog, Forum, Science Shop, WIKI. DIH provides different types of Open Source Softwares and demo applications, where farmers, developers and researchers can cooperate, test different API for new solutions and also provide common experiments upon geospatial information and agriculture. SmartAfriHub is a part of SmartAgriHubs which is an EU project with more than 150 partners in the European agri-food sector, which aggregates and supports various innovation hubs. During Hackathon was discussed user interfaces, functionality and data availability.

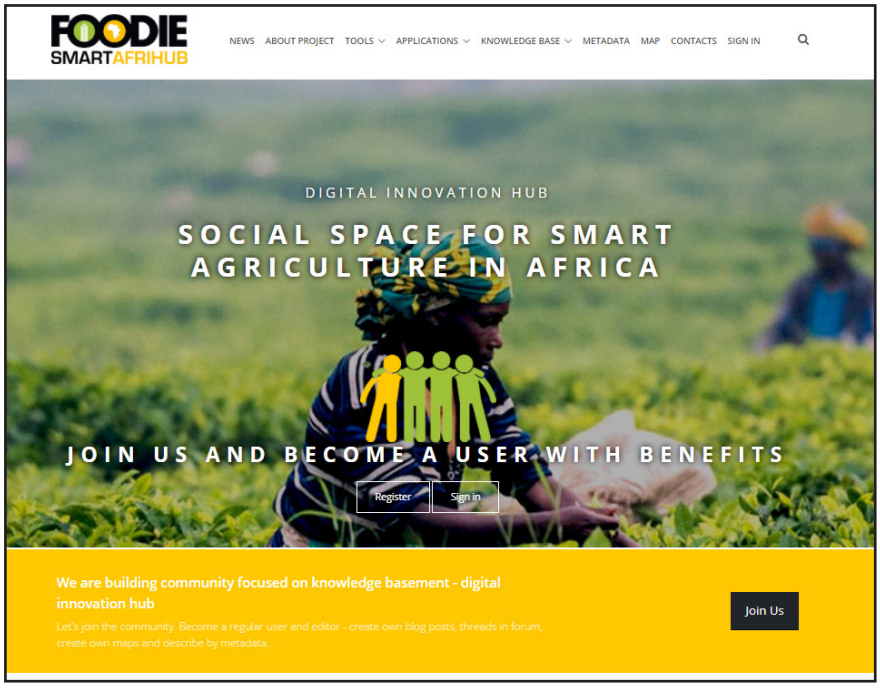
SmartAfriHub (Figure 2) is built on the Liferay portal framework which provides a robust platform to build a website on quickly and serve it to all clients - desktop, mobile, or anything in between. It provides all the standard applications which are needed. It also provides an easy-to-use development framework for new applications or customization.

The high-level ambition of SmartAfriHub is to increase the number and quality of innovations in Africa smart agriculture to enhance sustainability. SmartAfriHub's purpose is to be a knowledge and technology platform that enhances knowledge transfer and exchange with and for Africa smart agriculture practitioners, experts and researchers. Kampala INSPIRE Hackathon showed how to raise awareness of the hub in Africa continent, how to use the hub in order to develop and share relevant content to subscribers, and how to encourage users to exploit the Open Source Softwares that are available on SmartAfriHub.

In order to demonstrate and monitor SmartAfriHub's results and impacts the following circumstantial evidence i.e., Key Performance Indicators (KPI) as applied (Table 1).

The experiences with hub demonstrated that it will take longer time to attract a large sustainable community and build a platform as long time sustentable.

In any case, a small community is using the SmartAfriHub tools and content on a regular basis, but for large scale extension will be necessary to commit considerable human and financial effort to attract an expansive scale community. The KPIs show on table 1 how the number of views and visitors on the platform reflects the number of new contents e.g., blogs and news. The awareness raising and building a social space requires social media presence. The Twitter tweets, Facebook and Linkedin postings amplify and share messages, and redirect the visitors to the SmartAfriHub.



Source: SmartAfriHub, 2020

Figure 2: SmartAfriHub landing page.

Key Performance Indicators (KPI)	1.2.2020 - 31.3.2020	1.4.-31.5.2020 Kampala INSPIRE Hackathon	1.6.2020 -31.7.2020
Number of news/blogs	2	68	13
Number of users	82	1796	537
Number of visits	175	3474	1 268
Number of page views	641	10050	3 614
Number of unique page views	447	7414	2 629
Bouncerate	56.26%	37.04%	44.27%
Visit duration	00:01:42	00:02:03	00:01:34
Number of OpenSource Software; tools, applications	4 tools 6 applications	5 tools 8 applications	5 tools 8 applications
Number of operative entities	3	4	4

Source: Google analytics

Table 1: Key Performance Indicators of SmartAfriHub (measuring: 2 months intervals).

The SmartAfriHub evolution has taken place in 2 waves i.e., in the context of hackathons.

What is the best approach to build an active community?

Community building is about reaching out to people, connecting them to each other and to upkeep dialogue. In cooperation with African colleagues, the non-African adopt local manners, also in the digital arena. The commonly used, widely achievable, an easy mobile application in Africa is WhatsApp. SmartAfriHub WhatsApp group of 50 people valued a low threshold approach to be part of the community: easy to join in, comfortable to use and it allows group members a free choice to act more or less actively.

Joining the WhatsApp group is only the first low threshold step in building a SmartAfriHub community. The common journey is about to start and the second step is ahead. The second step is addressed for those who have a desire and a need to utilize the advanced digital tools provided by SmartAfriHub platform. Being part of the community creates opportunities for continuous learning, development and also business. They provide value and satisfaction to members, create welfare and provide earnings.

Two Afica oriented INSPIRE Hackathons demonstrate needs for other support to adopt ICT technologies for African Agriculture. These solutions are necessary to guarantee food and nutrition security in Africa. we identified number of needs and gaps, which are important for future adoption and also needs for additional investment

As one of the main goals of African INSPIRE Hackathons and SmartAfriHub was to connect people to the information, tools and applications, the SmartAfriHub community and platform was (and still is) a place to inform community about upcoming or just aired webinars which were organized under the hackathon webinar series, but we also follow and promote webinars and other events that are organized by our Kampala INSPIRE Hackathon co-organizers GODAN, Research Data Alliance (RDA)/Agricultural Data Interest Group (IGAD), RCMRD, Ruforum and AfriGEO. Last but not least, SmartAfriHub News and Blogs helps us with the promotion of the existence, purpose, features, tools and applications of SmartAfriHub platform.

One clear goal is to increase the number of subscribers of SmartAfriHub. It could be done by using the active SmartAfriHub community on WhatsUp. In Africa, the number of social media users, particularly by mobile applications, is 172 million. The extending mobile phone network has opened the world also to remote rural areas. In order to reach out, connect and communicate with African agriculture practitioners and experts in urban and rural areas Whatsapp is the most powerful application today - "When in Rome, do as the Romans do". Although the webinars about SmartAfriHub gathered a lot of publicity, the number of the registered users and visits of SmartAfriHub didn’t increase as much as expected, it's still too low and additional measures are needed. The team has learned that the social media promotion is not enough alone. We need a larger community and living ecosystem the members of which will gain true advantage of the use of SmartAfriHub and are willing to work with each other to enhance smart agriculture and a fair digital economy.

Build capacity by hands-on doing: The challenges aim was to facilitate the participants to develop

their own maps by using the tools and applications. The lack of open agriculture data in Africa is an obvious problem in the process. Although we have tools, applications and know-how, our progress is limited by the lack of right kind of open data. We also learnt that the work-based learning by doing was difficult to carry out due the lack of adequate internet connection. Hence the necessary direction is to provide mobile based applications to agriculture experts.

Social space for learning and networking: We gathered a group of experts who are interested in developing smart agriculture in Africa. The group has participants from many African countries hence the diversity in problems, practices and possible development path is remarkable. The members proved to be active and goal oriented, and they put effort on finding suitable agricultural data and to test them by different applications.

There's evidence that the group members enjoyed the challenge, co-operation and co-creation. It was shown when they voluntarily and actively participated and contributed to progress and communication. It also seems that personal networks were extended both among African members and in the African - Europe dimension.

What is most positive feedback is that we simulate the initial community in Africa, which is able to support and introduce new technologies and the number of requests and needs and effort is coming from these communities. This was demonstrated after Kampala Hackathon on COVID 19 Hackathon

Conclusion

“The future of agriculture and forestry will rely on digitalisation and Digital Innovation Hubs and Hackathons can help with this process. It could become part of agriculture education, research, innovation actions should focus on digitalisation that supports FAIR, open and ethic data management and knowledge exchange. We need to identi means also that advisory and support organisations have both capacity and know-how to guide the farmers to uptake the applications and tools. Because knowledge and innovations are crucial in helping farmers and rural communities meet the challenges of today and tomorrow to enhance sustainability and prevent hunger, the enhancement of African system of Agricultural Innovation Hubs earns increasing attention.

This paper examined the interactions and effects of the concepts that are assumed to advance digitalization of African Food System (AFS). The 5 Concepts are Open Agricultural Data, Open-Source Software and Hardware, Citizen Science, privacy and legal and ethical issues, and the enabling Digital Innovation Hub (DIH) - SmartAfriHub (https://www.smartafrihub.com/home). In order to achieve a sustained AFS, there is a need to continue to develop an open data community in Africa where farmers have equal access to data to enhance productivity.

Acknowledgments

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Dynamics of Food Price Volatility and Households' Welfare in Nigeria

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Abstract

One of the most important economic factors in food choice is the price. Food dynamics' value is a subject of controversies and opinions, especially price issues, and sensitivity is often peculiar to seasons and market forces. Price dynamics have the potential to introduce and change consumptions, thus affecting household welfare. This study examined the dynamics of food price volatility and households' welfare in Nigeria from 1990: Q1 to 2019: Q4. We sourced the study data from the Food and Agriculture Organization (FAO) and the World Bank (WB). We estimated the quadratic trend equation, Generalized Autoregressive Conditional Heteroscedasticity (GARCH), and Auto-Regressive Distributed Lag (ARDL) models. Food prices and depth of food deficit had a significant short-run impact on the households' welfare. Policymakers should focus on the short-term benefits while formulating policies aimed at households' welfare because policies aimed at the household level are impactful in the short-run compared to the long-run.

Keywords

Food, price, household, welfare, volatility.

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Introduction

One of the primary goals of economic development in the actual term is to improve household welfare. In Nigeria, although economic indicator based on 2019 reports from both World Bank and African Development Bank (AfDB) shows that she is the largest economy in Africa with a Gross Domestic Product of $446.543 billion and GDP growth rate of 2.3%, evidence indicates that Nigeria has the highest number of poor people globally, with most of the population struggling to survive on less than $2 daily. Poverty has economic and social implications such as productivity, food production and price, and household welfare. Nigeria's challenge is complicated because, over the year, there is a gap between food production and population growth, leading to an increase in food prices and the diversity of hungry people. National Social Register of Poor and Vulnerable Households (PVHHs) published that 2, 644, 495 households live in poverty with 11, 045 537 individuals (NSIP, 2020). About 42,912,900 households and 200,963,600 million people make up the population of Nigeria thrive on insufficient food; the statistics imply that 5.5 per cent of the entire Nigerian population is poor and vulnerable and can barely afford three portions of food per day. Since Nigeria is a food deficit country, and there is an ever-increasing demand for food, supply, and demand law play a significant role in food price determination. Therefore, rising food costs take the most substantial proportion of low to middle-income households, affecting these households' capacity to meet their other welfare needs. The welfare of households largely depends on the quantity and quality of food consumed. Amongst other welfare indicators such as shelter, health care, education, access to essential utilities like electricity and water, food is pivotal in determining individual and household welfare; hence it is at the centre of global Sustainable Development Goals (SDGs).

In recent times, global food demand and other agricultural products' uses put pressure on food production, leading to a sharp increase in food prices in both international and national markets. The susceptibility of food prices to changes exposes the fragile nature of the global food system. Therefore, addressing this has continued to command the interest of policymakers because food price is an essential aspect of inflation, and inflation affects households' consumption expenditure. Although global food commodity price has been on the decline since 2008,

in Nigeria, the reverse is the case as food prices have conti increased (SIA/FAO, 2008; Pinstrup-Andersen, 2015). Although the food deficit levels in other Sub-Saharan African countries are severe, and Nigeria will endure if the situation worsens (Ojo and Adebayo, 2012). Factors such as the high level of dependence of agriculture on rainfall, a low level of mechanisation, no automation, and small value addition have negatively affected Nigeria's food production due to exposure to dynamics of global trade and exchange rate vagaries. The most important crops in Nigeria include rice, cowpeas, beans, wheat, yam, cocoyam, cassava, vegetables, and palm oil with a good value chain capable of improving households' welfare through job creation and nutrition (PARI, 2015).

Evidence from several studies shows that household welfare is more tested correctly in terms of household consumption per capita and expenditure, including other well-being measures such as food security and household asset holding (ICRW, 2017; Moratti & Natali, 2012). Household consumption expenditure reflects their welfare status, and it reveals the portion of income and returns on investments (assets) that the households are willing and able to spend on food, education, and basic amenities that make up their welfare. These are more accurately predicted and measured using price changes in any given market and society since there is a nexus between a price change and household consumption expenditure and overall welfare.

Price volatility is the changes in the price of a commodity, and it measures price changes between specific periods (IFPRI, 2011; FAO and OECD, 2011). The continuous rise in food prices has many severe consequences on individuals' welfare and may lead to food riots, unrest, and crime (Braun, 2008). Although the food price increase is not peculiar to Nigeria like other developing countries, it has exacerbated due to its population growth. The population growth rate of 2.6 per cent causes insufficient food (World Bank, 2019). The population's geometric growth has dire consequences on the price of food products, affecting households' welfare. Food price volatility may not be problematic, mainly when the variation follows a known trend and market conditions. However, changes in food prices become an issue of worry when there are distortions in the trend. Such worrisome distortions affect the farmers, value chain actors, and households. Food price is an essential variable in household income and consumption decisions; price levels and fluctuations in food commodities' prices affect household income and consumption (Diaz-Bonilla, 2016).

The nexus between post-war periods, post-pandemic periods or post-political crises and food demand holds strong potential for food price volatility. For instance, evidence shows that the outbreak of Nigerian civil war in 1967 and the resultant agricultural challenges and the food blockade of the region occupied by secessionist Biafra led to food price volatility after the war (Iwuagwu, 2012), resulting in high food insecurity in Southeast Nigeria. With the recent coronavirus pandemic (COVID-19) that has disrupted the livelihood of many households and food supply chains, it has become imperative to study the trend of food prices, household welfare, and understand the impact of food prices on households' welfare.

Materials and methods

We sourced the data for this study from the Food and Agriculture Organization (FAO) database and World Development Indicators (WDI) of the World Bank. The data covered a period of 1990: Q1 to 2019: Q4. We used the quadratic trend equation, generalised Autoregressive Conditional Heteroscedasticity (GARCH) model, and the Auto-Regressive Distributed Lag (ARDL) model regression approach for the data analysis.

Model specification

Trend Aaalysis

The log quadratic trend equation, which shows either the acceleration, stagnation or deceleration of the time series data, is specified.

$$lnAVPIF = a + b_1 t + b_2 t^2 + u_i \quad (1)$$

$$lnHHW = a + b_1 t + b_2 t^2 + u_i \quad (2)$$

Where AVPIF is the average price of selected food commodities in Naira, HHW is the Household welfare (Household final consumption expenditure (₦)), a is the constant, t is the time, b is the coefficient of time, and ln is the natural log and u_i is the error term.

The Generalised Autoregressive Conditional Heteroskedasticity (GARCH)

Time series data, such as food prices, are volatile, heteroscedasticity, and leptokurtic (Popović, 2011). To address this, we adopt the GARCH model, as expressed by Bollerslev (1986).The standard GARCH (p, q) specification;

$$y_t = a + \sum_{i=1}^{k} \quad n_i x_t - 1\, \varepsilon_t \qquad (3)$$

Where y_t is a measure of food price volatility at time t, a is the mean, x_{t-1} is the exogenous variables, and ε_t is the error term.

$$\delta = \sqrt{\frac{1}{N} \sum_{i=1}^{k} (X_i - \bar{X})} \qquad (4)$$

Where δ is the variance, x_i is the mean and $\bar{X}$ is the mean deviation.

$$\delta t^2 = \omega + \sum_{i=1}^{p} ai\, \epsilon_{t-i}^2 + \sum_{i=1}^{q} \beta_i \delta_{t-i}^2 \qquad (5)$$

Where δ^{t2} is the conditional variance, p is the order of the GARCH, and $\delta_{t-i}^{\ 2}$ is the GARCH term.

The Auto-Regressive Distributed Lag Model

We estimate the Auto-Regressive Distributed Lag (ARDL) model, also referred to as the bounds testing approach to co-integration, in line with Pesaran et al. (2001) to examine the dynamics of food price volatility and household welfare. The ARDL applies on time series data with the order of integration I (0) and I (1) (i.e., Mixed order of the order of integration) and results in an unbiased long-run estimate, where a long-run relationship exists (Bawa et al., 2016; Udo et al., 2015). We estimated the model as follows.

$$\begin{aligned} HHW = {} & c_o + \delta_1 HHW_{t-1} + \delta_2 CPIF_{t-1} + \\ & + \delta_3 AVPIF_{t-1} + \delta_4 DFD_{t-1} + \delta_5 ACF_{t-1} + \\ & + \delta_6 ELE_{t-1} + \delta_7 EMP_{t-1} + \delta_8 FE_{t-1} + \\ & + \delta_9 FI_{t-1} + \delta_{10} FPI_{t-1} + \sum_{i=1}^{p4} b_1 HHW_{t-1} + \\ & + \sum_{i=0}^{p} b_2 CPIF_{t-1} + \sum_{i=0}^{p1} b_3 AVPIF_{t-1} + \\ & + \sum_{i=0}^{p4} b_4 DFD_{t-1} + \sum_{i=0}^{p} b_5 ACF_{t-1} + \\ & + \sum_{i=0}^{p} b_6 ELE_{t-1} + \sum_{i=0}^{p1} b_7 EMP_{t-1} + \\ & + \sum_{i=0}^{p} b_8 FE_{t-1} + \sum_{i=0}^{p4} b_9 FI_{t-1} + \\ & + \sum_{i=0}^{p} b_{10} FPI_{t-1} + \varepsilon_t \end{aligned} \qquad (6)$$

Where δ_i represent the long-run multipliers, c_o is the constant, bi is the coefficients, p is the lag length, *HHW* is the household welfare (Household final consumption expenditure (₦)), CPIF is the Consumer Prices, Food Indices, AVPIF is the average producer price of selected essential food commodities (₦) (i.e. beans, cassava, cocoyam, cowpea, millet, palm oil, rice, vegetables, wheat and yam), *ELE* is the access to electricity (% of the population in millions), *DFD* is the depth of food deficit (kilocalories per person), ACF is the access to cooking fuel (% of the population in millions), *EMP* is the employment status (% of the population in millions), *FPI* is the food production index (2004-2006 = 100), *FI* is the food import (% of merchandise import), FE is the food export (% of merchandise export), is the summation sign, and et is the error term. We sourced HHW, ELE, ACF, EMP, FE, FI and DFD from World Development Indicators while we sourced AVPIF and CPIF sourced from the Food and Agriculture Organization database.

We conducted the ARDL bound test following equation (6) to test for the existence of a long-run relationship. We tested the following hypotheses.

H_0 = the long-run multipliers are not significantly different from zero ($H_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = \delta_7 = \delta_8 = \delta_9 = \delta_{10} = 0$)

H_a = the long-run multipliers are significantly different from zero ($H_a = \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq \delta_6 \neq \delta_7 \neq \delta_2 \neq \delta_8 \neq \delta_9 \neq \delta_{10} \neq 0$)

We made use of the tabulated asymptotic critical valued bound by Pesaran et al. (2001), which provide a test for co-integration with I(0) and I(1) lower and upper boundaries, respectively. If the F-calculated value falls within or equal to the tabulated values, it suggests a long-run relationship; otherwise, it implies that only short-run relationships exist. Since there was co-integration among the variables, we estimate the conditional ARDL model.

$$\begin{aligned} HHW = {} & c_o + \sum_{i=1}^{p4} b_1 HHW_{t-1} + \sum_{i=0}^{p} b_2 CPIF_{t-1} + \\ & + \sum_{i=0}^{p1} b_3 AVPIF_{t-1} + \sum_{i=0}^{p4} b_4 DFD_{t-1} + \\ & + \sum_{i=0}^{p} b_5 ACF_{t-1} + \sum_{i=0}^{p} b_6 ELE_{t-1} + \\ & + \sum_{i=0}^{p} b_7 EMP_{t-1} + \sum_{i=0}^{p} b_8 FE_{t-1} + \\ & + \sum_{i=0}^{p} b_9 FI_{t-1} + \sum_{i=0}^{p} b_{10} FPI_{t-1} + \mu_t \end{aligned} \qquad (7)$$

We got the short-run dynamic parameters by estimating the error correction model.

$$\Delta HHW = c_o + \sum_{i=1}^{p4} b_1 \Delta HHW_{t-1} + \sum_{i=0}^{p} b_2 \Delta CPIF_{t-1} + \sum_{i=0}^{p1} b_3 \Delta AVPIF_{t-1} + \sum_{i=0}^{p4} b_4 \Delta DFD_{t-1} + \sum_{i=0} b_5 \Delta ACF_{t-1} + \sum_{i=0} b_6 \Delta ELE_{t-1} + \sum_{i=0} b_7 \Delta EMP_{t-1} + \sum_{i=0} b_8 \Delta FE_{t-1} + \sum_{i=0} b_9 \Delta FI_{t-1} + \sum_{i=0} b_{10} \Delta FPI_{t-1} + \vartheta ecm_{t-1} \quad (8)$$

Where ECM is the error correction term of equation (6) and ϑ is the speed of adjustment.

Results and discussion

Unit root tests results and trend in the price of selected food commodities

We tested the properties of the time-series data used for the analysis. We used Phillips-Peron (1988) test (P.P.) in determining the stationary of the variables under consideration, and we presented the results in Table 1. The unit root tests revealed that all the variables considered in this study were stationary at first difference.

From the Table 1, the entire test variables for the assessment of food price volatility on the welfare of households in Nigeria were stationary at the first difference based on the P.P. test statistics. One could reject the null hypothesis of nonstationary. The occurrence of unit roots in the data generation preliminarily shows shocks having a permanent or long-lasting effect.

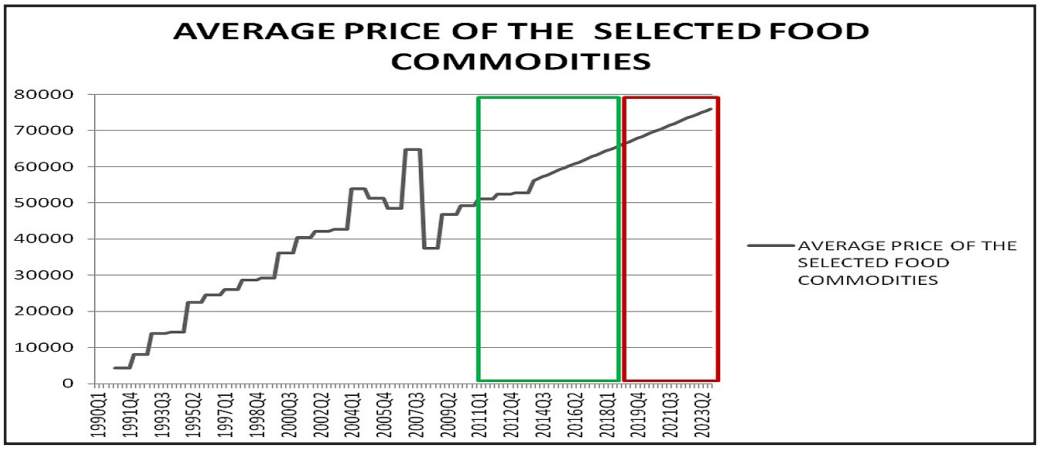
There has been considerable variability and instability in the prices of these food commodities. We relate this to the global hike in food price to the trend, and it shows that the prices of the selected food commodities have grown from the first quarter of 1990 before hitting the peak in the last quarter of 2007 (FAO, 2017). As shown in Figure 1, sharp growth, continuous fluctuations, and a sharp decline characterised the general trend pattern for cassava, cowpea, rice, wheat, palm oil, cocoyam, beans, vegetable, and yam for the period under study.

Egwuma, Ojeleye, and Adeolu (2017) reported that food inflation has increased with it influencing other macroeconomic variables. Taru (2014) said

Variables	Level	First difference	Decision
Access to cooking fuel and gas	-1.911024	-10.77033	I(1)
Average price of the selected food items in Naira (per ton)	- 2.201370	-8.905442	I(1)
Depth of food deficit	-2.146940	-11.24664	I(1)
Access to electricity	-1.300126	-10.79099	I(1)
Employment status	3.984839	-17.21190	I(1)
Food export	-2.663116	-11.47534	I(0), I(1)
Food import	-2.732243	-10.78255	I(0), I(1)
Food production index	-1.413168	-10.78326	I(1)
Household Welfare	-1.575734	-10.81241	I(1)
Consumer Price index (Food indices)	-3.672372	-11.28320	I(0), I(1)
Price of Beans in Naira (per ton)	-2.106437	-10.96121	I(1)
Price of cassava in Naira (per ton)	-1.604460	-10.90058	I(1)
Price of Cocoyam (per ton)	-1.720703	-10.77033	I(1)
Price of Cowpea in Naira (per ton)	-2.125041	-11.52827	I(1)
Price of Millet in Naira (per ton)	-1.897739	-11.40523	I(1)
Price of palm oil in Naira (per ton)	-1.565957	-10.77033	I(1)
Price of rice in Naira (per ton)	-1.757772	-10.93934	I(1)
Price of vegetable in Naira (per ton)	-1.553928	-10.77033	I(1)
Price of wheat in Naira (per ton)	-1.509354	-10.77970	I(1)
Price of yam in Naira (per ton)	-1.586433	-10.81144	I(1)

Source: World development indicators and FAO data in various years

Table 1: Unit root test using Phillips Perron.



Note: Portion bounded in green are estimates while portion bounded in red are forecasts
Source: Authors' analysis based on FAO, 2020.

Figure 1: Trend in the average price of selected food commodities in Nigeria.

that cereals, such as rice, have been fluctuating over the years and very volatile. He reported that seasonal factors were responsible for the volatility in price. Compton, Keats, and Wiggins (2010) argued that the increase in the oil price affected the food prices in oil-producing economies such as Nigeria because of excess foreign reserves available for food importation. The sharp decrease in the prices of food in 2012:Q4 is because of the increased funding of agriculture through the Agricultural Transformation Agenda (ATA) and NIRSAL that lead to the increase in food production; the rise in food production forced the prices of food to go down (Olomola and Nwafor, 2018).

Estimated growth in the trend of household welfare and cause of the average price of the selected food commodities

Table 2 shows the growth equation on household welfare and the average price of the selected food items. The growth equation shows a remarkable deceleration in the estimated quadratic time trend (b2), which was negative and significant for the household welfare and the average price of the selected food commodities.

The volatility of household welfare in Nigeria from 1990 to 2019

We tested for volatility in households' welfare (Household final consumption expenditure (₦)) in Nigeria as specified in equations 3 and 4. The heteroscedasticity test presented in Table 3 shows the presence of conditional volatility or ARCH (Autoregressive Conditional Heteroscedasticity); this implies that there is the need to run a GARCH model.

Table 4 shows the result of the volatility test for household welfare, and the result shows the households' welfare status. The ARCH (RESID $(-1)^2$) and the GARCH (GARCH(-1)) terms are

Variable	A	B	b2	R2	F	R
HHW	-7.40E+12	5.55E+11	-4.10E+09	0.41	40.66***	0.64
	(-4.57)***	(8.93)***	(-8.343)***			
AVPIF	-359.646	992.576	-3.963	0.93	734.90***	0.96
	(-0.25)	(17.89)***	(-8.923)***			

Note: *** indicates that the values are significant at 1%
Source: Authors' Analysis Based on FAO and WDI

Table 2: Estimated growth in the trend of Household welfare and Average price of the selected food commodities.

F-statistic	1326.21***	Prob. F(1,117)	0.00
Obs*R-squared	109.35***	Prob. Chi-Square(1)	0.00

Note: *** indicates that the values are significant at 1%
Source: Authors' Analysis Based on FAO and WDI

Table 3: Heteroskedasticity Test: ARCH.

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.44	8.59	0.05	0.96
AR(2)	0.31	4.36	0.07	0.94
AR(3)	0.25	6.84	0.04	0.97
AR(4)	0.08	1.94	0.04	0.97
MA(1)	0.65	8.61	0.08	0.93
MA(2)	0.37	5.57	0.07	0.95
		Variance Equation		
C	6.19E+25	1.21E+25	5.10***	0.00
RESID(-1)^2	0.10	0.04	2.62**	0.01
GARCH(-1)	-0.99	0.01	-328.84***	0.00
R-squared	0.93	Mean dependent var		6.17E+12
Adjusted R-squared	0.93	S.D. dependent var		7.60E+12
S.E. of regression	2.09E+12	Akaike info criterion		60.27
Sum squared resid	4.79E+26	Schwarz criterion		60.48
Log-likelihood	-3486.36	Hannan-Quinn criteria.		60.35
Durbin-Watson stat	2.03			
Inverted AR Roots	1.04	-.13-.46i	-.13+.46i	-.34
		Estimated AR process is nonstationary.		
Inverted MA Roots	-.33+.51i	-.33-.51i		

Note: *** indicates that the values are significant at 1%
Source: Authors' Analysis Based on FAO and WDI

Table 4: GARCH result in the volatility of household welfare.

significant at the 5% level. The result shows that household welfare is volatile. The summation of the ARCH (0.104270) and GARCH (-0.992148) is very close to one, and this indicates that household welfare will continue to be volatile, and it is in line with a priori expectation. Observations show that inflations in Nigeria fluctuate and affect household spending patterns.

The volatility of the average price of the select food commodities in Nigeria

We test for the volatility of the average price of the selected food commodities in Nigeria, as specified in equations 3 and 4. The heteroscedasticity test presented in Table 5 shows that there are the presences of conditional volatility or ARCH (Autoregressive Conditional Heteroscedasticity); this implies that there is a need to run a GARCH model.

F-statistic	27.91***	Prob. F(1,113)	0.00
Obs*R-squared	22.78***	Prob. Chi-Square(1)	0.00

Note: *** indicates that the values are significant at 1%
Source: Authors' Analysis Based on FAO and WDI

Table 5: Heteroskedasticity Test: ARCH.

Table 6 presents the volatility test result for the average price of the selected food commodities, and the result shows the average food price of the selected commodities. The GARCH (GARCH(-1)) terms are significant at the 5% level, which implies the possibility of a future forecast of the variance to be high for a prolonged time. The result shows that the average price of the selected food commodities is volatile in the long-run. The summation of the ARCH (-0.601548) and GARCH (-0.949755) is very close to one, and this shows that the average price of the selected essential food items will continue to be high and volatile.

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	0.34	29.96	0.01	0.99
AR(2)	0.23	71.48	0.01	0.99
AR(3)	0.30	70.40	0.01	0.99
AR(4)	0.14	8.61	0.02	0.99
MA(1)	0.63	29.29	0.02	0.98
MA(2)	0.28	54.81	0.02	0.99
		Variance Equation		
C	1.34E+09	2.92E+08	4.60***	0.00
RESID(-1)^2	-0.60	2.84	-0.21	0.83
GARCH(-1)	-0.95	0.04	-24.26***	0.00
R-squared	0.96	Mean dependent var		41823.20
Adjusted R-squared	0.96	S.D. dependent var		17813.89
S.E. of regression	3795.12	Akaike info criterion		22.16
Sum squared resid	1.58E+09	Schwarz criterion		22.37
Log-likelihood	-1276.25	Hannan-Quinn criteria.		22.25
Durbin-Watson stat	1.98			
Inverted AR Roots	1.00	-.13-.56i	-.13+.56i	-.41
		Estimated AR process is nonstationary.		
Inverted MA Roots	-.32+.42i	-.32-.42i		

Note: *** indicates that the values are significant at 1%
Source: Authors' Analysis Based on FAO and WDI

Table 6: GARCH result for the volatility of the average food price.

Determinants of food price volatility on household welfare in Nigeria from 1990 to 2019

The bound test presented in Table 7 shows that a long-run relationship exists between the variables, making it necessary to estimate an ARDL model. The F-statistics value of 4.862 is higher than the lower I(0) and upper I(1) bound, which indicate the presence of a long-run relationship among the variables.

Test Statistic	Value	K
F-statistic	4.86	9
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	1.88	2.99
5%	2.14	3.3
2.5%	2.37	3.6
1%	2.65	3.97

Source: Authors' Analysis Based on FAO and WDI

Table 7: Bound Test.

Table 8 shows the short-run ARDL model estimates. The estimates show that households' welfare in the 1st, 2nd, and 3rd lags were statistically significant at 1% and with a negative coefficient. This result implies that in the short-run, changes in the household welfare in the past periods had a negative effect on household welfare (Household final consumption expenditure (₦)). The average price of the selected food commodities is statistically significant at 1% and has a short-run positive effect on household welfare. Minot and Dewina (2015), and Mbegalo and Yu (2016) reported that the price of food had a negative impact on household welfare in the short-run for Ghana and Tanzania, respectively, except if the households are producers of the food commodities. In Nigeria, agriculture has accounted for approximately 50 per cent of household revenues in the last ten years and employs 35.1 per cent of the households (World Bank, 2020). The households consume most of the food commodities produced. The households take advantage of the price of the food commodities produced to improve their welfare; this is because they sell some food commodities produced in the market to generate income. Vu and Glewwe (2011) reported that higher food prices in 2007 and 2008 globally resulted in improved household welfare in Vietnam because most households are agribusiness-based households.

Food price increase for non-agribusiness

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(HHW(-1))	-0.34	0.10	-3.53***	0.00
D(HHW(-2))	-0.34	0.10	-3.52***	0.00
D(HHW(-3))	-0.34	0.10	-3.52***	0.00
D(CPIF)	-20811432310.94	15999086418.11	-1.30	0.41
D(AVPIF)	135401122.30	34291837.70	3.95***	0.00
D(DFD)	285279206926.61	21293295178.21	13.40***	0.00
D(DFD(-1))	258447945.00	35435137584.68	0.01	0.78
D(DFD(-2))	-140766975.05	35434744037.54	-0.01	0.73
D(DFD(-3))	111470405306.23	31913406396.36	3.49***	0.00
D(ACF)	-390007104245.43	551713410533.26	-0.71	0.57
D(ELE)	45815793604.32	53004503739.92	0.86	0.23
D(EMP)	324013.96	248797.23	1.30	0.02
D(F.E.)	-75225025745.38	134802468888.01	-0.56	0.42
D(F.I.)	-37077861351.36	28302548359.73	1.31	0.31
D(FI(-1))	2808055951.45	34837838456.01	0.08	0.55
D(FI(-2))	-60513273.71	34761926150.44	-0.01	0.82
D(FI(-3))	44819061950.95	26738246825.30	1.68	0.42
D(FPI)	-9455347305.83	6646449994.29	-1.42	0.44
ECM(-1)	-0.01	0.04	-0.34	0.73

Note: *,**,and *** indicates that the values are significant at 10%, 5%, 1% respectively
Source: Authors' Analysis Based on FAO and WDI

Table 8: ARDL (4, 0, 1, 4, 0, 0, 1, 0, 4, 0) Short-run coefficients.

households implies welfare decrease as they spend some resource meant to meet other aspects of their welfare on the purchase of food. The depth of food deficit is statistically significant at 1% and has a short-run positive effect on household welfare. Household consumption expenditure is a determinant of access to food. Food insecurity is a threat to poor households because they have limited food (FAO, 2013). The 3 rd lag of depth of food deficit is also significant at 1% and positively influences the household consumption expenditure. Households with food deficits experience seek remedy by channelling future income to meet household food needs. WHO (2006) reported that households with a very-low-income population like Nigeria are micronutrient deficient because of inadequate food intake. The Error Correction Term is the speed of adjustment of the variables returns to equilibrium because of a change in the model's other variables. The ECM coefficient of -0.007 shows that the rate of adjustment of the model variables is 0.07%; it also indicates that the model is converging at equilibrium, and the estimated model is very stable.

The long-run coefficients in Table 9 were not statistically significant. In the long-run consumer price index (food indices), access to cooking fuel and gas, employment status, and food import have a negative coefficient. In the long-run, these variables have a negative impact on the household. The CPIF in Nigeria has been on the increase (Adetiloye, 2010). This result implies that in the long-run, households will spend more on food, and this increased expenditure on food will reduce the ability of the households' to spend on other necessities resulting in the decrease in household welfare. The households' access to cooking fuel and gas is limited due to the increase in the price (Gujba et al., 2015), which will have an adverse long-run impact on the household's welfare. Nigeria has a high unemployment rate; the negative coefficient of the long-run ARDL estimates implies that the households' employment status will result in a decrease in household consumption expenditure. Nigeria spends billions of Naira importing food, and households bear the costs of the imports by paying higher prices for imported foods. The negative coefficient of the long-run ARDL estimates shows that food imports result in decreased household welfare; this is because the households spend more on imported food and limiting their capacity to meet other welfare needs.

The average price of the selected food commodities, depth of food deficit, and access to electricity have positive coefficients, showing a positive household

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CPIF	-1745571569839.72	5299087346563.38	-0.33	0.74
AVPIF	4258466803.62	12647321060.75	0.34	0.74
DFD	519708482170.94	1449757430504.98	0.36	0.72
ACF	-32712083581507.93	73175513970390.18	-0.45	0.66
ELE	3842827613710.59	9031113341031.80	0.43	0.67
EMP	-6873788.17	25380204.62	-0.27	0.79
FE	-6309544884739.75	26413259650338.22	-0.24	0.81
FI	-8526687345852.78	24716357175221.46	-0.35	0.73
FPI	-793073018398.08	2332649058914.13	-0.34	0.72
C	237282314784740.22	1016429983640436.60	0.23	0.82

Source: Authors' Analysis Based on FAO and WDI

Table 9: ARDL (4, 0, 1, 4, 0, 0, 1, 0, 4, 0) Long-run coefficients.

welfare influence. The increase in the average price of the selected food will increase the households' expenditure. The households cover their food deficit and increase their electricity access by spending more on nutrition and electricity to improve their welfare.

The Ramsey RESET test presented in Table 10 shows that the ARDL model is statistically stable. The t- statistics, and F-statistics are statistically significant at 1%, indicating that the model is statistically significant.

	Value	df	Probability
t-statistic	6.22***	91	0.00
F-statistic	38.70***	(1, 91)	0.00
F-test summary:			
	Sum of Sq.	df	Mean Squares
Test SSR	3.78E+25	1	3.78E+25
Restricted SSR	1.27E+26	92	1.38E+24
Unrestricted SSR	8.89E+25	91	9.77E+23

Note: *** indicate that the values are significant at 1
Source: Authors' Analysis Based on FAO and WDI

Table 10: Ramsey RESET Stability Test.

The Breusch-Godfrey Serial Correlation L. M. Test presented in Table 11 with an F-statistics value of 12.326 indicates that the model is free from serial correlation.

F-statistic	12.33***	Prob. F(2,91)	0.00
Obs*R-squared	24.73***	Prob. Chi-Square(2)	0.00

Note: *** indicate that the values are significant at 1%.
Source: Authors' Analysis Based on FAO and WDI

Table 11: Breusch-Godfrey Serial Correlation L.M. Test.

The wald test presented in Table 12 shows that the explanatory variables are important and significant in the model with a chi-square value of 1410.627, which significant at 1%.

Test Statistic	Value	Df	Prob.
F-statistic	156.7363***	(9, 92)	0.00
Chi-square	1410.627***	9	0.00

Note: *** indicate that the values are significant at 1%.
Null Hypothesis: C(1) = 0, C(2) = 0, C(3) = 0, C(4) = 0, C(5) = 0,C(6) = 0, C(7) = 0, C(8) = 0, C(9) = 0
Source: Authors' Analysis Based on FAO and WDI

Table 12. Wald Test.

Conclusion

The unit root test results show that the variables attained stationarity at a level or after differencing once. Thus, one may conclude that the variables are suitable for ARDL estimation. The occurrence of unit roots in the variables preliminarily test shows shocks having a permanent or long-lasting effect. The average price of the selected food items reflects the global hike in the price of food commodities in 2007/2008 before a decline in 2009. We expect the average price of the chosen food commodities to keep increasing through 2023. Already economic indicators show that Nigeria and many developing countries may not recover fully from the pandemic's impact in the next two years without adequate stimulus packages and incentives to the real sectors of the economy. Unfortunately, Nigeria's economy cannot support such investment and may likely slide into recession, leading to a further increase in food prices. The quadratic trend equation also shows that household welfare has experienced a remarkable deceleration. The price of the selected food commodities and household welfare were volatile. In the short-run average price of food and depth of food deficit were significant. In the long-run, the coefficients of the model

variables were not statistically significant; this implies that the variables do not impact the households' welfare strongly in the long-run. As a critical policymaker, while formulating economic policies, the government should consider the fact that food prices are sensitive to changes in macroeconomic policies. This consideration is because any wrong macroeconomic policy results in a food price increase, which affects household expenditure. Efforts to curtail extreme spikes in the price of food commodities can substantially enhance the households' food security and overall economic welfare. Strategies for growth in household income are critical for improved access to foods in terms of quantity and diversity and households' overall economic well-being.

If policy actions complement food distribution and are sensitively guided by welfare-related interventions, more sustainable livelihoods can be achieved. Households spend most of their consumption expenditure on expensive food imports. Food importation can be reduced by increasing imported foods' local production; this will leave households with more income to probably save or invest. Access to electricity by the household has a positive coefficient in the short-run; this implies that households spend a fortune on electricity, increasing their consumption expenditure.

Electricity has been a source of concern for the governments in Nigeria. They should be a genuine liberalisation and privatisation of the power sector to give more competitors access. With increased competition in the power sector, there will be more electricity supply for household productivity and subsequent welfare. Policymakers should focus on the short-term benefits while formulating policies aimed at households' welfare; This is because policies aimed at the household level are more impactful in the short-run compared to the long-run.

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Microfinance as a Mechanism against Financial Exclusion in the European Rural Areas – an Inspiration for the Czech Republic

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Abstract

One of the factors influencing the emergence of disparities between rural and urban regions is the varying level of financial inclusion of the population. The system of microfinancing is becoming an important mechanism against poverty and social exclusion in Europe. However, there is available very limited legal, regulatory and historical information on the microfinance system in the Czech Republic. As a result, microfinance institutions are absent and small entrepreneurs tend to use expensive consumer credit products, thereby increasing the risk of over-indebtedness. The aim of this research is to examine the repayment performance of the European microfinance institutions with increased share of clients from rural areas. Based on an empirical statistical analysis of an unique European microfinance institutions´ database, we are presenting evidence that suggests that microfinance systems perform better in rural than in urban areas. This finding is strongly recommended for consideration in the development of policies to guide legal frameworks regarding microfinancing.

Keywords

Microfinancing industry, quality of portfolio, rural economic development, social capital.

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Introduction

There is sufficient evidence suggesting a wide variety of inhabitants being either excluded from the job market or with a low probability of gaining access to a sustainable job. These excluded groups, in particular, include mothers on and directly after maternity leave, elderly people, unemployed graduates and ethnic minorities. These groups often also include persons who want to start or further develop their own businesses (micro-enterprises, self-employment) but due to social exclusion pressures they experience difficulties with obtaining credit facilities to do so. The exclusion of socially marginalized people from traditional banking services constitutes an important obstacle to the establishment of new business activities. The European Anti-Poverty Network, the EAPN, defines "social exclusion" as the social, financial, political and other similar processes which push individuals and groups of people to the edge of society eventually limiting their access to resources and opportunities. (EAPN, 2016)

The risk of social exclusion and poverty is higher in the rural regions in comparison to urban ones. Kučerová (2018) states that European rural areas are characterized by a higher degree of income poverty compared to urban areas across all European Union (EU) members. The Czech Republic is not an exception (Alina et al., 2020). This finding is supported by results of an empirical study carried out by Střeleček and Zdeněk (2011) who reported significant differences of incomes between rural and non-rural households in the Czech Republic. Stejskal and Stávková (2010) supported the divergences between rural and urban areas in their study on the incomes of Czech farmers. They reported that 12.1% of farming households are being threatened by income poverty. This statement is confirmed by the findings of Střeleček et al. (2004), who concludes that important differences in Czech regional structure are decisive in their influence on the development of rural populations.

According to Lee and Luce (2018) there is mounting evidence in the developed world to suggest that there

is geographical variation in access to finance. Zhao and Jones-Evans (2016) found evidence suggesting the presence of a regional-specific influence on small firms' access to bank finance. They presented evidence suggesting that the economic region where entrepreneurs are located matters and the operational proximity between banks and borrowers' communities appear to be important in small and medium enterprises' access to bank finance. Bečicová and Blažek (2015) confirmed that there is a credit gap in the Czech periphery. They concluded in their study, that entrepreneurs from periphery areas face the problem that the value of their premises, when setting them as collateral, is significantly underestimated.

The European Microfinance Network (EMN) states that microfinance offers people in many parts of the world, who are being excluded from formal financial services, the opportunity to obtain microloans in order to generate an income and engage in productive activities, often by expanding their small businesses (Lorenzi, 2016). According to the EMN (2019), microfinance, and microcredit, is not only developed in Africa, Latin America or Asia but also in Europe, where it has been initiated and implemented and has long proven necessary.In the recent past the European microfinance sector has made an important contribution to supporting micro-enterprises to establish self-employment opportunities as well as promoting social inclusion (EMN, 2019). While there is clear evidence that the microfinance industry in Europe is an effective financing channel for stimulating job creation and promoting social inclusion, the microfinance market in the Czech Republic is still in its infancy (Chmelíková et al.,2019). According to the Czech Ministry of Labour and Social Affairs, there is a lack of legal and regulatory support and no clear definition of the microfinance system. As a result, effective microfinance institutions (MFI) are absent, thus severely limiting the access of socially excluded people to financial credit resources. EMN (2019) did not identify any MFI in the Czech Republic. As a consequence, microfinance entrepreneurs tend to use very expensive conventional consumer credit products (from both bank and non-bank institutions) without any counselling services and increasing an already high risk of over-indebtedness. The inspiration for designing and launching microfinance legislation should be found in other European countries which have successfully developed microfinance systems. However, little is known about the impact of existing European microfinance on both social and financial performance of microfinance institutions.

Compared to traditional microfinance institutions from developing countries, the European ones in general suffer also from the lack of soft information about borrowers, collective wisdom, and the effectiveness of peer pressure in the relationship between lenders and borrowers. This information asymmetry leads to higher rates of interest or increased demands on the collateral value of property or fixed assets offered. The main difference between the two areas originates from the structure of the systems. Whereas microfinance clients and MFIs in developing countries are mostly a part of social networks that create social collateral for them (Biekpe, 2007), microfinance clients in Europe usually stand in an anonymous position. However, the intensity of social ties differs with the character of the regions. Theoretical models (Postelnicu, 2014) and empirical studies from developing economies (e.g. Karlan (2007), Cassar et al. (2007) and Al-Azzam and Mimouni (2012)) show that clients from rural areas rely upon social networks to overcome the information asymmetry better than lenders from urban areas.

In order to succeed with social inclusion and job creation efforts in the rural areas of the Czech Republic, there is a need to set up and develop the microfinance sector and especially to enhance the sustainability of microfinance institutions. As the European microfinance sector has expanded in recent years it can offer inspiration for the Czech Republic when setting up its microfinance system. However, little is known about the European microfinance industry and its drivers of both social and financial performance.

The aim of this research is to examine whether the European microfinance institutions with clients from rural areas perform better than remaining institutions. This expectation of better performance is driven by the fact that rural areas have conditions more conducive for the development of social networks than urban ones (Postelnicu, 2014). The social networking can result in conformity behaviour that may positively affect repayment. The study aims to investigate the conjecture that MFIs with clients from rural areas face lower agency conflicts between lenders and borrowers and have therefore improved repayment performance. This knowledge could be beneficial when designing and launching the microfinance system in the Czech Republic. This expectation

is also driven by the results of Pospěch et al. (2009: 294) who state "that Czech rural areas are becoming a part of what Castells (2000) has termed the "network society", where the geographical borders are being crossed by the strings of networks, tying together what, until recently, has been disconnected." Hubík (2007) sees the Czech countryside as a space which can quickly get ahead of the urban areas thanks to social and technological networks.

The remaining section of the paper is structured as follows: The second part introduces the microfinance industry in the European and develops the testing of the hypothesis, describes the used data and the methodology. The empirical study in the third part focuses on the relationship between repayment and the affiliation with rural areas. The concluding section discusses the main results and offers recommendations for the microfinance industry in the Czech Republic.

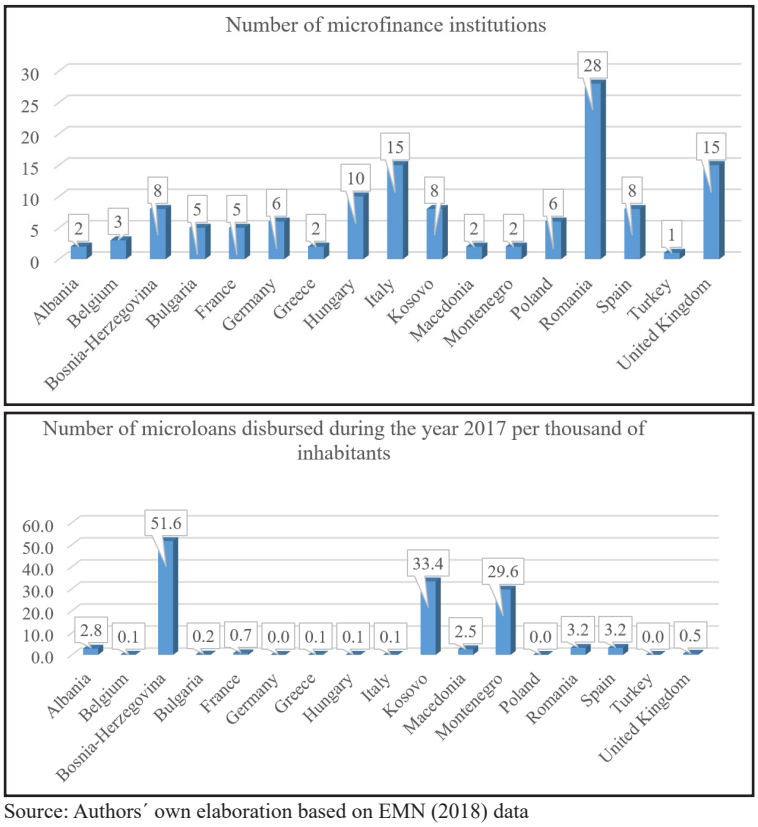
Materials and methods

The European Commission defines the term "microfinance" as financial loans of less than EUR 25,000, as well as guarantees for new and existing micro-enterprises (EC, 2018). Although the size of the loan may be far less, the specific financial amount will depend on the specific target group that the microcredit or guarantee is provided for and on the purchasing power for the country where the microfinance is provided.

According to the European Microfinance Network (EMN) the European microfinance sector has been steadily growing over recent years. The average number of microloans increased in the European countries from 30 thousand in 2003 to more than 600 thousand in 2017 which means an increase in the value of disbursed microloans from 210 million EUR in 2003 to more than 2000 million EUR in 2017. In 2017 European microfinance institutions reported almost 1 million total active borrowers.

Although these numbers document the overall trend in the Europe, they do not say anything about the distribution of microfinance services in particular countries. Based on data from the EMN Survey (2018), there is geographical variation in the access to microloans. Figure 1 represents the density and intensity of microfinance industry in particular European countries.

The picture documents unequal distribution



Source: Authors´ own elaboration based on EMN (2018) data

Figure 1: Density and intensity of microfinance industry in Europe in 2017.

of microfinance industry across Europe. The density is represented by number of microfinance institutions in particular countries, the intensity is expressed by number of microloans disbursed during the latest available year 2017 per thousands of inhabitants in particular countries. There are European countries in which microfinance markets are developed not at all or only to a very limited extent. The Czech Republic is, however, one of those countries, where microfinance industry is still in its infancy. The inspiration for designing and launching the microfinance legislative should be found in other European countries which have successfully-developed microfinance systems. However, little is known about the impact of existing European microfinance. A major obstacle in launching and developing microfinance industry in the Czech Republic is missing legislative and regulatory framework. On the other hand, there is a wide range of potential resources for microcredits. Resources for microfinance loans in the Czech Republic can be divided into two basic groups: public and private.

Public sources are largely provided from the EU budget and partly from the national or regional budgets of the Czech Republic. However, the main European microfinance facility for employment and social inclusion in the Czech Republic is still not used.). Public resources are distributed among final users in the following ways:

- Subsidies (irreversible contributions)
- Financial instruments (loans and guarantees)
- Indirect funding support (tax relief, counselling, information services, infrastructure).

Problems arising from the utilization of public sources in the microfinance sector are mostly connected with the fact that microloans or guarantees are often over dimensioned for the needs of micro-enterprises. Furthermore, public resources tend to be limited to certain sectors defined in the individual programs, which excludes potential borrowers. To complicate matters further the support from European public resources is not always stable. Changes in the conditions, aims and forms of micro-aid occur regularly.

Private sources for financing micro-enterprises can be divided into three groups - banking and non-banking institutions and new forms of financing. Banking and non-banking institutions are regulated by the central body of the Czech National Bank. The conditions for granting credit from banking institutions are considerably stricter than for non-bank institutions, which are however mainly focused on providing consumer credit. New forms of financing, including Crowdfunding or Peer-to-peer financing, represent marginal and limited forms of financing on the Czech financial market.

Problems connected with the microfinancing from private sources are connected particularly with the value of the loans, as the processes in banks are not designed for small loans and also require suitable collateral or proof of income from employment.

Hypothesis

The theoretical model of Postelnicu (2014), which provided the framework for evaluating the impact of social collateral pledged by group borrowers on group lending repayment, forms the basis for the formulation of our hypothesis. This theoretical model approach stresses the impact of network configuration on the amount of social collateral pledged and shows "*why the group lending methodology works better in rural areas than in urban areas, namely because rural social networks are typically denser than urban ones, which results in higher social collateral*" (Postelnicu, p.1, 2014). The available evidence on the importance of social ties in microfinance is scarce and stems solely from the conditions of the developing world. However, it confirms the theoretical prediction that social ties among stakeholders significantly influence the repayment performance and decrease the risk associated with the loan agreement. According to Mersland and Strom (2014), several proxies have been used in empirical studies to gauge the intensity of social ties. They include factors such as the duration of the relationship, geographic proximity, character of the relationship, the frequency of contact and sharing between group members. A brief review of the literature conducted by Mersland and Strom (2014) confirmed the unambiguous supreme role of geographic proximity. The social networks may convey soft information about borrower´s risk and therefore has the potential to compensate for the lack of hard information. This consequently reduces the need or demand for collateral or high interest rates, which are believed to be major obstacles for sustainable and non-interfering microfinance systems.

The research question can then be formulated to state: "To what extent will the intensity of social

ties among rural clients of European microfinance institutions improve the quality of a portfolio in terms of the number and value of microloans overdue more than 30 days and/or written-off loans?". Based on the findings from developing countries (e.g., Karlan (2007), Cassar et al. (2007) and Al-Azzam and Mimouni (2012)) and on the theoretical model of Postelnicu (2014), one may assume that the higher the ratio of rural clients in the portfolio of a microfinance institution, the more conducive are circumstances for building social networks, share information among stakeholders, substitute physical collateral and improve the general quality of the portfolio as measured by the number and value of loans written-off. To verify this conjecture, the following hypothesis may be formulated:

H1: The share of rural clients of MFIs is positively related to the quality of portfolio.

In order to test and then possibly support the hypotheses, the following wording has been used for its preliminary version:

H0: The share of rural clients of MFIs is not positively related to the quality of portfolio.

Hypothesis H1 reflects the findings of Al-Azzam and Mimouni (2012) who postulated that geographic proximity improves the repayment performance of borrowers. They confirm the theoretical prediction that internal ties among stakeholders affect their screening, monitoring and enforcement efforts, which in turn determine their repayment performance and the quality of the portfolio. It also reflects the findings of Chmelíková et al. (2019) whose analysis of data from European MFIs confirmed that the share of overdue loans is negatively related to the share of clients from rural areas.

Data

Data for our analysis come from a comprehensive overview of microcredit suppliers in Europe carried out by European Microfinance Network (EMN). According to EMN (2018), the survey has increased its coverage from 32 microlenders across 10 European countries participating in 2004 to 156 institutions from across 28 countries participating in the most recent survey of 2017. The EMN survey data include the standard MFI yearly indicators in the terms of size, age, legal form, the structure of clients and services, financial ratios, social outreach ratios and portfolio quality of the institutions. For our analysis, we deploy data on the share of rural clients and on quality of outstanding balance portfolio (measured by Write-off ratio and Portfolio overdue more than 30 days ratio) from 447 microfinance suppliers from across 29 European countries each MFI with 2–10 years of data over the period 2008–2017.

Methods

The financial and portfolio data of individual microfinance institutions are obtained from EMN survey, which covers a panel of 447 microfinance suppliers in the period between 2008 and 2017. The analysis of panel data represents the possibility of a cross-section of the monitored units in the monitored period therefore we deploy the panel regression analysis. A suitable method for processing a large sample is the selected method of panel analysis that allows the inclusion of these amounts of data depending on selected variables. All estimates are made in the software Gretl. We estimated the model with random effects (based on the results of the Hausman test) with robust standard errors, which are consistent against the consequences of autocorrelation and heteroscedasticity. Stationarity of variables was proved with the use of the unit root test Levin, Lin & Chu for the panel data (Levin et al., 2002).

To test the influence of share of rural clients on the quality of portfolio of European MFIs we use two regression models with the following variables:

- **Dependent variables:**
  - Portfolio overdue more than 30 days (*PAR30*), calculated as follows: (Outstanding balance portfolio overdue > 30 days / Gross Loan Portfolio) x 100
  - Written off ratio (*WOF*), calculated as follows: (Value of loans written-off / Average Gross Loan Portfolio) x 100
- **Independent variable:** Share of rural clients (*RUR*). This variable describes the share of rural population among all clients of particular microfinance suppliers,

All variables, including a description of the measures used and their descriptive statistics, are summarized in Table 1.

Variable	Abb.	Description	Mean	Median	Max.	Min.	Std. Dev.	Obs.
Portfolio overdue more than 30 days	PAR30	Outstanding balance portfolio overdue > 30 days as % of Average Gross Loan Portfolio	8.599	4.0	96.0	0.1	13.283	554
Write-off ratio	WOF	Value of loans written-off as % of Average Gross Loan Portfolio	3.746	2.2	24.0	0.1	4.333	364
Proportion of clients from rural areas	RUR	Rural population as % of total borrowers	31.354	25.00	99.3	1.0	27.475	639

Source: Gretl; authors' elaboration

Table 1: Description of variables and summary statistics.

Results and discussion

The hypothesis H0 has been tested in order to determine the relationship between the repayment performance of microfinance institutions and their share of clients from rural areas. Table 2 shows the results based on the estimation of the impact of the rural character of clients on the quality of portfolio of European MFIs which is expressed by their PAR30 and Write-off ratios.

	Dependent Variable	**Dependent Variable**
Independent Variable	*PAR30*	*W-OFF*
RUR	**−0.0924***** (0.0000)	**−0.0205 ***** (0.0024)
CONSTANT	**10.5327***** (0.0000)	**3.7178***** (0.0000)
AIC	3456.325	1287.996
Observations	454	260

Note: *** statistical significance at 0,01% level. Standard Errors are in parenthesis.

Source: Gretl; authors elaboration

Table 2: Model Table.

The negative sign of coefficients *b* shows, at statistical significant level of 0.05%, that repayment performance of particular MFIs is positively influenced by the higher share of the rural population (the higher are the PAR30 and Write-off ratios the worse is the quality of portfolio and overall repayment performance of the MFIs). This is in line with expectations stemming from previous empirical evidence (Al-Azzam and Mimouni (2012) and Chmelíková et al. (2019) as well as from the theoretical model developed by Postelnicu (2014). The null hypothesis of the independence assumption is rejected based on given statistical significance (p-value is less than the given significance level $\alpha = 0.05$). We can hence support the base hypothesis that increased share of rural population leads to improved quality of portfolio.

We have built our hypothesis on the theoretical model of Postelnicu (2014), who described denser social networks in rural areas in the comparison to urban ones. These are connected with an increased ability to create social capital and use it as a "soft" collateral in debt-creditor relationships. This connection was empirically verified by Mersland and Strom (2014), Karlan (2007), Cassar et al. (2007), or Al-Azzam and Mimouni (2012), who confirmed similar conclusions to ours in the conditions of developing world.

An important mechanism through which social capital influences the repayment behaviour of microfinance institutions' clients is peer pressure. According to Kandel and Lazear (1992) there is an emotional component of peer pressure that makes it effective in the battle against moral hazard – shame and guilt. Failure to repay a loan may cause a borrower to feel shame if others can observe the failure. The denser ties among borrowers are, the stronger is the influence of peer pressure. The social conditioning of shame can result in conformity behaviour that may positively influence repayment behaviour. Gallenstein et al. (2020) found that borrowers with more close relationships (family and friends) in their borrowing group increase risk-taking yet borrowers with more relationships that induce negative moral emotions (shame and guilt) reduce risk-taking.

Our results demonstrate that social capital helps to convey emotional concepts of shame and guilt and thus helps to improve the repayment performance of those European microfinance institutions, which have higher share of clients

from rural areas. Our results suggest that the risk of bad loans can be mitigated by peer pressure which consequently decreases the demand for collateral or high interest rates. The lack or undervaluing of physical collateral is seen as the main obstacle in using the bank loans in the peripheral regions of the Czech Republic. Blažek and Bečicová (2015) found that entrepreneurs from Czech periphery face the problem that the value of their premises, when setting them as collateral, is significantly underestimated.

The banking sector in the Czech Republic is strongly centralized (Blažek and Bečicová, 2015), which leads to credit-rationing for businesses located in peripheral regions (Dow, 1992). Blažek and Bečicová (2015) state that in centralized financial systems, the financial resources might be allocated mainly to enterprises located close to the centre, whereas credit applicants situated in distant regions might be exposed to a credit gap or even excluded. The citizens from rural areas thus have less access to capital sources and are being held back in their investment plans by a shortage of finance. Decreased interest of profit oriented banking institutions in rural areas leads thus to lower financial inclusion of rural Czech populations. Microfinance proves therefore to be very effective in the battle against social exclusion. No financial institution has, however, been identified by the authors of the microfinance sector survey in the Czech Republic (EMN, 2019).

Conclusion

The lack of microfinance institutions in the Czech Republic is certainly a major consequence of the limited legislative framework and regulation developed for this type of financial industry. This has become an object of criticism from the regulatory bodies of the European Union (EMN, 2009). The missing legislatory framework for the microfinance industry is also accompanied by a serious lack of regulatory mechanisms. However, the role of the regulation in this sector is not explicit. Hartarska and Nadolnyak (2007) postulate that regulation has no impact on financial performance and offers weak evidence that regulated MFIs serve less poor borrowers. Mersland and Strøm (2014) show that the launching of regulation into the microfinance sector does not improve social efficiency nor accelerates future development. Their findings are supported by Cull et al. (2009).

Our findings confirm that clients from rural areas have better payment morals, thus improving the performance of the microfinance institutions. This finding is strongly recommended for consideration in the development of policies to guide legal frameworks regarding microfinancing. This may also support the further growth of the microfinancing industry and contribute positively to moderate the regional disparities between rural and urban regions.

To support the genesis of new microfinance institutions in the Czech Republic the policymakers are encouraged to design a suitable legislative framework for this industry. The results of this study clearly suggest that the repayment performance of microfinance institutions in rural areas is higher than in non-rural areas. This finding is consistent with empirical results from the developing world (e.g., Wydick, 1999; Ahlin and Townsend, 2007) and therefore provides a clue to policymakers of how to use the potential of rural networks to improve the repayment behaviour of microfinance clients and their communities. Stiglitz (1990), a former Nobel prize winner, postulates that peer monitoring is largely responsible for the successful financial performance of the microfinance institutions and of similar group lending programs. His analysis suggests some of the ingredients in the design of successful peer monitoring systems - the members of the group must be provided with incentives to monitor the actions of their peers, the smaller the groups are the lower is the risk of free riders' occurrence and the more homogenous the group is the lower is the riskiness of default. Despite Stiglitz´s results were driven from conditions in the developing world, the data of our analysis suggest, that similar principles could work in the European countries as well.

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Comparison of Situation in the Slovak and Czech Market of Milk and Dairy Products

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Abstract

The paper is focused on dairy sector with the emphasis on the development of consumption of milk and dairy products, including cheese, curd and other dairy products, in the last 15 years in the Slovak Republic and in the Czech Republic. The aim of the paper is to identify the level of milk and dairy products consumption, as well as to identify the main determinants affecting the consumption. Paper is also aimed at milk production with emphasis on the main problems that may affect future development on the dairy market. The primary data are obtained by consumer survey and survey aimed focused on producers of milk and dairy products. Based on the results we have identified that the milk and dairy products consumption by Slovak consumers is lower compared to the Czech Republic and the quality and price are considered as the main determinants influencing the consumption. We also found out that milk and dairy products producers are adapting their production to demand, but it is important to point out the barriers related in particular to the introduction of new technologies into production, rising input prices or growing consumer disinterest in the consumption of milk and dairy products.

Keywords

Slovak market, Czech market, milk, dairy products, consumption.

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Introduction

Milk and dairy products can be generally considered as recommended food for all age categories of consumers that are very difficult to substitute, and with regard to children's consumers, their intake is irreplaceable. Milk and dairy products gain their importance also in international trade within the EU in in extra-EU trade (Yurik et al., 2020). For this reason, it is important to draw attention to children and the need to include milk and dairy products into their daily meals. Recognizing the need for milk by children of low age can lead to a positive relationship and a regular consumption of dairy foods even in adulthood (Kubicová et al, 2019).

Milk primarily intended for consumption can be characterized as a physiological fluid obtained from the mammary glands of agricultural mammals during the lactation period (Keresteš, 2016). In the conditions of the Slovak Republic and the Czech Republic, cow's, goat's and sheep's milk is processed. Cow's milk is the most widespread and distributed, so the paper focuses on this type of milk and on consumption aspects related to consumer behaviour on the market of milk and dairy products. The importance of the topic is based mainly on the need to address the current level of consumption due to its irreplaceable place in the nutrition of the population (Kubicová and Habánová, 2012).

Ware (2016) consider as a significant positive of cow's milk its content of a wide range of proteins, including all essential amino acids that have a beneficial effect on the growth and recovery of human muscle tissue. Cow's milk and high-

fat milk products contain a sufficient amount of saturated fat, which can be considered as the energy source needed to increase the muscle mass in the body. Maintaining a healthy amount of muscle in the body is one of the basic prerequisites for promoting metabolism and ensuring optimal body weight. It can be said that by consuming of milk, consumers can increase their muscular mass and receive the energy they need to exercise and promote a healthy lifestyle. Based on a rational diet, milk and dairy products represent one of the most important food groups. In the context of the above milk could be defined as a complex balanced food (Špička et al., 2015; Maitah and Smutka, 2012; Čuboň et al., 2012; O'Neil and Fulgoni, 2009). Information on the composition of cow's milk is given in Table 1.

Ingredient	%
Water	87.0 %
Dry Matter	13.0 %
Protein	3.2 %
Lactose (carbohydrate)	4.8 %
Fat	4.2 %
Minerals	0.8 %

Source: own processing based on Obermaier and Čejna, 2013

Table 1: Composition of Cow´s Milk %.

Milk and dairy products can be generally considered as recommended food for all age categories of consumers that are very difficult to substitute, and with regard to children's consumers, their intake is irreplaceable (De Pelsmaeker et al., 2013). Milk is an important source of essential nutrients, such as vitamin D, calcium and magnesium (Nicklas et al., 2009) and milk consumption are associated with a reduced risk of mortality (Bongard et al., 2012). Milk and dairy products can be considered as products that help maintain good health, as a prevention of some diseases and also as a support in their treatment (Habánová et al., 2010).

Consumption of milk and dairy products has positive health effects for people (Košičiarová et al., 2017), which are mainly related to the development of the brain and nervous tissues. Garcia, Osburn and Cullor (2019) statet that dairy products have many benefits and are considered as key nutritious sources of proteins, fats and micronutrients with positive health impacts. Due to the fact, that milk contains minerals, especially phosphorus and calcium, milk consumption has a positive effect on the structure of bones and teeth (Rizzolli, 2016). Other proven effects of milk are a positive effect on the regulation of body temperature, as well as an effect on the intestinal microflora and bowel movement. Consumption of milk and dairy products strengthens muscle mass and growth, especially in early childhood (Geng et al., 2017) and has positive effects against obesity (Thorning et al., 2016). Moreover, live dairy cultures that are characterized by probiotic properties and biological value significantly affect nutritional metabolism and human health. Sour milk drinks with probiotic cultures as well as sour and matured cheeses are important in solving individual health problems, such as digestive problems, pressure problems, even cancer suppression, etc. (Rosa et al., 2017). There is increasing evidence suggesting that especially the fermented dairy products, cheese and yoghurt, are associated with a reduced risk of type 2 diabetes (Astrup, 2014).

In the context of a brief overview, the irreplaceable position of milk and dairy products in human nutrition can be deduced. In the Slovak Republic, the recommended consumption dose of milk and dairy products is at least 220 kg per person and per year, but in reality the milk consumption is only around 150 kg - 160 kg. This fact is alarming, and it is necessary to lead discussions related to consumption level and to propose measures to increase the consumption of healthy dairy products, mainly in the interests of public health. In connection with the above, the aim of the paper is to point out the development of milk and dairy consumption in the period 2009 to 2018 in the Slovak Republic in comparison with the Czech Republic and to identify the main determinants affecting the level of consumption as there is a knowledge gap in this field of research that needs to be fulfilled. This type of study is currently absent and it is very important to deal with the indicated aspects. Therefore, the presented scientific paper has a real potential to become a benefit for the scientific research area, as well as the analysed market of milk and dairy products.

Materials and methods

The aim of the paper was achieved by processing secondary data from the Statistical Office of the Slovak Republic (SO SR) and the Statistical Office of the Czech Republic (SO CR). The obtained secondary data are the basis for development of consumption of milk and dairy products until 2020 using the coefficient of determination R^2, as well as for calculation of the average growth coefficient using k´. In the context of the above the regression analysis was applied and there

were used linear, quadratic and cubic regression functions for express the trend in the development of annual consumption of milk and dairy products in the Slovak Republic and in the Czech Republic.

Primary data were obtained through consumer survey. The aim of survey was to identify the level of milk and dairy products consumption, as well as to identify the main determinants affecting the consumption. Survey was conducted on a sample of 516 respondents in Slovakia and was implemented in 2018 by electronic version. Respondents participating in the survey were diversified into 8 categories, by gender (women 64.1%, males 35.9%), age (up to 25 years 43.0%, 26-35 years 23.3%, 36-50 years 19.2%, 51-60 years 8.5%, more than 61 years 6.0%), residence (countryside 48.6%, city 51.4), education (basic 1.7%, secondary school 45.9%, university 52.3%), economic status (student 36.2%, employed 48.3%, the self-employed person 4.7%, unemployed 1.2%, maternity leave 2.9%, retired 6.8%), monthly household income (less than 1,000 Euro 19.8%, 1,001-2,000 Euro 54.7%, 2,001-3,500 Euro 23.1%, 3,501-4,500 Euro 2.1%, more than 4,501 Euro 0.4 %), monthly income of respondents (less than 400 Euro 39.5%, 401 - 800 Euro 39.3%, 801 – 1,200 Euro 15.9%, 1,201 – 1,600 Euro 3.9%, more than 1,601 Euro 1.4 %). by the number of members of the household (1 member 3.7%; 2 members 18.8%; 3 members 22.9%; 4 members 37.6%; 5 members 12.0%; more than 5 members 5.0%).

Primary data were obtained by the survey focused on milk and dairy producers. The aim was to find out information about production with emphasis on the main problems that may affect their future operation on the Slovak dairy market. The survey was realised in 2018 by personal and e-mail communications and was attended by 23 companies from Slovakia. Business entities were divided according to legal form of business (cooperative 43.5%, joint stock company 21.7%, limited liability company 13%, self-employed farmer 13%, self-employed person 8.7%), enterprise size (micro enterprise 30.4%, small enterprise 21.7%, medium enterprise 47.8%) and type of produced milk (cow milk 91.3%, sheep milk 26.1%, goat milk 8.7%).

For a deeper analysis of the research objectives, the following hypotheses were formulated:

Hypothesis 1: We assume that there exists the dependency between the level of milk and dairy products consumption and selected demographic criteria.

Hypothesis 2: We assume that consumers assess the importance of the individual criteria for consumption of milk and dairy products differently.

Hypothesis 3: We assume that there exists the dependency between the future level of milk and dairy products consumption and the current level of milk and dairy products consumption

The formulated hypotheses were tested by applying the following statistical tests: Chi-square test for independence of two variables; Cramer's coefficient; Friedman test. All the above-mentioned tests have been calculated in statistical software XL Stat. In hypothesis testing, if the p-value is lower than significant level 0.05, the null hypothesis is rejected, and the alternative hypothesis is confirmed.

Results and discussion

Consumption of milk and dairy products has increased slightly in the long-term perspective, but still does not reach the required annual consumption at the level of the recommended doses. The mentioned is confirmed by the achieved values of monitored foods per capita in the Slovak Republic in the period 2009 - 2018. The development in consumption was accompanied by a slightly increasing trend and ranged from 153.8 kg to 171.1 kg per capita and year and the average growth in total annual consumption of milk and dairy products was on the level of 1.1% ($k' = 1.011914$). The largest increase in consumption was recorded in 2010, when consumption increased to 162.8 kg, and compared to 2009 this meant an increase of 9 kg. The change was caused by the implementation of the campaign “Objav mlieko”, which had a great impact, especially on school-age consumers. After the end of the campaign, there was an immediate decrease in the consumption of milk and dairy products. Since 2011, there have been several attempts to increase consumption through various information and promotion campaigns aimed at motivating consumers to consume milk and dairy products (Slovenský zväz prvovýrobcov mlieka, 2020). Despite efforts, milk consumption is currently only 171.1 kg. We have chosen a linear function that acquires the following parameters as a suitable function to describe the trend in the development of total consumption of milk and dairy products in the Slovak Republic:

$q^t = 152.35 + 2.2721 * t \quad R^2 = 0.768$

The consumption of milk and dairy products is incomparably lower in comparison with the Czech Republic. Czech consumers consume milk and dairy products in the range that covers the range of recommended doses and in the observed period 2009-2018 reached the level of 249.7 kg to 245.8 kg. The trend in the consumption of milk and dairy products was thus declining with an average annual decrease of 0.17% (k´ = 0.998252). The stated values of consumption are achieved by the implementation of very successful promotion project "Bíle Plus" which was realised in 2010 - 2013. This project helped to eliminate negative trends in national consumption and revive its growth (Agrární komora České republiky). Based on the achieved results, the program was extended to other years and was also partially implemented in the Slovak Republic. We expressed the trend of the development of the total consumption of milk and dairy products in the Czech Republic in the years 2009 - 2018 by a cubic function with the following parameters:

$q^t = 270.61 - 23.563 * t + 4.3766 * t^2 - 0.227 * t^3$

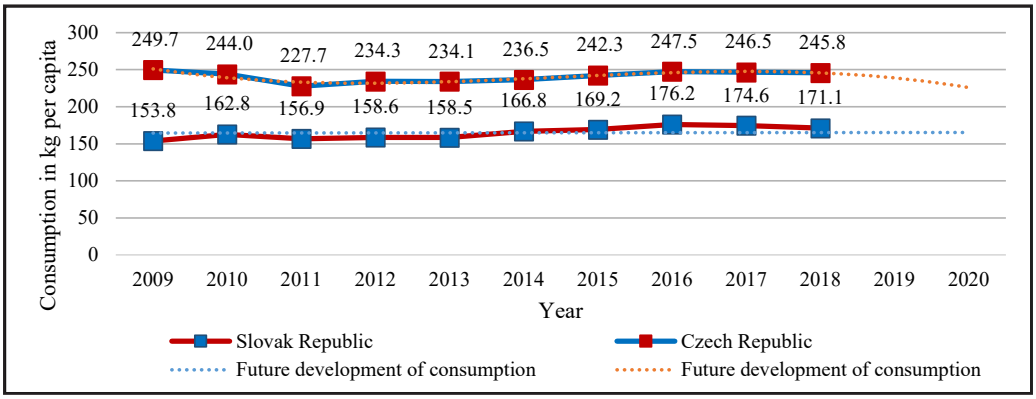
$R^2 = 0.8586$

With a view to the future, it is possible to assume that in the next period there will be a continuing slightly increasing trend in the consumption of milk and dairy products in the Slovak Republic. Matošková and Gálik (2016) assume that the level of consumption will be influenced by the development of prices of milk and dairy products in relation to household income, gross domestic product and its distribution among the population, as well as living standards or individual consumer behaviour. In the Czech Republic a declining trend in the consumption of milk and dairy products is expected, which may be caused mainly by insufficient consumer information about the importance of milk consumption, as well as the spread of vegan lifestyle, or negative consequences of the current situation on the food market (Náš chov, 2020).

Milk, cheese, cottage cheese and sour milk products contribute to the total consumption of milk and dairy products the most. The development of milk consumption in the analysed period 2009 - 2018 had a declining trend from the long-term perspective (Figure 1). In the observed period, the average annual decrease was 0.81%. In the first year, milk consumption was recorded at 49.5 kg per capita, but in the last year was only 46.0 kg. The largest increase was recorded in 2010 and milk consumption was positively affected by the mentioned promotional program. In the context of the above, it is important to emphasize that milk consumption has been eliminated to the current value since 2011. Milk consumption is lower compared to the recommended dose and lags behind by almost 50%. This fact could be caused by the increasing milk prices and constantly expanding the range of dairy products, especially cheese, sour milk and other dairy products. We have chosen a linear function with the following parameters to express the trend in the development of milk consumption in the Slovak Republic in the period 2009 - 2018:

$q^t = 54.293 - 0.8533 * t \quad R^2 = 0.631$

For comparison with the Czech Republic, it is important to emphasize that even the milk consumption by Czech consumers is not sufficient according to the recommendations of rational nutrition. Over the last 10 years, milk consumption has been recorded at about the same level with slight fluctuations. The average annual decline coefficient was recorded at only 0.02% (k´ = 0.999814). We have chosen a cubic function with the following parameters to express



Source: own processing according to SO SR and SO CR

Figure 1: Comparison of the development trend of annual total consumption of milk and dairy products per capita and year in the Slovak Republic and in the Czech Republic.

the trend of milk consumption in the Czech Republic in the years 2009 - 2018:

$q^t = 60.4 – 1.7915 * t + 0.4999 * t^2 – 0.0329 * t^3$

$R^2 = 0.485$

We assume that in the next period there will be a continuing declining trend in milk consumption in the Slovak Republic and the Czech Republic, which may be caused not only by rising household incomes, rising milk prices, but also a relatively wide range of dairy products (Kubicová and Habánová, 2012). We expect a decrease in milk consumption to the level of approximately 43 kg per consumer in the Slovak Republic and approximately 54 kg per capita in the Czech Republic (Figure 2).

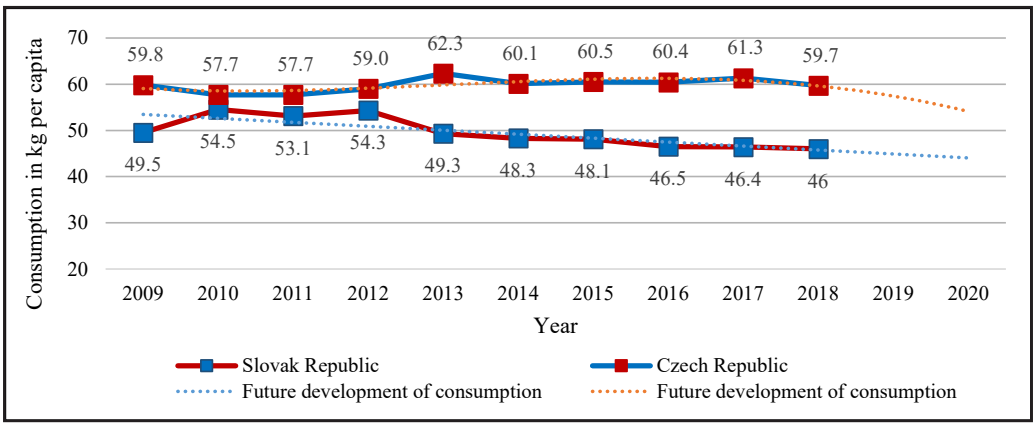
Consumption of cheese and curd had a slightly increasing trend in the observed period of 2009 - 2018 and the average annual growth of consumption was recorded at the level of 3.5% (k´ = 1,0345). In 2009, consumption was at the level of 9.8 kg and in the last analysed year up to the level of 13.3 kg, which represented an increase in consumption by 35.7%. In comparison with the recommended doses of cheese consumption, the average annual consumption of cheese by Slovak consumers is sufficient. Despite the favourable development of consumption, the consumption of curd does not cover the recommended doses and lags behind by 12.5%. The trend of the consumption of cheese and curd in the Slovak Republic in the years 2009 - 2018 was expressed by a linear function with the following parameters:

$q^t = 8.64 + 0.5218 * t \qquad R^2 = 0.8704$

The consumption of cheese and cottage cheese is at a sufficient level and covers the minimum amount of the recommended dose compared to the Czech Republic. The consumption of curd was gradually increased by an average of 0.8% (k´=1,0077) per year during the years 2009 and 2018 in the Czech Republic. In the first monitored period, the annual consumption of curd reached the level of 16.7 kg per capita, while in 2018 it increased by 7.2% to 17.9 kg. The favourable development of the consumption of cheese and curd in the Czech Republic was positively influenced mainly by the constantly expanding range of curds, especially flavoured curds, which are becoming more and more popular among consumers. We have chosen a quadratic function with the following parameters to describe the trend in the development of annual curd consumption in the Czech Republic,

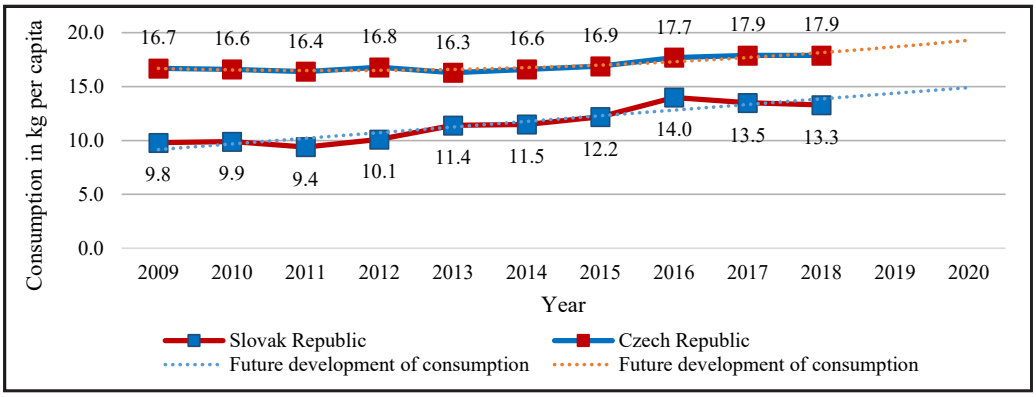
$q^t = 16.897 + 0.2447 * t + 0.0371 * t^2 \qquad R^2 = 0.8597$

Based on the development of consumption of cheese and curd on the Slovak and Czech market, we can evaluate and assume a gradually increasing interest of consumers in the consumption of unflavoured and flavoured curd. In the next two years in the Slovak Republic, we assume that the amount of consumed curd should approach the minimum limit of the recommended dose. In the case of the Czech Republic, we also assume a positive development and an increase in annual consumption to the level of approximately 5 kg per capita. The demand for cheese and curd should be influenced mainly by an increase in household income, expansion of curd assortment or increased preference and consumer awareness about the necessity of curd consumption. These aspects were also important according to Kubicová and Dobák (2012). In the next two years, we expect an increase in the consumption of cheese and curd by Slovak consumers by approximately 1.5 kg and by Czech consumers by 1.0 kg per year (Figure 3).



Source: own processing according to SO SR and SO CR

Figure 2: Comparison of the development trend of annual consumption of milk per capita and year in the Slovak Republic and in the Czech Republic.



Source: own processing according to SO SR and SO CR

Figure 3: Comparison of the development trend of annual consumption of cheese and curd per capita and year in the Slovak Republic and in the Czech Republic.

Consumption of other dairy products by Slovak consumers, of which sour milk products are an important part, recorded a gradual increase in 2009 - 2018 with an average annual growth of 2.29%. It is important to highlight the favourable growth in consumption by 48.8% from 13.7 kg in 2009 to 16.9 kg in the last year. The consumption of dairy products was recorded slightly below the level of the recommended dose of 14 kg until 2011. However, since 2012 it has increased and has reached the minimum level of recommended dose. Nowadays, consumption is approximately 20.0% above the recommendations for a rational diet. Yoghurts have a significant share on the other dairy products and their sales are growing due to the constantly expanding offer (Nouzovská, 2007). We chose a linear function with the following parameters to express the development trend of the annual consumption of other dairy products in the Slovak Republic in the observed period.

$q^t = 12.8 - 0.4836 * t \qquad R^2 = 0.881$

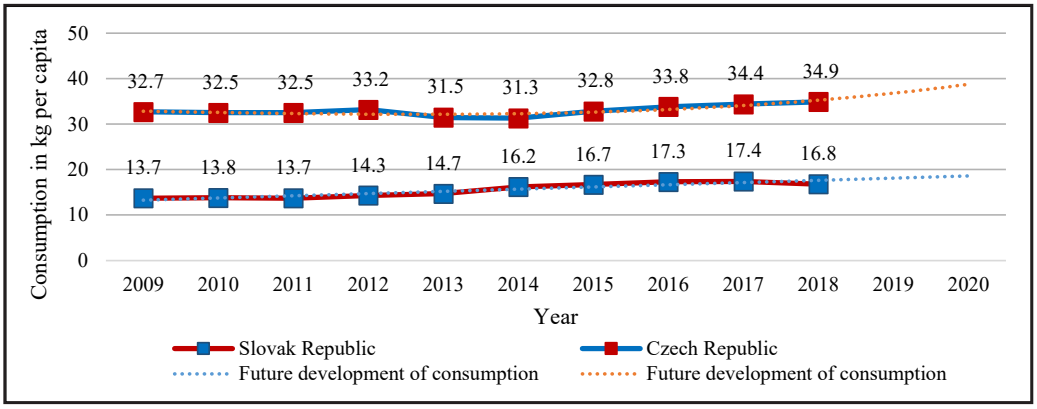
In the Czech Republic, the consumption of other dairy products was higher compared to the Slovak Republic. In the observed period 2009 - 2018 the annual consumption of other dairy products, especially sour milk products, ranged from 32.5 kg in 2010 and 2011 to 34.9 kg in the last observed year. The average annual consumption of other dairy products by Czech consumers is higher by almost 50.0% compared to the range of recommended doses. This fact may be caused by a wide range of dairy products, mainly yogurt and other sour milk products, that are becoming increasingly preferred by consumers. Moreover, the Czech Republic has one of the highest consumption of yoghurts and other sour milk products in Central Europe (Zemědelec, 2018). The cubic function with the following parameters was chosen to express the development trend of the annual consumption of other dairy products in the Czech Republic in the years 2009 - 2018:

$q^t = 33.126 - 0.2759 * t + 0.0165 * t^2 + 0.0065 * t^3$

$R^2 = 0.7435$

In the next two years, we expect gradually increasing consumption of these types of food. The level of consumption will be affected by rising consumer prices of sour milk products and other dairy products, household income, assortment of products, consumer prices of other dairy products, as well as the promotion of positive health effects. We assume the above on the basis of studies by Kubicová (2008), whose research was focused on a detailed examination of the development of consumer demand for sour milk products (Figure 4).

The consumer survey was conducted in connection with the analysis of the market of milk and dairy products in the Slovak Republic and was focused on identifying the amount of consumption of the monitored products, as well as the main factors determining the consumption. The results of the survey showed that only 0.4% of respondents do not consume milk or any dairy products, and they are probably consumers with lactose intolerance who are not looking for lactose-free alternatives to milk and dairy products. 10.4% of consumers annually consume milk and dairy products in the recommended interval, which is at the level of 206-240 kg per year. The results point to the fact that 56.2% of respondents consume less than 206 kg of milk and dairy products per year and 36.9% of consumers consume milk and dairy products excessively, above the level of 240 kg. Slovak consumers most consume milk, sour milk products, cheese and curd and these products have



Source: own processing according to SO SR and SO CR

Figure 4: Comparison of the development trend of annual consumption of other dairy products per capita and year in the Slovak Republic and in the Czech Republic.

the largest share on total milk and dairy products consumption. In the context of this question, we assumed the dependence between the amount of consumption of milk and dairy products and selected demographic characteristics (age, gender, education, monthly household income). Based on the Chi test of square contingency, it can be stated that the dependence was confirmed only in the case of monthly household income (p-value = 0.006). From the aspect of dependence tightness, there is a very weak dependence proved by the calculation of the Cramer coefficient (0.119). Based on the above it could be concluded that the annual consumption of milk and dairy products depends on the monthly household income. However, it is very important to emphasize that most consumers from all income groups are characterized by insufficient consumption of the monitored products (Figure 5).

	p-value	Cramerov V coefficient
Current consumption of milk and dairy products and age of respondents	0.393	-
Current consumption of milk and dairy products and gender of respondents	0.121	-
Current consumption of milk and dairy products and education of respondents	0.251	-
Current consumption of milk and dairy products and household monthly income	0.0060	0.119

Source: Statistical program XLSTAT, 2020

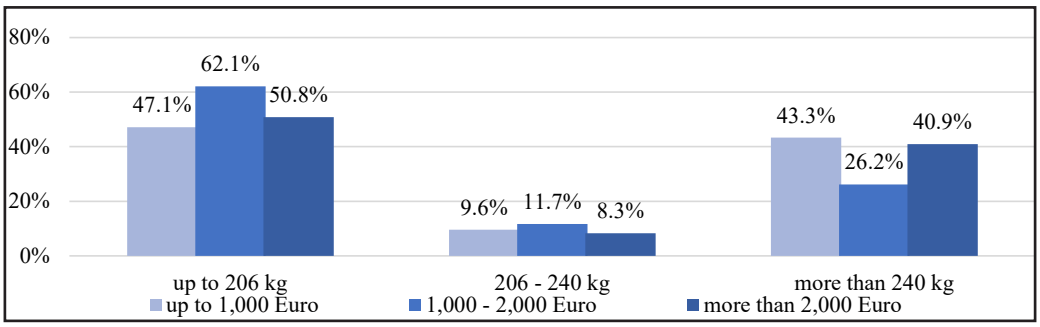
Table 2: The current level of consumption of milk and dairy products depending on selected demographic characteristics.

From the point of view of distribution to individual types of dairy products, it can be stated that the most consumed are cheese, curd, sour milk production and other dairy products. These are also confirmed by the results of the research of Kapsdorferová and Nagyová (2005), which was realised in Slovakia.

The results of our research showed that 10.0% of consumers do not consume milk. 52.7% of respondents consume an average of 0.01 to 0.2 liters of milk per day, which represents the amount of milk up to 21 grams. The recommended dose of milk consumption is at the level of 27 grams and the stated amount of milk is consumed by 9.5% of consumers. 18.1% of respondents consume 32 to 51 grams of milk per day and 9.7% of respondents state an average daily milk consumption of more than 52 grams, which in combination with relatively high consumption of other dairy products, can cause excessive milk consumption and dairy products.

The results of the survey also point to the consumption of cheeses and curds. Based on results it can be stated that only 4.4% of consumers consume the required amount of cheese and curds according to daily recommended doses (25-30 grams). It is also important to note that 4.1% of respondents do not consume cheese and curd at all and 23.7% of consumers consume them, but in insufficient quantities (less than 25 grams per day). On the other hand, the results show that almost 70% of respondents excessive consume curd and cheese, which could be justified by a wide range of cheese and curd.

Consumer research was also focused on the consumption of yoghurts, sour milk products and other dairy products. Based on the results, it can be stated that 9.3% of respondents consume dairy products daily in the range of recommended



Source: consumer survey

Figure 5: Annual consumption of respondents according to household monthly income.

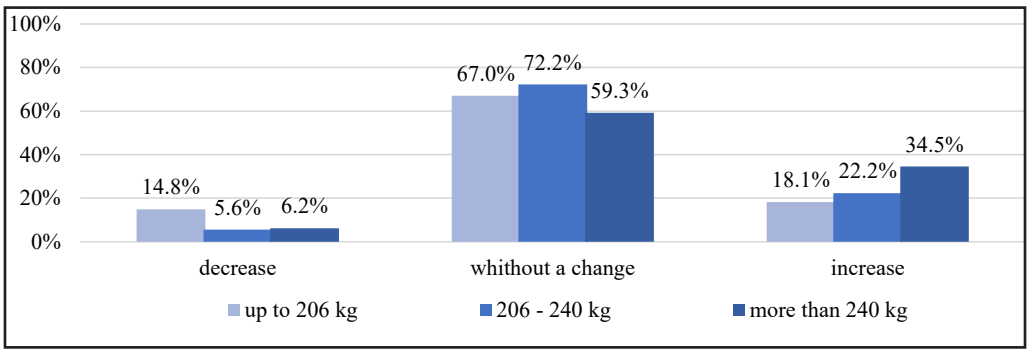
doses (75-90 grams). It is important to note that 7.7% of consumers do not consume sour milk and other dairy products and prefer milk, cheese and curd. On the other hand, 81.9% of respondents consume sour milk and other dairy products more than recommended doses and their average daily consumption is above 90 grams. High consumption could be caused mainly by a wide range of yoghurts, yoghurt milks, acidophilic milks, milk rice, kefir, or sour milks and probiotics. These products are preferred and looked for by consumers mainly because of taste and positive health effects.

In comparison with the Czech Republic, it can be noted that according to the research of Brazdová et al. (2014) cheese, milk, cream, cream yoghurts are the most consumed by Czech consumers and processed cheeses and low-fat yoghurts are the least preferred in consumption.

We have identified factors that are important for Slovak consumers in the issue of consumption of milk and dairy products. Koprda (2014) emphasizes that consumer behaviour is complex of behaviour that is not influenced by just one factor. Consumers rated ten factors that can determine their consumer behaviour on a scale of 1 to 4, with 1 being the least important factor and 4 being the most important factor. Based on the results, it can be stated that quality (3.78), composition, durability and price are the most important factors for Slovak consumers. The GfK survey (2017) has shown that for the Slovak consumer is still a very important price when deciding about purchasing chosen food, including milk and dairy products, but the emphasis on quality is clearly rising. Other less important factors determining the consumption of milk and dairy products are nutrition information, country of origin, package size and producer. Consumers are least affected by the appearance of packaging (2.57) and promotion (2.73). Nagyová et al. (2020) concluded that consumers are unaffected by packaging, packaging material and brand at purchase and consumption. It follows from the above that we have confirmed the similarity and relevance of the results we have achieved. In the context of the evaluation of individual factors influencing the choice of monitored foods, we identified differences in the evaluation of determinants based on the Friedman test, which was statistically proven by the calculated p-value (<0.0001). For comparison with the Czech Republic, it is possible to point out the example of Hes et al. (2009), who concluded in their study that the purchase and consumption of food, including milk and dairy products, is largely determined by the quality and properties of dairy products, as well as their price. In the context of the above, it could be concluded the comparable consumer behavior on the Slovak and Czech milk markets.

We identified an insufficient level of consumption and we were interested in the development of consumption of monitored foods over the next 5 years. It can be stated that 64.7% of consumers do not plan to change the amount of consumed milk and dairy products. 10.4% of respondents expect a decrease in the consumption of milk and dairy products and only 24.7% of respondents stated a planned increase in the consumption of milk and dairy products. In connection with this question, we assumed a dependence between the future consumption of milk and dairy products and the current consumption of milk and dairy products. Based on the Chi square contingency test, it can be stated that the dependence was confirmed (p-value = 0.0001). From the aspect of dependence tightness, there is a medium-strong dependence proved by the calculation of the Cramer coefficient (0.30) (Figure 6).

The future development of milk and dairy products consumption can be determined mainly by main factors such as price and quality of products, but also by the level of supply of milk and dairy



Source: consumer survey

Figure 6: Development of milk and dairy products consumption in the next 5 years according to current consumption of milk and dairy products.

products in the market.

The aim of the survey focused on producers of milk and dairy products was to map out the situation on the Slovak dairy market with an emphasis on production.

The entities are mainly focused on the production different types of cheese, including "parenice", "nite", "korbáčiky" and "oštiepky" (60.8%), curd (34.8%), yoghurts (17.4%), butter (17.4%) and cream (13.0%). Enterprises focused on the production of dairy products use milk from their own resources (82.6%), buy milk from Slovak local producers (8.7%), or use a combination of the above options (8.7%). On the issue of production, it is necessary to analyse the change in the amount of production over the last 5 years. The results showed that 65.2% of subjects have increased the production as a results of higher demand resulting from consumer interest in quality milk and dairy products, as well as of increased livestock and increased productivity, the introduction of modernization and new technologies into the production process or changes in the organizational structure of the company. On the other hand, 26.1% of entities have decreased the production as a result of the low purchase price of raw cow's milk, the cancellation of milk and dairy import quotas, reduction of dairy cows and reduction of productivity due to rising livestock costs or negative effects of agricultural policy.

In order to keep production volume of milk and dairy products with a tendency for growth, subjects use various forms of promotion with the emphasise on highlighting the milk origin, production process, traditional recipes, composition of dairy products without preservatives, quality of products, justification of product price and importance of consumption with positive health effects.

We also addressed milk and dairy products producers with a question concerning the problems of the dairy industry. It can be stated that the most significant problems are low state subsidies, milk quotas and high imports of foreign dairy products, low consumption, lack of interest in working in the dairy industry, unskilled labour, inability to use innovation in the production process and capital intensity of production technologies, high costs of milk production associated with low purchase prices of milk and high requirements for the production. Švikruhová et al. (2020) found that rising costs are also a problem for producers, either because of rising energy prices or because of rising labour costs caused by the government measures. In the Czech Republic Naglova et al. (2017) and Špička and Smutka (2014) identified another problem in production, which is related to strong pressure from foreign competition and has a negative impact on Czech companies operating in the dairy industry.

In order to address the situation on the dairy market, producers and processors have the possible suggestions in the form of higher support for domestic farmers by the state, financial subsidies, creating of suitable conditions for business entities, reduction of imports of milk and dairy products, or sales support for the Slovak dairy products with an appeal to increase the consumption of milk and dairy products. Horská et al. (2020) concluded that in order to keep and increase milk production, it is necessary to increase sales, which is possible by promoting the product itself with regard to its quality, freshness and location, as well as consumer recommendations and customer loyalty. Vasylieva (2017) found out that reducing retail prices and raising solvency of population would be the option for supporting the food industry, as well as effectively using quite big amount of public subsidies from the Rural Development Programme (Špička, 2015).

Conclusion

The paper was focused on identifying the consumption of milk and dairy products in the Slovak Republic and the Czech Republic, the factors determining consumption, as well as the problems of milk and dairy products producers. Current consumption is at the level of 160 kg per capita and year, which does not cover even the recommended consumption dose. In terms of distribution between individual dairy products, we can conclude that there is a sufficient level of consumption in the case of sour milk products, yoghurts and other dairy products. For comparison with the Czech Republic, we found out that Czech consumers consume up to 250 kg of milk and dairy products on average per year, so the level of recommended consumption is reached. In the questionnaire survey realised in the Slovak Republic, we also examined the amount of consumed milk, cheese, curd and other dairy products by all respondents. Subsequently, the data were compared with the recommended consumption doses. In general, it can be stated that 56.2 % respondents consume milk less than the level of the recommended doses, but the consumption of cheese, curd and other dairy products is higher compared to the recommended doses. It could be concluded, that 74.4 % respondents consume cheese and curd in sufficient or excessive amount, and 91,2 % respondents stated that they consume other dairy products mainly yogurts and sour-milk products in the level of recommended doses or their consumption is even higher. Based on the results, we have identified quality and price as the main determinants influencing milk and dairy products consumption. Slovak consumers consider these factors as the most important between ten evaluated factors on the scale from 1 to 4 according the importance. With a view to the future, it is probably possible that Slovak consumers will increasingly focus on products with higher added value. The results showed that 24.7 % respondent are planning to increase their milk and dairy consumption. Milk and dairy products producers are adapting their production to demand, but it is important to point out the problems related in particular to the introduction of new technologies into production, rising input prices or growing consumer disinterest in the consumption of milk and dairy products. In comparison with the Czech Republic, it is possible to point out very similar consumer behaviour, while Czech consumers focus mainly on low-fat yoghurts. From the point of view of production, Czech producers identify identical problems as Slovak producers, which is confirmed by several Czech researches. In the market of milk and dairy products in both countries, we propose that measures be taken to support and maintain production and to ensure greater promotion in order to increase consumption, with an emphasis on quality, nutritional value and positive health effects. The paper reflected the current issues of the situation on the dairy market not only from the point of view of consumers but also from producers, and is becoming relevant for the scientific community as well as for the general public. The paper compared the situation on the Slovak and Czech market of milk and dairy products, which has acquired an international dimension and can be used as a basis for other scientific research and application. In the context of the above, it is necessary to constantly monitor the situation on the Slovak and Czech market of milk and dairy products. It is also necessary to carry out research that will be oriented towards consumers and producers on the milk and dairy products market, and thus it will be possible to anticipate the future perspective direction of dairy sector in the Slovak Republic and the Czech Republic. Currently we are facing new challenges of digital and technology transformation in all economies in the world (Rymarczyk, 2020; Młody, 2018; Sieja & Wach, 2019), so next research should include also these issues into considerations, as the Industry 4.0 is connected also with a new model of a customer bahviour from the marketing perspective.

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Students' Processing of Differently Structured Text Materials Focused on Agricultural Waste Disposal Using Eye-tracking

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Abstract

This study was focused on agricultural waste disposal (AWD) textual materials. Two educational texts are compared: designed texts traditionally with no purposeful design and structured knowledge texts, including the textual form of knowledge units. Eye-tracking technology is employed for retrieving the values of critical indicators specifying the way of reading the texts. We analysed users' visual attention and looking behaviour during the reading process. Thirty-three students worked with 45 pieces of educational texts accompanied by a didactic test. Statistical analyses show statistically significant differences neither in any indicator within studying the texts nor in the users' success rate in the didactic test. The users can work with the knowledge structured texts equivalently with the designed texts in the traditional way. The positive effect for AWD is that users can process knowledge structured texts with better results.

Keywords

Agricultural waste disposal (AWD), eye tracking, knowledge unit (KU), knowledge engineering, reading process, areas of interest.

Mudrychová, K., Houšková Beránková, M., Horáková, T., Houška, M. and Mudrychová, J. (2021) "Students' Processing of Differently Structured Text Materials Focused on Agricultural Waste Disposal Using Eye-tracking", *AGRIS on-line Papers in Economics and Informatics*, Vol. 13, No. 4, pp. 85-99. ISSN 1804-1930. DOI 10.7160/aol.2021.130408.

Introduction

Waste disposal in agriculture and the environment

The importance of waste disposal nowadays is noticeable concerning new technologies and environmental studies. Waste disposal in agriculture is one part of the whole waste disposal. It is advantageous, almost inexpensive and renewable energy with a massive amount of and wide varieties in agriculture. Those wastes can be used in agriculture as feed for farm animals (livestock), thrown away directly or burned. Therefore, based on recent studies, the focus is to utilise the efficiency of waste disposal in agriculture with less impact on the environment or even improve the quality of the environment. There are commonly known processes such as anaerobic digestion (Golecha and Gan, 2016; Mancini et al., 2018) and fermentation (Ji et al., 2014; Reichardt et al., 2009) that can be the improvement done. Other processes such as gasification, pyrolysis (Catto et al., 2010; Lim et al., 2012) or chemical treatments (Horax et al., 2017; Shen et al., 2012) of biomass which produces gas (Park et al., 2017; Wang et al., 2019), liquid (Yue et al., 2016) or carbon-rich solid materials (Horax et al., 2017; Shen et al., 2012; Wang, Wu and Sun, 2018) through synthesis could be used for the improvements as well.

That is why it is essential to start teaching students mentioned above. The authors' focus was on university students who have already some experience with waste processing due to their university studies. We focused specifically on textual materials from waste disposal and how to improve students' transfer of knowledge about waste disposal. Students usually have a pretty wide range of textual materials where teachers make sure their students get the necessary knowledge for their studies.

Considering learning processes and strategies, Oxford et al. (2017) or Griffiths et al. (2013) provide a different view on learning processes and their division, description, or even determination of which learning strategies should be used. Also, those authors used different approaches in various

research disciplines. The research done by Oxford and Randall (2017) was focused on the process of learning foreign languages to find out and learn how to manage and control the effort of learning a new language. However, the research done by Griffiths et al. (2012) looked at the same problem and discovered that learning strategies are often chosen and created by the learner, not by the teacher. It is clear from studies that many authors, such as those mentioned above, agree with some basic standards about strategies, typically that the involvement of the learner and his/her responsibility for the learning process is significant (Griffiths et al., 2017).

Moreover, a positive impact on learning performance can be observed when teachers use more visual materials, pictures, and specific words to research learning. Nevertheless, the process and the integration of textual and visual materials require much effort. The solution should be to have more visual materials in the process of learning; these include verbal cues that can guide the learners. Therefore, learners can use them more efficiently and match their attention to visual materials with the one to textual materials and vice versa (Ching, 2012; Mayer, 2014; Mayer, Lee and Peebles, 2014; Navarro et al., 2015).

Based on the above, the authors decided to test students on pieces of textual materials that provided information about waste treatment in different conditions and locations, waste treatment, and other related procedures. Those textual materials were already used in Horáková and Houška (2014) study or formerly in Enviregion (2014) textbook.

Knowledge vs traditionally structured text

This study differentiates the educational text into two shapes: designed texts traditionally and knowledge structured texts. The information or didactic content of the text is the same, but the presentation style of the texts are different. Traditionally written texts are written in a manner following the educational standards by the authorities. Still, the author's personality and writing style can still influence textual materials, in which sentences are not built for a learning purpose. It is hard for authors to separate their writing style even if they follow the standards by which those books, textual materials, and other literary pieces used in education should be written.

On the other hand, the style of knowledge structured texts is perfectly aligned with the process of knowledge representation, such as production rules or, preferably, knowledge units. The personal style of writing of individual authors is suppressed, and so, the traditionally designed text, which is written in books, articles, journals, and others. In our study, traditionally created texts represent a standard, original text that gives us the same information as a knowledge structured text. Both types of texts provide us the same information and knowledge.

We can look at a knowledge unit (KU) such as an "information bit" or a kind of entity. In this study, we use the definition of a knowledge unit, divided into four parts. According to Dömeová et al. (2008), those four parts are as follows: problem situation (called part X), elementary problem (called part Y), objectives of the elementary problem to solve (called part Z), and solution of the elementary problem (called part Q). Textual form of the KU is: if we solve a problem Y in a problem situation X subject to the objective Z, then we should apply the solution Q. We used this definition of a knowledge unit for constructing knowledge structured texts, and part of the results was published in Mudrychová et al. (2017).

Knowledge unit can be represented in two forms, and one of them is structured, e. g.: X = to dispose of waste with minimal environmental damage, Y = when looking for the most suitable and efficient ways, Q = environmental aspects must be taken, Z = into account in addition to economic aspects. Another form is to formulate a knowledge unit in textual form, e. g.: “When looking for the most suitable and efficient ways to dispose of waste with minimal environmental damage, environmental aspects must be taken into account in addition to economic issues” (Horáková, Houška and Dömeová. 2017; Mudrychová, Houšková Beránková and Horáková, 2018; Houška and Houšková Beránková, 2006).

Research focus

Our research is focused on differences in the reading process of traditionally and knowledge structured text by users. It means that reading behaviour is measured in time units of eye movements through the whole reading process; measuring is by eye-tracking technology.

This is related to visual attention and what does it mean for authors. Visual attention can be understood as a set of cognitive and psychological mechanisms that modulate visual information present to a respondent. Those processes allow for processing rapidly and accurately a relevant stimulus and separate it from irrelevant. It is necessary to integrate visual information

into objects that can be successively identified and be recognised or remembered (Holmquist, 2011).

Research question: Are there differences between users' reading processes of knowledge and traditionally designed text?

If users' results are much significantly better in didactic tests and/or results of their reading processes are significantly faster, traditionally structured texts will be considered to re-write and re-structure to knowledge structured form.

Sub-research questions are as follows:

S*ub-RQ1: Are there differences in looking behaviour during users' reading processes of knowledge and traditionally structured text? – it is related to H01 and H02.*

Sub-RQ2: Are there differences in visual attention during users' reading processes of knowledge and traditionally structured text? – it is related to H03 and H04.

Sub-RQ3: Are there differences in visual attention during users' reading processes among parts of knowledge units? – it is related to H05 and H06.

Above mentioned sub-research questions are elaborated into statistical hypotheses.

Materials and methods

Eye movements on the screen are tracked using two primary groups of parameters. One is based on eye fixations in particular areas of interest; the other operates with eye visits in the areas. Duration of a visit contains all the fixations that occurred during one visit within the AOI. This variable contains the saccadic duration (quick jumps from one fixation to the other) among those fixations within that AOI until a fixation occurred outside the AOI. Visit count is the total number of all visits within the AOI. On the other hand, the duration of fixations is the sum of durations of all distinct fixations in the corresponding area within an AOI (Kim et al., 2012).

We used mean values and metrics which provide Tobii Studio in relation to the methodology of Holmquist (2011) and based on studies such as Shokishalov and Wang (2019) and Norqvist et al. (2019). Eye tracker trials range of users' lost attention were between 300 ms to 1800 ms.

Educational, scientific research and other creative activities at the Czech University of Life Sciences Prague (CZU) must be following the CZU Code of Ethics. The Ethical Committee of the CZU supervises it. The opinion of the CZU Ethics Committee is not required for the implementation of IGA FEM grants, only if the planned research could significantly interfere with the personal integrity of the examined subjects, such as animal experiments and other similar. The IGA FEM management will contact the CZU Ethics Committee and will request an opinion on this matter. As the research whose results are published in the article does not fall into this category, the opinion of the CZU Ethics Committee was not required. The authors got the confirmative approval of the mentioned information above.

Procedure of experiment

The experiment itself started with an introduction to avoin any misunderstanding and interruption during the process, and a short questionnaire. Each participant had to fill up basic personal information, e. g., year of birth, sex, study programme etc. and also information about eyes and head injuries.

The eye-tracking part followed. First step of that is calibration, which is made automatically by the software. The calibration process was undertaken on average 2-3 times per participant. Second step is partcipants' work with stimuli under eye-tracking recording. Participants task was to read stimuli carefully and try to remember as much as they can. We prepared one document which included both types of texts - knowledge and traditional designed text. Stimuli consisted of 45 slides in the PDF file in total. The 1st page contained instructions for participants. 22 slides with statemets regarding AWP followed. Half of the text slides were written in the traditional style, and half were in the knowledge style, they were in random positions within the text. Is was not allowed to go back to previous slides.

As mentioned in the introduction section, selected pieces of text were taken from a specific field of studies (studies of environment, waste, landscape, and others). Typically, the length of such designed texts was 3 to 5 rows, and every single piece of the text was presented on a single page of a PDF file. The font size of the text was 28 points, and the font type was set up as Calibri style, the interline used in the text was 10 points from the bottom of the high line type to the top of the standard line type. Textual materials were presented as a centrally located object, black letters on a white page; no other colours were allowed to disturb other colours or objects participants.

Third (last) part of eye-traking was focused on the didactic test, which was presented on last 22 slides of stimuli. The didactic test contained 22 questions; those questions were written in the form of a statement, and the participant had to accept or deny it. It was not allowed to go back to study text materials. We followed standard procedures in preparation for the didactic test (Pumilia-Gnarini et al., 2012). The didactic test was used as a control mechanism to see how participants react immediately after reading the textual material.

We used an eye-tracking laboratory at the CZU called HUBRU (Human Behavior Research Unit). There are available two computers with built-in Tobii Pro Eye Tracker X2-60. The experiment was conducted in a darkened room (the windows were darkened) with sound insulation for participants to concentrate on their tasks. Stimuli were controlled using the Tobii Pro Studio software. The eye tracker sampling rate was about 60 Hz (with a minimum and maximum error of 0 and 16.67 ms, respectively).

The presentation of textual materials (both statements and questions) in PDF was on a computer. The viewing distance was 50 cm in front of the centre of the screen. Each participant worked with the same stimuli and always in the same design, the designed were not alternated.

Areas of interest (AOI)

Areas of interest (AOI) are described as part of the text or image on the screen highlighted by eye-tracking tools. Those parts of text or image are the most relevant for research and examine eye movements patterns such as words, sentences, and images (Holmquist et al. 2011; Mudrychová et al., 2017). Those areas of interest were created for text types (traditionally designed text and knowledge structured text). For knowledge structured text, the areas of interest were divided into four parts corresponding to the parts of the knowledge unit (X, Y, Z, Q). In the traditionally designed text, the AOIs were used on the same piece of information. In general, two types of areas of interest exist: static or dynamic. We only worked with static AOIs, and we collected statistics and data throughout the time spent on media, i.e., pdf file (Holmquist et al., 2011; Mudrychová, Houšková Beránková and Horáková, 2018).

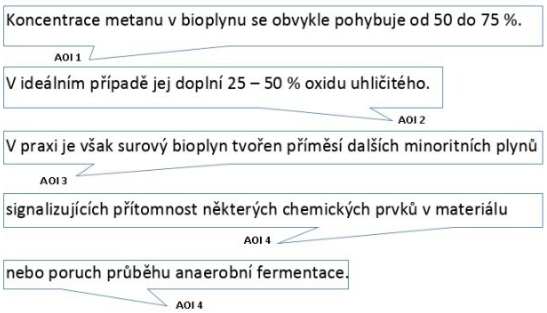
Creating the areas of interest within the stimuli

Each screen with a traditionally designed/ knowledge structured text contained 4 areas of interest. The screens with didactic questions (test) always contained three AOIs—one contained the statement; two contained the TRUE/FALSE answers.

See Figure 1 for testing examples of constructing stimuli for knowledge structured text and traditionally structured text (Figure 2). All textual materials were extracted from the source Enviregion (2014). The translation of Figure 1 content is:" If we choose technology for waste disposal in order to achieve maximum efficiency, it is necessary to start by evaluating the amount and composition of waste.". The AOI 1 represents part of KU called X, the AOI 2 represents part Y, the AOI 3 represents part Z, and the AOI 4 reprezents part Q.

Source: authors' processing (source: Enviregion, 2014)

Figure 1: Knowledge structured example of construction KUs (AOIs) within the piece of text.



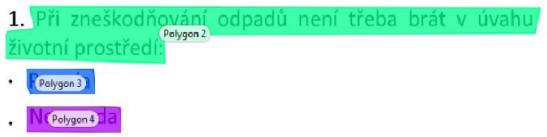
Source: authors' processing (source: Enviregion, 2014)

Figure 2: Traditionally structured example of construction AOIs within the piece of text.

The translation of Figure 2 content is: "The methane concentration in the biogas typically ranges from 50 to 75%. Ideally, it is supplemented with 25 - 50% carbon dioxide. In practice, however, raw biogas is formed by the addition of other minor gases signalling the presence of some chemical elements in the material or disturbances in the course of anaerobic fermentation.". AOIs represent parts of the traditional text which contain the same information as these in the KU.

Also, see examples in the original Czech language of the question with answers (Figure 3)

directly exported from Tobii Pro Studio software. The translation of Figure 3 content is: "The environment does not have to be taken into account when disposing of waste. True/False".



Source: authors' processing

Figure 3: Example of the didactic question with answers and AOI within the text.

Participants and their selection

In this study, the purposefully selected research sample of homogeneous respondents has been used. In particular, the sample consisted of university students of bachelor's and master's degrees in economic studies. The group contained 13 male students and 20 female students, all being 20 to 29 years old. Most of those students were right-handed. Only three of them were left-handed. None of the participants had dyslexia, nor did they have any neurological disorder. They all had a normal or corrected-to-normal vision. All participants provided consent before participating (signed the consent).

All participants had to go through the preview test option before starting the main eye-tracking recording. Each participant could use as much time as needed, so time was unlimited for them in this experiment. We used full-screen mode without any annoying elements. The record was made in one frame, and data from the TET (Tobii Eye Tracker) were separately stored in databases and were assigned to the individual participant. The entire procedure lasted for approximately 45–60 min.

Evaluation

The following metrics are used to evaluate this experiment (Mudrychová et al., 2017; Kim, Ritchie and Mccormick, 2012).

- Visit Duration (seconds, mean values): These metrics measure the duration of each visit within an AOI. This visit is defined as the interval of time between the first fixation on that particular AOI and the subsequent fixation outside that AOI.
- Total Visit Duration (seconds, mean values): These metrics measure the total duration of all visits within the active AOI.
- Total Fixation Duration (seconds, mean values): These metrics measured the duration of each fixation within an AOI and were presented in work of Mudrychová, Housková Beránková, and Horáková (2018).
- Fixation Count (some occurrences, mean values): These metrics measure the number of times the participant fixates on an AOI.
- Analysis of Variance (ANOVA) is used to determine the differences among the mean values of the fixation count among the AOIs representing each part of knowledge units (X, Y, Z, Q) in the knowledge structured text. Furthermore, ANOVA is used for comparison of the mean values of the Fixation Count among the AOIs representing each part of the knowledge unit and corresponding parts of the traditionally structured text. The samples of knowledge structured texts and traditionally structured texts are considered independent even though those texts represent the same piece of explicit knowledge and differ only in the form of the representation. This method is related to null hypotheses that are listed in the Results chapter.
- Consequently, the non-parametric test for independent measures is employed as another method for analysing the hypotheses listed in the Results chapter: H0.1 through H04. As usual, the hypotheses are formulated, i.e., the null hypothesis supposes that no difference between the mean values of the parameters mentioned above exists at the significant level alpha, such as in the study of (Mudrychová et al., 2017).

Statistical hypotheses

The complete list of six null hypotheses tested for the statistical analysis follows. The third null hypothesis (H0.3) has already been tested in the work of Mudrychová, Housková Beránková and Horáková (2018). However, it is essential to incorporate H0.3 among the others to achieve a complex overview of the results of the eye-tracking experiment that has been carried out to understand users/readers' processes and if the difference between textual styles is essential for them or not.

- H0.1: There is no difference in the mean values of Visit Duration of all participants between the knowledge structured text and the traditionally designed text.

- H0.2: There is no difference in the mean values of Total Visit Duration of all participants between the knowledge structured text and the traditionally designed text.
- H0.3: There is no difference in the mean values of Total Fixation Duration of all participants between the knowledge structured text and the traditionally designed text; it was already presented in the study of Mudrychová et al. (2018).
- H0.4: There is no difference in the mean values of the Fixation Count of all participants between the knowledge structured text and traditionally designed text.
- H0.5: There is no difference in the mean values of the Fixation Count among the AOIs representing each part of knowledge units (X, Y, Z, Q).
- H0.6: There is no difference in the Fixation Count's mean values among the AOIs representing each part of the knowledge unit and corresponding parts of the traditionally designed text.

Statistical analysis

As the first step of the statistical analysis, some elementary characteristics were calculated. As the second step of the analysis, the Shapiro-Wilk W test (Schmidt et al., 2017) was used to examine whether selected data was normally distributed. The third step consisted of using the relevant parametric or non-parametric test for testing the average values (arithmetic mean) of indicators measured for the comparison of two types of texts (knowledge and traditional design). Non-parametric tests for two independent measures were used for the data of variables: Total Fixation Duration, Fixation Count, Visit Duration, and Total Visit Duration. Parametric test, i.e., One-Way Analysis of Variance (ANOVA), was used to determine fferences among the average values of the Fixation Count among the AOIs representing parts of KUs. Moreover, ANOVA was used to determine the average values of the Fixation Count within the AOIs representing each part of the KU and the equivalent part of the traditionally structured text. Post-hoc analysis and Scheffé's test was used. This was chosen as it is typically used for unequal sample sizes, and Scheffé's method controls the overall confidence level.

Results and discussion

The didactic test checked knowledge transfer. The results of the experiment were summarised. The students reached the success rate of more than 62.3% of correct answers in the didactic test. We see the didactic test as successful as it passed the limit of 60 % of correct answers (Pumilia-Gnarini et al., 2012). The correct answers in the didactic test also gave researchers different results for correct answers for knowledge structured text and traditionally designed text separately. Students reached 50.7% of correct answers for questions from knowledge structured texts and 49.3% of correct answers for questions om the traditionally designed text; part of the results was published in the work of (Mudrychová, Houšková Beránková and Horáková, 2018).

We have considered the correlation between the reading performance of knowledge units (knowledge structured text) and areas of interest in the case of traditionally structured text. Also, that correlation we related to every metric we wanted to investigate – Visit Duration, Total Visit Duration, Fixation Count and Total Fixation Count. We focused on reading performance and its differences across different structured texts, as described in Table 1.

The difference in the reading performance of different structured texts

Group of variables: Visit Duration, Total Visit Duration, Total Fixation Duration, Fixation Count

Data were left-skewed for all results of the metrics such as Total Visit Duration, Fixation Count and Total Fixation Count. The results of the Shapiro-Wilk W test were as follows: $W = 0.91795$ (knowledge structured text), $p = 0.00$ (knowledge structured text), and $W = 0.93602$ (traditionally designed text), $p = 0.00$ (traditionally designed text); p-values for both cases were lower than the significance level $\alpha = 0.05$; the null hypotheses regarding the normality of the distribution of the data was rejected. Wald-Wolfowitz test was chosen for non-parametric testing (Table 1).

In the Wald-Wolfowitz test, was grouping variable "Type of text (knowledge structured text or traditionally designed text)" was used.

P-values for all tested cases (see Table 1) were higher than the significance level $\alpha = 0.05$. The null hypotheses H0.1, H0.2, H0.3, and H0.4 the test was not rejected.

The *p*-value of *Z* adjusted for measured mean values of all participants of the Visit Duration indicator was $p = 0.393$. Therefore H0.1 was not rejected.

Variable	Valid N Know. Text	Valid N Tra. Text	Mean Know. Text	Mean Tra. Text	*Z*[a]	*p*-value*	*Z* adj.[b]	p-value of Z adj.*	No. of runs[c]	No. of ties[d]
Visit Duration	363	363	2.859	2.948	-0.891	0.373	0.854	0.393	352	160
Total Visit Duration	363	363	8.574	8.905	-0.966	0.334	0.928	0.353	351	59
Total Fixation Duration	363	363	6.330	5.941	0	1.000	-0.037	0.970	364	89
Fixation Count	363	363	33.675	33.725	-0.074	0.941	0.037	0.970	363	304

Note: Know. Text = Knowledge Text, Tra. Text = Traditional Text, No. = number, adj. = adjusted
[a] *Z* represents scores of measures of standard deviation. The Z-value measures the difference between an observed statistic and its shypothesised population parameter in units of the standard deviation.
[b] *Z* adjusted represents scores that estimate the number of false positives for a given confidence level and adjust the critical p-value accordingly.
[c] No. of runs represents two independent samples that are ranked in increasing order. Each value is coded as 1 or 2 and the total number is summed up in the total number of runs. The number of runs is the number of group changes plus one.
[d] No. of ties represents ties involving observations from the two groups. Both the minimum and maximum numbers of runs possible are calculated.
* $p < .05$

Source: authors' processing, software used: STATISTICA 12 (StatSoft)

Table 1: Non-parametric test of knowledge structured text and traditionally designed text: Visit Duration, Total Visit Duration, Total Fixation Duration, Fixation Count—Wald-Wolfowitz test.

There is no difference between the knowledge structured text and the traditionally designed text for the mean values of Visit Duration. Those mean values describe time (in seconds) as the duration of each visit within an AOI spent by those participants.

The *p*-value of *Z* adjusted for tested mean values of all participants of the Total Visit Duration indicator was $p = 0.353$. Therefore H0.2 was not rejected. There is no difference between the knowledge structured text and the traditionally designed text for the mean values of Total Visit Duration exists. Those mean values describe time (in seconds) as the total duration of all visits within an AOI spent by those participants.

The *p*-value of *Z* adjusted for tested mean values of all participants of the Total Fixation Duration indicator was $p = 0.970$. Therefore H0.3 was not rejected. There is no difference between the knowledge structured text and the traditionally designed text for the mean values of Total Fixation Duration. Those mean values describe time (in seconds) as the total fixation duration of all visits within an AOI spent by those participants. The results for this selected variable have been presented in the work of Mudrychová, Houšková Beránková, and Horáková (2018).

The *p*-value of *Z* adjusted for measured mean values of all participants of the Fixation Count indicator was $p = 0.970$. Therefore H0.4 was not rejected. There is no difference between the knowledge structured text and the traditionally designed text for the mean values of the Fixation Count. Those mean values describe time (in seconds) as the fixation count of all visits within an AOI spent by those participants.

Group of variables: Fixation Count among the AOIs representing parts of KUs

Results of the Shapiro-Wilk W test were as follows: $W = 0.93889$ (X), $p = 0.06306$ (X), $W = 0.94236$ (Y), $p = 0.07956$ (Y); $W = 0.96620$ (Z), $p = 0.383$ (Z); $W = 0.97260$ (Q), $p = 0.5521$ (Q) (Table 2). In all cases, the p-values were higher than the significance level $\alpha = 0.05$; the null hypothesis regarding the normality of the distribution of the data was not rejected. Consequently, one-way ANOVA was used. The post-hoc analysis was carried out using Scheffé's test (Table 3). Levene's test did not reject the null hypothesis.

Variable	df1[a]	df2[b]	*F*[c]	*p*-value (sig.)*
Results	1.047	5.712	1.832	0.145

Note: Levene's test tests the null hypothesis that the population variances are equal or not. That is called homogeneity of variance or homoskedasticity.
[a] df1 represents the ANOVA test which involves comparing known means in sets of data. That represents the number of cells that are free to vary to get to a given grand mean.
[b] df2 represents the total number of observations in all cells. That means degrees of freedoms lost as the cell means are set.
[c] F represents an F-test of equality of variances. This test tests the null hypothesis that two normal populations have the same variance. F-value is used to calculate the p-value, which is used to decide the statistical significance of the terms and models.
* $p < .05$

Source: authors' processing, software used: STATISTICA 12 (StatSoft)

Table 2: Levene's test of homogeneity of each part of the knowledge unit X, Y, Z, Q.

Effect	SUM of square	df[b]	Mean square	F[d]	p-value (sig.)*
Absolute value	1132016	1	1132016	654.129	0.000
Type of KU	24757	3	8252	4.769	0.004
Error	221513	128	17301		

Note: One-way ANOVA is used to determine whether any of the differences between the means are statistically significant. Compare the p-value to set up a significance level to assess the null hypothesis.
[a] Sum of the square is the sum of the squares of the deviations of all the observations from their mean.
[b] df represents the ANOVA test which involves comparing known means in sets of data. That represents the number of cells means that are free to vary to get to a given grand mean.
[c] Mean square represents an estimate of the population variance. This statistic is calculated by dividing the corresponding sum of squares by the degrees of freedom.
[d] *F* represents an F-test of equality of variances. This test tests the null hypothesis that two normal populations have the same variance. F-value is used to calculate the p-value, which is used to decide about the statistical significance of the terms and models.
*$p < .05$

Source: authors' processing, software used: STATISTICA 12 (StatSoft)

Table 3: One-way ANOVA of each part of the knowledge unit X, Y, Z, Q.

The *p*-value provided the results for rejecting H0.5. It means that at least one difference exists in the mean values of the Fixation Count among the AOIs representing each part of the KU. The post-hoc analysis was carried out using Scheffé's test. The results of Scheffé's test of each part of the KU indicated that there was a significant difference between parts X and Y and X and Q, as highlighted in Table 4. The p-values were significant for variables X and Y and variables X and Q. The difference between those two combinations of individual parts of the knowledge unit was significant.

The difference lies in that the results from the Fixation Count of participants and its mean values were higher for the part Y if we compare results of parts X and Y. If we think about the difference between parts X and Q, the results for the Fixation Count of participants and its mean values were higher for the part Q.

Type of KU	X	Y	Z	Q
X		0.031	0.546	0.013
Y	0.031		0.489	0.991
Z	0.546	0.489		0.317
Q	0.013	0.991	0.317	

Source: authors' processing, software used: STATISTICA 12 (StatSoft)

Table 4: Schaffe's test of all individual parts of knowledge unit X, Y, Z, Q.

Schaffe's test is a part of post-hoc analysis of ANOVA. The Scheffé's test typically corrects alpha level for complex and straightforward comparisons of mean values. A complex comprising of mean values involves comparing more than one pair of means simultaneously.

The results of Levene's test showed no data indicating that the variance in each group was significantly different (i.e., the dispersion homogeneity condition was met). In summary, the difference between part X of the knowledge unit and AOI 1 of the traditionally structured text has not been proven. The same result was obtained for part Y of the knowledge unit and AOI 2, part Z of the knowledge unit and AOI 3, and part Q of the knowledge unit and AOI 4.

Group of variables: Fixation Count within the AOIs representing each part of the KU and the equivalent part of the traditionally designed text

The results of the Shapiro-Wilk W test were as follows (Table 5): $W = 0.92191$ (AOI 1), $p = 0.20071$ (AOI 1), $W = 0.94540$ (AOI 2), $p = 0.09765$ (AOI 2); $W = 0.97410$ (AOI 3), $p = 0.60099$ (AOI 3); $W = 0.97051$ (AOI 4), $p = 0.49429$ (AOI 4). In all cases, the *p*-values were higher than the significance level $\alpha = 0.05$; the null hypotheses regarding the normality of the distribution of the data selected were not rejected. Consequently, one-way ANOVA was used (Table 6). The result of significance or insignificance of each part of AOIs of traditionally designed texts and each part of the KU of knowledge structured texts were obtained using Schaffe's test. Levene's test proved the homogeneity.

There are no significant differences between those two types of parts of knowledge units and areas of interest of traditionally designed text, so H0.6 was not rejected. In this case, it means that there is no difference between part X of the knowledge unit and the corresponding AOI 1 of traditionally

Variable	df1[a]	df2[b]	*F*[c]	p-value (sig.)*
X vs AOI 1	409.023	617.784	0.662	0.419
Y vs AOI 2	1027.109	542.958	1.892	0.174
Z vs AOI 3	17.955	574.771	0.031	0.860
Q vs AOI 4	289.560119	799.3728	0.362234	0.549394

Note: Levene's test tests the null hypothesis that the population variances are equal or not. That is called homogeneity of variance or homoskedasticity.
[a] df1 represents the ANOVA test which involves comparing known means in sets of data. That represents the number of cells means that are free to vary to get to a given grand mean
[b] df2 represents the total number of observations in all cells. That means degrees of freedoms lost as the cell means are set.
[c] *F* represents an F-test of equality of variances. This test tests the null hypothesis that two normal populations have the same variance. F-value is used to calculate the p-value, which is used to decide the statistical significance of the terms and models.
* $p < .05$
Source: authors' processing, software used: STATISTICA 12 (StatSoft)

Table 5: Levene's test of Fixation Count for X and AOI 1, Y and AOI 2, Z and AOI 3, Q and AOI 4.

Effect: X vs AOI 1	SUM of square	df[b]	Mean squares	*F*[d]	*p*-value (sig.)*
Absolute value	401388	1	401388	2.682	0.000
Type of KU vs AOI	1.953	1	1.953	131	0.258
Error	95798	64	1.497		
Effect: Y vs AOI 2	SUM of squares	df	Mean square	F	p-value (sig.)*
Absolute value	581298	1	581298	305.812	0.000
Type of KU vs AOI	6167	1	6167	3.245	0.076
Error	121653	64	1901		
Effect: Z vs AOI 3	SUM of squares	df	Mean square	F	p-value (sig.)*
Absolute value	508292	1	508292	312	0.000
Type of KU vs AOI	3.879	1	3.878788	0.002	0.961
Error	104232	64	1629		
Effect: Q vs AOI 4	SUM of squares	df	Mean square	F	p-value (sig.)*
Absolute value	814741	1	814741	371	0.000
Type of KU vs AOI	1196	1	1196	0.545	0.463
Error	140472	64	2195		

Note:
[a] Sum of the square is the sum of the squares of the deviations of all the observations from their mean.
[b] df represents total degrees of freedom. It is the amount of information in data. The analysis uses that information to estimate the values of unknown population parameters.
[c] Mean square represents an estimate of the population variance. This statistic is calculated by dividing the corresponding sum of squares by the degrees of freedom.
[d] *F* means F-test and is used to test if a relationship exists between the dependent and independent variables. This test is based on the F distribution is used. The statistic is a ratio of the model mean square and the residual mean square.
* $p < .05$
Source: authors' processing, software used: STATISTICA 12 (StatSoft)

Table 6. One-factor ANOVA for Fixation Count - the difference between each part of the knowledge unit X, Y, Z, Q and the corresponding part of AOI 1, AOI 2, AOI 3, AOI 4 of traditionally structured texts.

designed text, part Y of the knowledge unit Y and the corresponding AOI 2, part Z of the knowledge unit and the corresponding AOI 3, part Q of the knowledge unit and the corresponding AOI 4.

We report in our study, as mentioned above, that no difference between knowledge structured text and traditionally designed text in all eye-tracking indicators, such as Visit Duration, Total Visit Duration, Fixation Count, and Total

Fixation Duration. By using the non-parametric test for independent measures, the existence of this difference was tested. The non-parametric test provided results where the p-values were significantly higher than $\alpha = 0.05$. That is why the null hypothesis was not rejected at the significance level for hypotheses H0.1 through H0.4. Moreover, we did not extend the hypothesis H0.6 related to differences between each part of the knowledge unit (X, Y, Z, Q) and the corresponding part of the traditionally designed text (AOI 1, AOI 2, AOI 3, AOI 4). On the other hand, a difference among the parts of the knowledge unit related to hypothesis H0.5 was proven to exist, specifically between parts X and Y and X and Q.

The answer to our research question is that users can work with knowledge and traditionally designed texts equivalently. Knowledge structured text and its form does not cause harm to their reading process. The results from the didactic test were slightly better from answered questions that followed knowledge structured texts, but not significantly higher. We can conclude that the conversion of texts will not add any new value to users from knowledge structured to traditionally designed texts. The most positive fact is that if users have to use any organisation manual, regulation or guideline, they can proceed with knowledge structured text and understand it similarly in a better way than traditionally structured text. That means for organisations that if they use such textual materials for their organizational processes, their employees can understand better what they should do, and there should be the elimination of wrong proceeding with the process (also in AWD). For example, users using manuals on how they have to proceed with hazardous waste treatment will understand those processes better, and there is a potential decrease of cases with human factor impact on hazardous waste treatment (poor handling and transport, improper storage and others) (Saedi-Mobarakeh et al., 2019). It has an impact on employees' ability to understand it. Also, it can have an impact on their competencies and the effectiveness of their work. We are convinced that our results in H0.5 support this idea. From the results, we found out that participants focused more on the part of knowledge units Y and Q than X. It means they focused more on elementary problems and solutions to the elementary problem than on problem situations. Those parts of the knowledge unit are the most important from the learning process perspective, and those results are desirable.

This study can follow in future research studies such as Shotter (2013), who provided reading times on preview/target words. Those words were embedded in a few sentences and were moderately constrained. The idea shared by the target/synonym word can be highly predicted. On the other hand, authors such as Metusalem et al. (2012) and Roland et al. (2012) focused on the whole context in text and that it might constrain a particular idea that leads to a faster reading process of the target. Other authors followed that idea and developed it, even more, DeLong et al. (2014) and Smith and Levy (2013) discovered the occurrence that suggested the sentence constraint can lead readers to generate expectations about upcoming words in the text. It is often a phenomenon that readers make a specific, unitary prediction of the upcoming word. It aligns with already mentioned studies of DeLong et al. (2014) and Smith and Levy (2013) about this interpretation with the idea of pre-activation/anticipation. That pre-activation/anticipation happens in a qualitatively graded mode.

The difference between this study and the study of Stein (2001) is that eye-tracking technologies were not used to investigate students' physical pre-requisites. Stein (2001) worked with neurodevelopmental disorders of students and screen reading skills only. As mentioned from the perspective, we focused on their reading process to make the knowledge transfer process more comfortable or faster for them. Differences among students in how they read, process and evaluate text can be seen, and the difference among students and their possible disorders can be checked (Stein, 2001). Dyslexia is quite common among students and can be easily identified via eye-tracking technology. Few authors work with the assumption of dyslexia and the fact of different processing of words by students with or without dyslexia (Moody, 2010; Wigfield et al., 2014; Stein, 2001; Sim, Cassidy and Read, 2013).

AWD deals with many regulations, rules, and also technical issues. The gap consists of the unbalanced level of users' knowledge and not well-structured texts. Based on the above mentioned, we are partially compliant with the study of Mateer et al. (2020) as they focused on predicting the proper waste disposal in correlation with users observations. It is similar to our study in that case, in that we observed our users and how they process textual materials to see their performance.

Conclusion

In the study, we used different textual materials focused on agricultural waste disposal (AWD) to investigate the differences in the reading process of knowledge and traditionally structured text. We were able to identify that there are differences between those types of textual materials, but they are not for students. We could indicate specific cases where some differences were present (such as answering didactic tests after knowledge-constructed texts). That could be very useful for a follow-up experiment needed to vary the differences between those different types of textual materials in the larger text (here we used 3 – 5 lines texts as mentioned in methodology). Also, there is a possibility of preparing more extensive textual materials and a more substantial didactic test. Moreover, there can be a comparison between languages and between native speakers with non-native speakers.

Not structured and semi-structured educational texts (whether a knowledge structured text or a traditionally designed text) will result in learning and reading difficulties for students. It can be an issue, especially in such studies as agricultural waste disposal (AWD) and processing of waste in agriculture in general. Waste management as a parent field is connected to how effectively process wastes and agriculture, crop production, animal production, agriculture machinery, and many others.

The primary limits of this study relate to the research sample. We purposefully chose the homogeneous group of the students to carry out the quantitative analysis. The inherent disadvantage of this approach is that the results are not to be generalised and exploited for other specific target groups. On the other hand, this is an opportunity for future research. We will define other relevant groups of potential beneficiaries of the research and their unique characteristics and extend the eye-tracking study. We will develop the assignment target group vs the most efficient educational texts for the group in the final state. This could provide waste disposal studies with a better overview for students.

Furthermore, after the study's success with students, it is possible to extend research groups as mentioned above and apply them in daily practice. As was mentioned in our study, our results are used for waste disposal studies and various other organisations that have processes recorded in the form of manuals, organisation regulations, guidelines, and other forms.ss. Those materials are usually in textual format, and if it is wrongly written (users do not understand textual material properly), they can incorrectly proceed with the process (even, e.g. the process of waste processing and any other waste disposal process).

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How the Income Elasticity of Meat Consumption differs between social groups? A case of the UK and the Czech Republic

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Abstract

The purpose of the article is to show different consumer behaviour between ten different income levels (deciles) and different countries and to examine the elasticity distance between income deciles in the UK (a high-income country) and the Czech Republic (a low-income country) within the context of meat consumption. The official statistic services provided data in the Czech Republic (Czech Statistical Office, 2020) and the UK (Office for National Statistics, 2020). Data on the Czech Republic come from the household budget surveys (HBS). In contrast, corresponding data on UK consumers was drawn from the Living Costs and Food survey, which succeeded the National food survey and household expenditure survey. Both sets of data were set according to households' structure from the EU-SILC Survey (national module of the European Union – Statistics on Income and Living Conditions). To estimate the income elasticity of meat in the Czech Republic and the United Kingdom in different consumer income groups, a time series cointegration analysis was applied to analyse the annual data for 2000-2017. The Törnquist equation and the difference between income elasticity in monetary and natural expression show saturation and preference of high quality meat in the higher-income consumers in the UK than the same groups in the Czech Republic and overall increasing demand for quality in other income groups. The results support the theory of nutrition transitions. The value of the research is that it would enable the exploration of the potential impact and nature of fiscal interventions for improving diets whilst enabling food producers to forecast meat consumption within the different customer segments.

Keywords

Price elasticity, income elasticity, meat consumption, saturation limit.

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Introduction

Livestock production is an important agricultural activity in the EU with some 45.2 million tons of meat produced across the 28 member states, which for the UK alone, represent 55.7% of all agricultural income (Cook, 2018). Meat remains an essential source of agri-business and food business income and essential use of land.

An examination of consumption trends shows significant variation between Lesser Economically Developed Countries (LEDCs) and More Economically Developed Countries (MEDCs). Such trends can be attributed variously; not least to income variations stimulated by economic, political and social change. For instance, after 1990, following the fall of the Soviet Union, Central-and Eastern European countries per capita consumption of meat increased. Further increases per capita were evident in many of these countries following their entry into the EU in 2004; Czech Republic households showed stronger demand for higher-quality meat. Also, increased purchasing power made many Czech households more concerned as to product quality and content than under previous regimes (Euromonitor International, 2018).

Yet from the supply side, with the fall of the Eastern Block, Czech Republic meat producers and processors were faced with increased competition from new market entrants from western Europe. These events led to greater market concentration within the meat processing

sectors (Blazkova, 2016; Spicka, 2016), and a further reduction in their self-sufficiency in pork and poultry.

The situation in meat production and processing varies across Central European countries. The Czech Republic is surrounded by highly concentrated meat processing capacities in Germany and Poland. Poland is one of the top five producers of pork and poultry meat in the European Union. German meat processing capacities are in top-five ranking in beef, pork and poultry meat. Meat processing capacities in Austria are not so concentrated, but they are remarkable for high technology and labour productivity (Marquer, Rabade and Forti, 2015). Consequently, the policymakers, meat producers and producers need to find a way to promote indigenous production and convince customers to buy higher-quality meat products of Czech origin.

Income elasticity is an important determinant of consumer behaviour and is worth greater investigation. The benefits of improving self-sufficiency in the Czech Republic are both economic and social. The solutions can be seen to be in the hands of the policymakers, meat producers and producers.

The UK is similarly faced with a lack of self-sufficiency in meat production areas and is >72% self-sufficiency in poultry and >60% in pork. In conditions, of uncertainty in the political upheaval following Brexit may be faced with preferential trade agreements with the US, which could further threaten the self-sufficiency of the UK meat sector.

Demand-side and the factors affecting meat choice in the UK can be distinctive from the Czech Republic. The decline in meat consumption in the home and changes to consumption patterns have been linked to various factors such as consumer concerns over the impact of animal production on greenhouse emissions, animal welfare and concerns over the meat consumption on human health (Melina, Craig and Levin, 2016; Santeramo et al., 2018). Essential suggestions have been made within nutritional guidelines that encourage consumers to eat less meat, mainly processed meat products.

The meat production and patterns differ between the Czech Republic and the UK. British consumers prefer more beef and veal (11.4 kg per capita, 2019) and sheep meat (3.9 kg per capita, 2019) than the Czech consumers (9.1 kg beef and veal per capita, 2019; 0.4 kg sheep meat per capita, 2019). On the contrary, Czech consumers prefer pork meat (43 kg per capita, 2019) much more than British consumers (16 kg per capita, 2019). The consumption of poultry meat does not significantly differ between the Czech Republic and the UK (OECD, 2020; Czech Statistical Office 2020; meat consumption is measured in thousand tonnes of carcass weight). The differences are rooted in the history. Beef and sheep farming has a long tradition in the UK while large intensive pig farms has been typical type of farming in the Czechoslovakia since 50s/60s of the 20th century.

In the UK, beef is more consumed in the UK than a decade ago due to population growth. Nevertheless, per capita consumption remains relatively flat with any reduction yet to show in annual per capita figures. Sheep-meat (mostly lamb) consumption has seen a gradual decline in the UK for some time due to limited cooking versatility and a perceived higher price point. "*Although consumption has trended down 10% in the last decade, it is still much higher in the UK on a per capita basis than in many other developed nations, a legacy of the historic importance of the wool trade within Britain's economy. Today consumers benefit from a high-quality product being readily available locally*" (Norton, 2020). Increasing productivity of pork and poultry farms reduced the production costs and price of pork and poultry meat and make them more affordable for Britons and partially substituted some of the beef and lamb within consumers' baskets (Norton, 2020).

In the Czech Republic, pork meat consumption is relatively stable in the recent years. The beef meat consumption has been slightly increasing in the recent years but it is much lower than before 1990. The total production of beef in the Czech Republic has long exceeded domestic consumption (Ministry of Agriculture, 2020). The popularity of the poultry meat has increased in the Czech Republic for a long time but the Czech Republic is not self-sufficient in the poultry meat production. The main reasons why the consumption of beef meat dropped and the popularity of poultry meat increased in the Czech Republic in the last thirty years are dietary concerns (consumers prefer poultry meat to red meat) and price relations (poultry meat became cheaper due to large-scale production and the price pressure of foreign production).

Research suggests that dietary change can be facilitated through prices and taxation schemes and health food subsides (Niebylski et al., 2015). Taxation of unhealthy food increases food prices

and changes consumer preferences towards healthier food. Unhealthy food taxes and healthy food subsidies should be a minimum of 10 to 15% and preferably used in tandem (Smed, Jensen and Denver, 2007). In their systematic literature review, Thow et al. (2010) confirmed that taxes and subsidies influenced consumption in the desired direction, with larger taxes being associated with more significant changes in consumption, body weight and disease incidence. This conclusion is relevant for multiple-nutrient studies which allowed for substitution between different kinds of food. However, other studies suggested that a single target food would as extant research had failed to appreciate that consumers would simply switch to alternative foods.

Indeed, previous research suggests that different socio-economic and demographic groups respond differently to any price adjustment as a consequence of taxation (Spicka and Naglova, 2017) and to assess how policymakers can influence choice there is a need for greater understanding of the dynamics of price changes within the spectrum of income brackets. Thus, this paper examines the extent to which an understanding of price sensitivity can be used to influence dietary and food choices because the price is an important factor in food choice, especially for low-income consumers which are significantly more conscious of value and price than higher-income consumers (Steenhuis, Waterlander and de Mul, 2011). The quantification of price sensitivity and consumption saturation for different income levels between consumers and countries brings new information about consumer behaviour. This study focuses on meat as an essential part of the human diet in dietary concerns.

The article aims to calculate income elasticity and consumption saturation of major groups of meat and meat products in the Czech Republic and the United Kingdom in different income groups of consumers. The purpose of the article is to show different consumer behaviour between ten different income levels (deciles) and different countries. The literature review revealed interesting topics which are worth to be investigated. Thus, the article measures the elasticity distance between income deciles in the UK and the Czech Republic, countries with different level of income and consumer preferences.

The comparison with the United Kingdom should reveal differences between countries with different purchasing power and consumption patterns. The United Kingdom is considered as a high-income country (GDP per capita in PPS = 104 % of the EU 27 in 2019, Eurostat) compared to the Czech Republic (GDP per capita in PPS = 92 % of the EU 27 in 2019, Eurostat).

The results can help policymakers set some fiscal interventions to improve diets and food producers to forecast meat consumption in different customer segments. Alternatively, policymakers might consider regressive food taxes to make healthy foods for a low-income population more affordable. Producers and retailers can use income elasticity information in targeting promotional discounts (Kučerová and Zeman, 2013).

Theoretical background

The conceptual basis for the estimation of income and price elasticity is the neoclassical theory of consumer behaviour. Income elasticity of demand measures sensitivity of the quantity demand for a good or service to a 1% change in income, while other factors are constant (Benda Prokeinova and Hanova, 2016). It is similar to price elasticity of demand which "describes the percentage by which the demanded quantity of a food changes in response to a 1% increase in the price of the food" (Green et al., 2013). It is an important indicator of past and future consumers behaviour, and it is closely related to the income distribution of the population. The comparison between monetary and natural income elasticity also enables to reveal preferences of meat quality (Hálová, 2006). In this context, the key concern of this paper is the demand for meat and meat products.

This paper particularly compares consumption patterns and the influence of price on consumption patterns in the UK and the Czech Republic between 2000 and 2017. The question emerges as to whether the manipulation of prices through taxation can alter the nature of consumption and dietary choice.

It is possible to distinguish inferior, normal, necessity, luxury and superior goods through income elasticity. The case study from Slovakia indicated that dairy products, fruits and vegetables are perceived as luxuries. On the other hand, cereals, meat and fish and other food are normal goods with positive budget elasticity smaller than one and price inelastic demand (Cupák, Pokrivčák and Rizov, 2015; Hupková, Bielik and Turčeková, 2009).

There are differences in income elasticity between low-income customers and high-income customers (Smed et al., 2007). It is vital to stress Engel's law (Pearce, 1986), which assumes a falling proportion

of income spent on food when income rises, even if absolute expenditure on food rises (less than proportionally). Engel curves vary by gender and householder education, the number of minor children and adults (Li, Song and Ma, 2015).

Much literature empirically estimates income or price elasticity of various goods in different regions (Clements and Si, 2016; Muhammad et al., 2017; Ren et al., 2018). They use various methods of elasticity estimation. Experimental studies are the widely used way how to estimate willingness-to-pay for goods and services. Their main advantage is that "the controlled nature of experimental settings can help to disentangle the effect of the pricing intervention from confounders" (Mizdrak et al., 2015). On the other hand, they "cannot be used in isolation to determine the effects of pricing interventions" (Mizdrak et al., 2015). Another study used sectional, cohort and quasi-experimental research methods, mostly used supermarket scanner surveys (Green et al., 2013).

An important finding from the systematic literature review is that demand for all food groups was more responsive to price changes in lower-income countries than higher-income countries (Green et al., 2013). Generally, all meat products' income elasticities tend to decline as per capita income increases (De Zhou et al., 2018). The income elasticity also depends on the importance of particular food category in the consumption. For example, pork meat's income elasticity, the most important meat consumed in China, declined faster with higher per capita income than the elasticity any other meat products (poultry, beef & mutton).

It has implications for the Czech Republic, where people are quite sensitive to price changes and look for discounts. Green's literature review found the highest predicted price elasticities for meat in low-income countries he implication of the finding is twofold. First, the Czech government and food processors' efforts to promote Czech products, which are mostly more expensive than imported food, can harm low-income groups. Second, at the aggregate level, "increases in food prices are likely to have a disproportionately greater impact on food consumption in low-income countries" (Green et al., 2013).

Alternative results can be found when calculating income elasticity in the high-income country, like in Sweden (Lundberg and Lundberg, 2012), not between high- and low- income countries. In the high-income countries, additional income does not result in higher calories intake (as in low-income countries). Still, it may rather result in more aspirational spending towards diet diversification, improved quality, convenience, organic, fair trade, and animal welfare (Regmi and Meade, 2013). In the high-income country, the income elasticity is significantly higher for high-income households than in low-income households. Authors explain the effect by substitution of normal goods by exclusive goods when receiving an increase in income. This is an important difference from the low-income countries in Africa (Dubihlela, 2014). The difference in income elasticity between high- and low-income countries is also relevant for this study, which evaluates the differences between the United Kingdom (as a representant of the high-income country) and the Czech Republic (middle-income country) in Europe.

However, there are also significant differences in income elasticities across food and nutrient groups in low-income countries where people prefer basic diets, not exclusive food. Even in the low-income countries, the later research confirmed: "lower-income elasticities of basic foods compared to the less basic and more aspirational foods" (Colen et al., 2018). However, meat and fish consumption are no longer considered a luxury than in the past (Regmi and Meade, 2013).

Systematic literature review about price elasticity was conducted in the United States (Andreyeva, Long and Brownell, 2010). Authors found absolute value of mean price elasticity estimate at 0.75 for beef meat (0.67–0.83, 95% confidence interval), 0.72 for pork meat (0.66–0.78, 95 % CI) and 0.68 for poultry meat (0.44–0.92, 95% CI). The study points out the public health perspective. There is an area for investigation the cross-effects of price changes on substitutions from unhealthy to healthy food choices (e.g. from pork to poultry) or alternative substitutions.

Some empirical studies focus on the income elasticity of food in Central Europe and the UK. The income elasticity of meat and meat products' expenditures varied between 0.372 in the highest quartile to 0.725 in the lowest quartile in Slovakia. Moreover, low-income households have unmet nutritional needs due to their low purchasing power. The income elasticity of bread and bakery products did not vary so much between income quartiles (Kubicová et al., 2011). Later study calculated income elasticity of meat at 0.915 on average by a different method (Cupák et al., 2015). Another

study focused on patterns, and preference changes in the consumer demand for meat in Slovakia showed that beef (2.162) and pork (1.027) were expenditure (income) elastic and hence could be considered as a luxury, while poultry (0.043) and fish (–0.345) were income inelastic meaning that those were of necessity" (Benda Prokeinova and Hanova, 2016). In the Czech Republic, the income elasticity of meat and meat products was 0.8346 in the 1990s (Syrovátka, 2012), later study confirmed income elasticity of meat and meat products between 0.3 (pork meat) and 0.6 (beef) in the Czech Republic in 2004 (Hálová, 2006).

The study of food prices and household income in the UK confirmed lower-income elasticities for meat and fish than in Slovakia (De Agostini, 2014). The assumption is that the income elasticities of meat and meat products are higher in the Czech Republic than in the UK, indicating the relationships between food income elasticities in the EU study (Salotti et al., 2015). However, meat prices and income elasticities are more elastic than other food products such as dairy and eggs (Tiffin et al., 2011). Research in other countries such as Slovakia (Kubicová et al., 2011) a UK study suggests that price and income elasticity varies across socio-economic and demographic groups. Tiffin et al. (2011), based on findings within an earlier publication (Tiffin and Arnoult, 2010), find that price and income elasticities for meat for low-income families are lower than those of the total UK population. They conclude meat consumption in lower-income households in the UK are less affected by income changes than the national average (Tiffin et al., 2011). The literature also suggests that low incomes and children's presence may have a negative impact on dietary quality (Tiffin and Arnoult, 2010). Similar results have been determined by Green et al. (Green et al., 2013) in a systematic review of over 162 different countries' studies.

Studies about meat consumption in the UK have a strong focus on the effects of fiscal policy on a diet. The general conclusion is that "food taxes and subsidies have the potential to contribute to healthy consumption patterns at the population level" (Thow et al., 2010) but "the tax is insufficient to achieve this goal for fat intakes" (Tiffin and Arnoult, 2011). More impact evaluation is needed in developing countries.

The methodological problem related to the calculation of income elasticity is to select a suitable functional form. Different models are used for stationary elasticity estimation, changing elasticities over time and relationships between income and price elasticities. When estimating the right functional form of the income/price elasticity, locally flexible functional forms have proved popular in empirical applications - indirect translog model (Christensen, Jorgenson and Lau, 1975), generalised Leontief, Fourier flexible demand model (Gallant, 1981), all explained by (Wohlgenant, 1984), and almost ideal demand system (AIDS).

The cross-effects between food and other goods or between different food categories can be captured through almost ideal demand system AIDS, developed by (Deaton and Muellbauer, 1980) and applied recently in the linear form, e.g., by Aftab, Yaseen and Anwar (2017), quadratic form (Konig and Dovadova, 2016) and generalised form (Hovhannisyan and Gould, 2014). The AIDS system has been widely used in the price- and income elasticity estimation because its properties in relation to the consumers' preferences are well known (Ulubasoglu et al., 2015). However, "one drawback with this approach is the complexity of the demand system and the increasing number of parameters to be estimated as the number of equations and covariates increases" (Lundberg and Lundberg, 2012). An alternative approach is to estimate one single demand function where all other consumption determinants are regarded as the numerate goods, recently described by (Lundberg and Lundberg, 2012). The approach enables to include many potentially important determinants of food demand and expenditure.

Time series analysis, especially cointegration and error correction (ECM) analysis, was applied by Türkekul and Unakitan (2011). This approach is useful when data about prices, income and consumption in various income groups are available in a sufficiently long time series. Using time-series here makes sense statistically to control the correlation in elasticity between different time points (Engle and Granger, 1987). We will follow this approach in the article.

Material and methods

The official statistic services provided data in the Czech Republic (Czech Statistical Office, 2020) and the UK (Office for National Statistics, 2020) because they are not publicly available. The Czech Republic uses representative household budget surveys (HBS) in approximately 3000

households (Czech Statistical Office, 2020). Selection of households for HBS had been made using a quota sampling technique till 2016. The quota frames used to be set following households' structure from EU-SILC Survey (national module of European Union – Statistics on Income and Living Conditions). The sampling and reporting unit of HBS was the private household whose members entered all expenses into diaries during the whole year. Diaries used to be structured according to international COICOP (Classification of Individual Consumption by Purpose) classification. Meat and meat products in the COICOP are classified in the following way; some items were joined because of data availability.

The Czech database was manually harmonised with Living costs and food survey (LCF). Like the HBS, data is collected for a sample of more than 5000 households across the United Kingdom using self-reported diaries (Office for National Statistics, 2020). The investigated product group – meat and meat products – includes the following groups of products.

- 01.1.2.2: Meat, fresh, chilled or frozen
  - **Beef** = Beef joints (on the bone); Beef joints (boned); Beefsteak (less expensive), Beefsteak (more expensive); Minced beef; All other beef and veal
  - **Pork** = Pork joints; Pork chops; Pork fillets and steaks; All other pork
  - Poultry = Chicken, uncooked (whole chicken or chicken pieces); Other poultry, uncooked (including frozen); Cooked poultry not purchased in cans
- 01.1.2.3: Meat, dried, salted, in brine or smoked
  - **Bacon and ham** = cooked, uncooked
- 01.1.2.4: Offal, blood and other parts of slaughtered animals, fresh, chilled or frozen, dried, salted, in brine or smoked
  - **Other meat and offal** = Liver of all animals; Other fresh, chilled and frozen meat; Mutton and lamb
- 01.1.2.5: Meat, offal, blood and other parts of slaughtered animals' preparations
  - **Canned meat, other meat-based products** = Sausages (uncooked); Meat pies and sausage rolls; ready to eat; Meat pies, pastries and puddings, frozen or not frozen; Burgers, frozen or not frozen; Ready meals and convenience meat products; Pate and delicatessen type sausage; Meat pastes and spreads; Takeaway meats; Corned beef, canned or sliced; Other cooked meat; Other canned meat and canned meat products

Fish and seafood are not included because of their marginality in the Czech Republic. Meat and meat products do not include public catering and eating in restaurants. If we include the food outside the home in foodservice operations etc., then consumption of meat has risen in the UK. This is because more and more consumption takes place outside the home. That´s the main limitation of the study.

Data about net monetary income, net monetary expenditures and natural consumption of meat and meat products per capita are divided by income deciles. For example, the first 10% decile covers 10 % of the households with the lowest income. We also calculated the unit price as the annual net monetary expenditure divided per capita by annual natural consumption. Deciles make the analysis more detailed than quintiles which have been usually published. Because monetary data from the Czech Republic and the UK are not comparable, they were converted to Euro through the Eurostat's official annual average exchange rate.

The time series starts in 2000 because of the strategic document Agenda 2000 that established pre-accession negotiations on EU enlargement (the Czech Republic joined the EU in 2004). Another reason is methodological. The Czech Statistical Office has used the COICOP classification since 1999/2000. The older data are not comparable. Due to major changes in methodology in the Czech Republic, the HBS time series was discontinued in 2016, but authors received an estimation by Czech Statistical Office for 2017. So, the time series covers 18 years (2000–2017).

To estimate the income elasticity of meat in the Czech Republic and the United Kingdom in different income groups of consumers, a cointegration analysis of time series was performed (Engle and Granger, 1987). We identified the cointegration analysis and separated the long-term relationships between the analyzed indicators from the short-term relationships using an error correction model (ECM).

Since our goal is to estimate elasticity and all analysed time series are non-stationary,

a cointegration regression model in logarithmic expression in the form of

$$\ln CON_t = \beta_0 + \beta_1 \ln INC_t + \varepsilon_t \quad \text{or}$$

$$\ln NME_t = \beta_0 + \beta_1 \ln INC_t + \varepsilon_t, \qquad (1)$$

where *CON* is natural meat consumption (kg per capita per year), NME is average net money expenditure (monetary consumption per capita per year) and *INC* is annual average net money income per capita, β_0 a β_1 (β_1 expresses elasticity) are model parameters that we estimate through OLS and ε_t is a non-systematic component of the model with white noise properties.

Regression models of non-stationary time series are often burdened by so-called spurious regression. To eliminate this problem, we performed an Engle-Granger test of cointegration (Engle and Granger, 1987) using the ADF unit-root test (Dickey and Fuller, 1979). The last step of our analysis was to perform diagnostic tests on the estimated models, i.e. the Breusch-Godfrey test of autocorrelation (Breusch and Godfrey, 1986), the ARCH test of heteroscedasticity (Darnell, 1994) and the Jarque -Bera normality test (Jarque and Bera, 1980).

To estimate the saturation level, a1 of the second Törnquist function was calculated (Hálová, 2015). A basic economic assumption is that if a disposable income increases, the consumption of considered estate will increase and vice versa. However, this statement is true only up to a specific income limit. To obtain such an income limit, when the consumption grows no longer further, we speak about a level of saturation with the given estate. The consumer is unwilling to spend his/her income to purchase such an estate and orientates to other goods. The second Törnquist function can be expressed in the following way.

$$y_i = a_1 \frac{x_p - a_3}{a_2 + x_p} \qquad (2)$$

Parameters a_1 and a_2 were estimated by iterative gradient optimisation method (MS Excel solver).

To reveal the demand for quality, the authors calculated the difference between monetary and natural income elasticities (monetary minus natural elasticities). The greater the difference between income elasticity in monetary and natural expression, the more the consumer chooses better quality goods and vice versa. The consumer is willing to provide much higher expenditure on higher-quality goods with approximately the same demand in kind.

Results and discussion

Table 1 shows the estimates of the dependence of natural consumption on income (first part) and the dependence of net monetary expenditures on income (second part) for the UK. Table 2 then contains the same estimates for the Czech Republic. The second and third columns of the tables contain parameter estimates and their significance level (the elasticity parameter is highlighted). R^2_{adj} demonstrates the quality of the model. This is followed by a cointegration test (ADF test) and individual diagnostic tests on the estimated models. The last column, denoted by D, represents the year for which it was necessary to introduce the dummy variable in the case of a structural breakpoint in the analysed time series.

At the 5% significance level, the results show that the ADF test rejected the spurious regression in all models. Furthermore, the dependence of each pair of matching deciles of individual indicators was demonstrated in all models (statistically insignificant intercepts were left in the models for their comparability). Diagnostic tests show that the non-systematic component of the models is not autocorrelated, homoskedastic and has a normal distribution, i.e. it has white noise characteristics in all models.

Income is an important driving force that motivates people to change their consumption patterns. In the Czech Republic, the income elasticity in terms of natural consumption and net monetary expenditures is higher in first-decile households than in top-decile households. There are two possible reasons. Meat is a relatively expensive commodity, and wealthier consumers start to value health and environmental concerns (Vranken et al., 2014). Inter-deciles differences have no apparent trend in the UK. It confirms the empirical results that there is no clear relation between meat consumption and income. Still, there is a set of high-income countries where meat consumption is relatively low (Mathijs, 2015). Instead of the linear relationship between income and meat consumption, the authors suggested a non-linear, U-shaped relationship between meat consumption and income. “Initially, meat consumption increases with income, but from a certain point onwards higher levels of income lead to lower levels of meat consumption” (Mathijs, 2015; Vranken et al., 2014).

The income elasticity coefficient can be interpreted as a 1 per cent increase in the income is associated with a certain percentage decrease in quantity

dec.	$\hat{\beta}_0$		$\hat{\beta}_1$		R^2_{adj}	ADF		Breusch-Godfrey		ARCH		Jarque-Bera		D
	t	p-value	t	p-value		t	p-value	F	p-value	F	p-value	JB	p-value	
consumption of meat														
10	5.721	0.000	-0.209	0.018	0.275	-3.112	0.004	0.915	0.425	1.580	0.229	0.262	0.877	
20	8.429	0.000	-0.476	0.000	0.638	-3.017	0.005	0.616	0.555	0.852	0.372	0.693	0.707	
30	6.414	0.000	-0.255	0.008	0.342	-2.721	0.010	0.638	0.544	0.030	0.864	0.591	0.744	
40	6.584	0.000	-0.269	0.019	0.512	-2.430	0.019	1.691	0.222	0.058	0.814	4.307	0.116	2009
50	7.350	0.000	-0.340	0.001	0.473	-4.004	0.001	1.810	0.203	0.007	0.934	0.009	0.995	
60	6.466	0.000	-0.246	0.000	0.564	-4.724	0.000	0.262	0.774	0.007	0.934	1.023	0.600	
70	7.896	0.000	-0.381	0.001	0.509	-3.908	0.001	0.064	0.939	0.048	0.830	0.481	0.786	
80	7.372	0.000	-0.324	0.000	0.560	-4.074	0.001	0.526	0.603	1.249	0.283	0.423	0.809	
90	6.289	0.000	-0.217	0.012	0.555	-4.728	0.000	0.655	0.537	0.131	0.722	0.201	0.905	2005, 2008
100	7.311	0.000	-0.301	0.008	0.343	-3.069	0.005	1.184	0.337	0.471	0.504	3.142	0.208	
net money expenditures														
10	-0.841	0.441	0.694	0.000	0.674	-2.734	0.010	1.306	0.304	0.516	0.484	1.333	0.513	
20	1.438	0.058	0.429	0.000	0.671	-3.106	0.004	1.008	0.392	0.140	0.714	0.245	0.885	
30	-2.413	0.002	0.822	0.000	0.919	-3.381	0.003	0.413	0.671	0.845	0.373	0.527	0.768	2000
40	-3.336	0.004	0.904	0.000	0.838	-3.137	0.004	0.235	0.794	0.293	0.597	0.565	0.754	
50	-3.351	0.036	0.896	0.000	0.697	-2.654	0.012	1.102	0.361	0.065	0.803	0.753	0.686	
60	-3.543	0.006	0.907	0.000	0.809	-2.054	0.042	3.210	0.074	0.652	0.433	0.553	0.758	
70	-2.476	0.051	0.794	0.000	0.751	-2.264	0.027	1.719	0.218	0.148	0.706	0.379	0.827	
80	-2.131	0.068	0.753	0.000	0.763	-2.776	0.010	1.048	0.378	0.481	0.499	2.785	0.248	
90	-3.620	0.001	0.884	0.000	0.877	-3.413	0.002	0.483	0.627	0.989	0.337	0.263	0.877	
100	-2.433	0.134	0.741	0.000	0.638	-3.222	0.003	0.231	0.797	1.245	0.283	0.931	0.628	

Source: own calculations

Table 1: Income elasticity coefficients of meat consumption in the UK.

dec.	$\hat{\beta}_0$		$\hat{\beta}_1$		R^2_{adj}	ADF		Breusch-Godfrey		ARCH		Jarque-Bera		D
	t	p-value	t	p-value		t	p-value	F	p-value	F	p-value	JB	p-value	
consumption of meat														
10	-1.768	0.025	0.494	0.000	0.784	-2.221	0.030	2.517	0.119	0.241	0.631	0.109	0.947	
20	0.829	0.123	0.264	0.000	0.748	-3.350	0.002	1.397	0.285	0.225	0.642	0.813	0.666	2008
30	-0.050	0.934	0.354	0.000	0.742	-4.393	0.000	0.983	0.400	0.238	0.633	1.321	0.517	
40	0.644	0.251	0.297	0.000	0.708	-2.474	0.017	1.601	0.242	1.851	0.195	1.089	0.580	2016
50	0.225	0.762	0.334	0.000	0.632	-2.377	0.021	1.373	0.288	0.040	0.844	0.800	0.670	
60	1.268	0.058	0.244	0.000	0.561	-2.598	0.013	0.699	0.515	0.020	0.891	0.523	0.770	
70	-0.491	0.322	0.390	0.000	0.851	-5.432	0.000	0.717	0.506	1.635	0.222	0.050	0.975	
80	0.257	0.713	0.329	0.000	0.665	-3.148	0.004	0.261	0.775	1.868	0.193	0.164	0.921	
90	1.395	0.055	0.233	0.001	0.511	-3.737	0.001	0.014	0.986	0.475	0.502	0.235	0.889	
100	1.897	0.000	0.188	0.000	0.681	-2.787	0.009	0.543	0.594	0.420	0.527	2.024	0.363	
net money expenditures														
10	-2.092	0.001	0.925	0.000	0.961	-3.052	0.005	1.148	0.347	0.096	0.762	0.669	0.716	
20	0.657	0.280	0.675	0.000	0.914	-5.339	0.000	0.001	0.999	2.480	0.138	0.727	0.695	
30	0.522	0.451	0.693	0.000	0.897	-2.333	0.024	0.672	0.528	1.502	0.241	0.443	0.801	
40	1.646	0.003	0.597	0.000	0.930	-2.595	0.014	2.151	0.156	0.151	0.703	0.102	0.950	
50	0.891	0.205	0.662	0.000	0.891	-3.119	0.004	0.812	0.465	1.971	0.182	0.173	0.917	
60	1.733	0.002	0.589	0.000	0.937	-2.763	0.010	1.165	0.343	0.308	0.588	0.538	0.764	
70	0.657	0.351	0.675	0.000	0.895	-2.773	0.009	0.931	0.419	0.392	0.541	1.215	0.545	
80	0.857	0.252	0.656	0.000	0.881	-2.714	0.010	1.645	0.231	0.119	0.735	0.571	0.751	
90	1.571	0.022	0.593	0.000	0.895	-3.127	0.004	1.116	0.357	0.123	0.731	1.431	0.489	
100	2.343	0.000	0.517	0.000	0.909	-2.603	0.013	2.344	0.138	0.256	0.621	0.715	0.699	2001, 2013

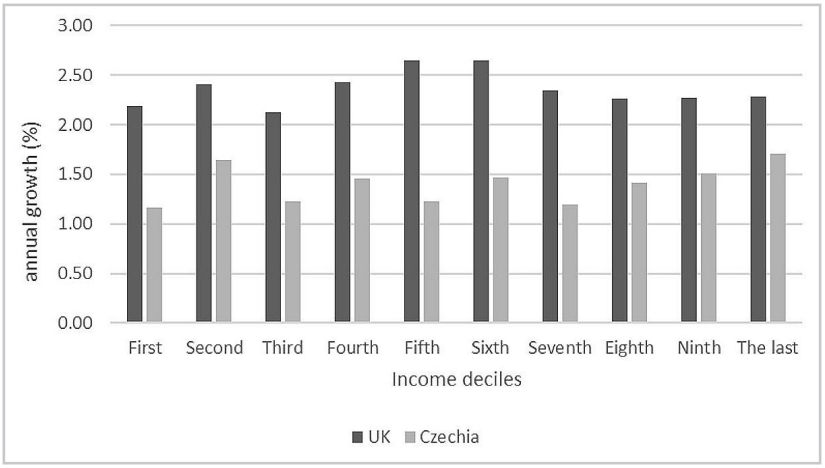
Source: own calculations

Table 2: Income elasticity coefficients of meat consumption in the Czech Republic.

demanded (sales), on average. For example, when considering the first income decile and natural meat consumption in the Czech Republic, the elasticity is 0.494. So, a 1 per cent increase in the income is associated with a 0.494 per cent increase in quantity demanded. The elasticity calculated from the net money expenditures is always higher than elasticity based on natural consumption because of price-related effects.

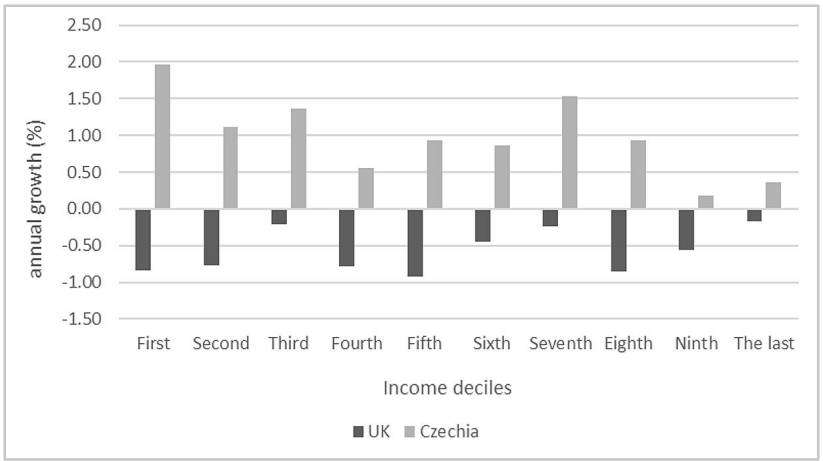
At first glance, there is a big difference in the income elasticity of natural consumption between the two countries. The income elasticity of meat is positive in the Czech Republic ranging between 0.188 and 0.494; the UK has negative income elasticity from -0.476 to -0.209. However, the income elasticity of net money expenditures is positive in both countries. The chief cause of the discrepancy between income elasticity of natural consumption and net monetary expenditures is the UK's unit price (Figure 1).

Figure 1 clearly shows the higher price growth of meat in the UK than in the Czech Republic in all income deciles. However, the UK's meat consumption declines in the long term in all income deciles, as Figure 2 presents. The more detailed statistics revealed that the decline of red meat consumption was more dynamic than poultry meat consumption in most income deciles in the UK. Alternatively, there is a positive relationship between income development and meat consumption in the Czech Republic. Thus, the results indicate completely different dietary trends between the two countries. Increasing evidence suggests that a final shift occurs, following behavioural change towards consuming higher-quality fats, more whole grains, fruit and vegetables, and particularly less meat in high-income and developed countries, such as the UK (Mathijs, 2015). This process is called nutrition transitions (Popkin, 2006). There are various factors which can cause a downward trend



Source: authors

Figure 1: Average annual growth of per-unit meat prices (%).



Source: authors

Figure 2: Average annual growth of natural meat consumption (%).

in meat consumption in high-income countries.

The possible explanation of different consumption trends in the Czech Republic and the UK can be found in saturation level and different demand for quality. Tables 3 a 4 present differences between monetary and natural income elasticities in both countries.

The differences are similar in the lower-income deciles in both countries but significantly differ in higher-income deciles between the Czech Republic and the UK. The critical finding is that consumers with above-average income in the UK prefer quality much more than the same groups in the Czech Republic. Nevertheless, the demand for quality has increased in all income groups in the Czech Republic and lower-income groups in the UK. Alternatively, the higher-income groups in the UK have not increased the demand for quality in the long period since they are nearly saturated (Table 5).

In the UK, the saturation limit is lower than in the Czech Republic, and consumers focus

CZ	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Trend (geo-mean)
First 10 %	0.052	0.060	0.063	0.061	0.068	0.074	0.060	0.063	0.067	0.062	0.050	0.049	0.050	0.047	0.050	0.056	0.063	0.073	102.0
Second 10 %	0.057	0.066	0.070	0.067	0.076	0.083	0.069	0.075	0.079	0.075	0.059	0.060	0.062	0.058	0.060	0.068	0.076	0.090	102.7
Third 10 %	0.059	0.069	0.073	0.071	0.079	0.087	0.073	0.080	0.084	0.081	0.063	0.065	0.066	0.062	0.064	0.073	0.080	0.097	102.9
Fourth 10 %	0.061	0.070	0.074	0.072	0.081	0.089	0.076	0.084	0.088	0.085	0.066	0.067	0.069	0.065	0.066	0.076	0.083	0.100	103.0
Fifth 10 %	0.062	0.072	0.076	0.074	0.083	0.091	0.078	0.087	0.091	0.089	0.068	0.070	0.071	0.067	0.068	0.079	0.085	0.104	103.1
Sixth 10 %	0.063	0.073	0.077	0.075	0.085	0.093	0.081	0.089	0.094	0.093	0.070	0.072	0.073	0.069	0.069	0.081	0.088	0.109	103.3
Seventh 10 %	0.064	0.074	0.079	0.077	0.086	0.096	0.084	0.093	0.098	0.098	0.072	0.076	0.075	0.072	0.071	0.084	0.090	0.114	103.5
Eighth 10 %	0.065	0.075	0.080	0.078	0.088	0.098	0.087	0.097	0.103	0.105	0.076	0.080	0.078	0.075	0.073	0.088	0.094	0.120	103.7
Ninth 10 %	0.065	0.076	0.081	0.080	0.090	0.101	0.091	0.101	0.107	0.112	0.079	0.084	0.080	0.079	0.076	0.092	0.097	0.128	104.0
The last 10 %	0.063	0.074	0.080	0.079	0.089	0.101	0.094	0.106	0.113	0.124	0.082	0.091	0.083	0.084	0.077	0.097	0.099	0.138	104.7

Source: own calculation

Table 3: Differences between monetary and natural income elasticities in the Czech Republic.

UK	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Trend (geo-mean)
First 10 %	0.036	0.053	0.052	0.069	0.047	0.078	0.065	0.054	0.060	0.055	0.046	0.051	0.060	0.057	0.062	0.057	0.063	0.062	103.2
Second 10 %	0.062	0.083	0.086	0.108	0.077	0.118	0.104	0.086	0.099	0.087	0.077	0.080	0.093	0.093	0.103	0.097	0.105	0.103	103.1
Third 10 %	0.082	0.103	0.109	0.132	0.094	0.141	0.127	0.106	0.124	0.106	0.096	0.097	0.109	0.112	0.124	0.111	0.119	0.117	102.1
Fourth 10 %	0.103	0.123	0.128	0.154	0.111	0.162	0.146	0.125	0.145	0.123	0.112	0.113	0.127	0.128	0.142	0.127	0.136	0.134	101.6
Fifth 10 %	0.122	0.141	0.145	0.175	0.126	0.180	0.165	0.142	0.164	0.140	0.127	0.129	0.144	0.143	0.158	0.143	0.142	0.150	101.2
Sixth 10 %	0.144	0.162	0.163	0.195	0.141	0.199	0.184	0.161	0.183	0.157	0.144	0.147	0.162	0.161	0.177	0.161	0.168	0.168	100.9
Seventh 10 %	0.167	0.183	0.183	0.218	0.159	0.220	0.204	0.181	0.204	0.176	0.164	0.167	0.181	0.180	0.197	0.181	0.181	0.188	100.7
Eighth 10 %	0.200	0.208	0.205	0.242	0.180	0.243	0.228	0.206	0.233	0.198	0.189	0.190	0.203	0.201	0.220	0.206	0.212	0.212	100.3
Ninth 10 %	0.252	0.246	0.236	0.276	0.211	0.278	0.263	0.239	0.272	0.230	0.224	0.224	0.235	0.233	0.251	0.237	0.239	0.243	99.8
The last 10 %	0.492	0.363	0.337	0.364	0.319	0.369	0.355	0.348	0.376	0.318	0.328	0.338	0.329	0.318	0.325	0.329	0.323	0.335	97.8

Source: own calculation

Table 4: Differences between monetary and natural income elasticities in the UK.

	Monetary (USD/cap)		Natural (kg/cap)	
	CZ	UK	CZ	UK
Saturation limit	628.4	494.4	86.8	54.2
The share of consumption to the saturation limit				
First 10 %	40.3%	62.2%	46.4%	87.8%
Second 10 %	48.4%	71.9%	53.5%	94.3%
Third 10 %	57.0%	75.2%	64.0%	96.3%
Fourth 10 %	60.8%	75.3%	67.4%	95.9%
Fifth 10 %	63.4%	78.2%	70.8%	96.2%
Sixth 10 %	65.6%	81.6%	71.4%	97.9%
Seventh 10 %	66.5%	85.9%	71.3%	98.3%
Eighth 10 %	70.4%	88.8%	75.6%	98.7%
Ninth 10 %	75.0%	94.6%	78.2%	98.7%
The last 10 %	78.8%	100.0%	80.2%	93.9%

Source: own calculation

Table 5: Saturation limit and the share of consumption to saturation limit (%) in monetary and natural expression (average of 2000–2017).

on other goods and services. In the Czech Republic, there is a potential to increase monetary and natural expression consumption, not in the UK where the saturation level was nearly reached.

Firstly, there are the impacts culture and tradition on preferred food choice and the choice of meats between the UK and the Czech Republic. The UK consumers prefer beef, poultry, fish and tinned meat while the most favourite meat of Czech consumers is pork and poultry meat. The Czech Republic is landlocked and does not have access to fresh seafood.

A second factor can be identified from recent studies, which have shown that the mortality rate could be affected by high intake of both red and processed meat whilst there are no or only moderate inverse associations observed for poultry (Etemadi et al., 2017; Wang et al., 2016). However, the results may be biased as high meat intakes may be associated with other major risk factors such as smoking, alcohol consumption and obesity. The most substantial evidence was found in association with colorectal cancer. Red meat is classified as probably carcinogenic to humans (Bouvard et al., 2015). Processed meat consumption also seems to be associated with risk for cardiovascular disease (Rohrmann et al., 2013) and chronic diseases such as diabetes and obesity (Wolk, 2017).

Additionally, meat consumption is associated with the level of income and wellbeing. “In high-income Western countries, a lower meat intake may be a marker of a health-conscious lifestyle, but in low-income countries, lower meat intakes are more likely to be markers of poverty and associated with other risk factors for poor health” (Godfray et al., 2018). Moreover, people in low-come countries often have limited access to alternative nutrient-dense foods.

The economic impacts of red meat consumption are closely associated with nutritional and environmental issues. The consumption of different types of meat and meat products has significant effects on people’s health, and livestock production can negatively affect the environment. Thus, the taxation of unhealthy food is a topical issue in developed countries. Attempts to change diets through fiscal interventions also lies within a rational choice framework. For example, a coalition of the UK’s health professions has called for a climate tax imposed on food with a heavy environmental impact by 2025, unless the industry takes voluntary action on the impact of their products. Denmark operated a tax on the 496 saturated fat content of foods between 2011 and 2012, raising prices of some meat products by 15% (Godfray et al., 2018). A recent study estimated that “under optimal taxation, prices for processed meat increased by 25% on average, ranging from 1% in low-income countries to over 100% in high-income countries, and prices for red meat increased by 4%, ranging from 0.2% to over 20%. Consumption of processed meat decreased by 16% on average, ranging from 1% to 25%, whilst red meat consumption remained stable

as a substitution for processed meat compensated price-related reductions" (Springmann et al., 2018). Optimal taxation will also reduce the number of deaths attributable to red and processed meat consumption and save health costs globally (Springmann et al., 2018). Another study, however, concluded that meat consumption is difficult to influence through direct policy intervention. "Acting indirectly on consumers' preferences and consumption habits (for instance through information, education policy and increased availability of ready-made plant-based products) could be of key importance for mitigating the rise of meat consumption per capita all over the world" (Milford et al., 2019).

People in high-income countries have become more concerned about the impact of meat production on the environment. The FAO study provided evidence that meat produces more emissions per unit of energy than plant-based agriculture (Gerber et al., 2013). Ruminant production produces more emissions than that of nonruminant mammals and poultry. In contrast, intensive rearing tends to produce fewer GHG emissions than more extensive systems per unit of output despite having other environmental disadvantages (Godfray et al., 2018). Livestock production is also associated with water consumption. The study on livestock production's water footprint showed that beef farming is more water demanding than chicken production per kilogram of meat (Mekonnen and Hoekstra, 2012). Alternatively, replacing cropland with permanent pasture is one practice promoted for its potential to sequester soil carbon, i. e. particularly in hill farming or farming on marginal land. There is an argument that continued permanent pasture even where there are ruminants present a carbon zero scenario. Overall, public interventions in the form of nutrient tax to reduce red meat consumption would positively impact greenhouse gas emissions (Farchi et al., 2017; Harding and Lovenheim, 2017).

Finally, there is a growing concern within the younger generation concerning husbandry practices and animal welfare. Positive attitudes towards animal welfare are associated with consuming less meat and greater 'higher welfare' meat purchases (Clonan et al., 2015). There is an increasing trend of veganism, vegetarianism, and flexitarians. The research on the association of animal health concerns with diet choice provided evidence that contrast between flexitarians and vegetarians is greater than the contrast between flexitarians and full-time meat-eaters (De Backer and Hudders, 2015).

Conclusion

The article's purpose was to point out the difference in consumer behaviour between ten different income levels (deciles) across two countries: the Czech Republic and the UK. The two countries have different consumer preferences and income level. Meat consumption has been widely discussed because of environmental and health impacts, especially in the case of red meat.

The most influential finding is a big difference in the income elasticity of natural consumption between the two countries. The income elasticity of meat consumption is positive in the Czech Republic, while the UK has negative income elasticity. In other words, the natural consumption of meat increased with incomes grew in the Czech Republic. In contrast, there appears to be a diametric relationship between meat and income had in the UK. Nonetheless, the income elasticity of net money expenditures is positive in both countries. The chief cause of the discrepancy between income elasticity of natural consumption and net monetary expenditures is the higher unit price found in the UK. There was a higher price increase in the UK than in the Czech Republic in all income deciles.

The meat consumption patterns differ between the Czech Republic and the UK. Britons prefer beef, veal and sheep meat while pork meat is much more popular in the Czech Republic. Moreover, the UK's meat consumption is nearly saturated, and consumers in higher-income deciles are looking for high-quality meat much more than the same groups in the Czech Republic. The demand for quality has been increasing in all income groups in the Czech Republic and lower-income groups in the UK, which is an important signal for meat processors.

The results provide evidence that consumers in the UK are close to consumption saturation prefer high-quality meat which could have positive nutritional effects. Moreover, high-income countries discuss taxation of unhealthy food, which could lead to significant health and environmental benefits, particularly in high and middle-income countries, as recent studies found it.

In the Czech Republic, the income elasticity in terms of natural consumption and net monetary

expenditures is higher in first-decile households than in top-decile households. The Czech case explains the popularity of discount campaigns in low-income households, especially households of seniors. On the contrary, the inter-deciles differences have no evident trend in the UK, which indicates the overall downward trend of household meat consumption. The article indicates completely different trends of human diet between the two countries. It supports the theory of nutrition transitions when the UK as a high income country is gradually changing consumer behaviour toward a healthy, high-quality and balanced diet.

The article's main limitation is that it doesn't include the food outside the home in food service operations. Then the consumption of meat has risen in the UK. This is because more and more consumption takes place outside the home. Further research could follow this trend.

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Evaluation of Frequencies for the IoT Telemetry in Smart Agriculture

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Abstract

The IoT is becoming a widely known technology for the gathering of telemetry data, while mostly the concept of Smart cities is usually seen as the most challenging area for implementation. The different situations can be found in the smart agriculture concept, where different requirements and especially conditions exist. The purpose of this paper is to make an overview of IoT frequency bands available, with special focus on the situation in the EU, their theoretical usability and, using experimental measurements of typical background noise in different bands and calculations of transmission reliability on expected distance, estimate the practical usability of those technologies in the smart agriculture, compared to the smart city's requirements. Most of the IoT installations outside 5G systems are in the 900 MHz band, but is this well-suitable for smart agriculture?

Keywords

IoT, LoraWan, Sigfox, telemetry, FSPL.

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Introduction

The smart agriculture concept expects achieving and use of the right data at the right moment – mostly immediately when needed or when they become available. When working with data readings from the field (terrain) either long-term readings may be used – obtained on a time-to-time basis by aerial photography, satellite measurements, drones, or land-based agricultural vehicles, when they perform any agricultural operation. This is used for data with long-term validity, which are expected to stay unchanged by nature or any other expected effects. To gain access to field-measured data more often, there are several techniques available. The old-fashioned way is always to physically attend to the location and measure the required values or retrieve a memory device with on/site recordings. This approach limits the usability of such acquiring data due to the random character of measurement intervals, location on points within the area, physical capabilities of an explorer and covered area. Theoretically, possible solutions may be based on fixed sensors (or sensor stations) in terrain, connected to the data concentrator using fixed-line, such as RS-485, Ethernet or a different proprietary standard. This would provide needed data in an online regime, two-way communication, but is difficult to build up, especially in rural areas, fields, and forests. Having as much data from terrain is crucial for making the right decisions (Šilerová et al., 2019).

A typical data, obtained in the industry and smart city environments, focus on the energy, parking (Chatzigiannakis et al., 2016), lighting, etc. (Zanella et al., 2014); all at a high rate of measurements in time, causing a massive demand for data link capacity and multiple access. On contrary, in an agricultural environment, a different type of data and frequency of their acquiring is required (Playán et al., 2018). According to (Koprda et al., 2017) mainly weather, humidity (Jeong et al., 2018), wind direction, and strength values are needed in such conditions. Those readings are made much rarely, not creating a massive machine-to-machine communication (MMC), but devices are spread out on significantly larger distances. Thus approaches, typical for a Smart city/smart campus solution may not be the best for smart agriculture too and a different point of view should be used. A different type of data may be gathered from agricultural machines, tractors, harvesters, etc. Those sources are not present in terrain all the time, they are equipped with a high capacity power source and are large in size. This paper won't focus on such devices, while they are perfectly capable of using more traditional mobile networks.

New technologies in the 20th and 21st centuries allowed us to retrieve such data using automatic remote-controlled devices. These telemetry (téle – remote, métron - measurement) devices can operate independently and automatically transmit measured data. Those transmissions may be either one-directional (blind transmission) where the device transmits in given time intervals or when the measured value got changed, but without possibility to receive commands and acknowledgement, or bi-directional when a device can be called (addressed) for control purposes. Currently, two main groups of technologies may be used. First, based on one-use units usually build on a case-by-case basis with integrated radio modem and second, so-called IoT (Internet of Things) devices (Atzori et al., 2017) which tend to be more universal, mass-produced, and usually cheaper in terms of purchase. However, the authors of this paper would like to focus on, whether is a low price a regular reason to use such technology in agriculture.

Those commercially available technologies span through a wide variety of prices and capabilities, so far, no structured comparison of them was made for agricultural use. This paper will partially use results from (Stočes et al., 2016) and extend them by previously mentioned in-house solutions that were used in previous years and are still competitors to them.

The IoT is not just one technology, but several different techniques of how to get small amounts of data from the field to the processing point (Centenaro et al., 2016). What is common for all of them (techniques) is an expectation of very low bitrate (in 10s or 100s bits per second), low power usage on terminal devices-often battery-powered, small physical dimensions, and installation at non-dominant sites (terminals). This creates a situation very different from classical computer networks and using legacy approaches for the development and implementation of this technology would result in unexpected, unwanted, and too expensive solutions without practical usabilityMost of the IoT studies are focused on city-wide (Centenaro et al., 2016) or industrial use (Shete and Agrawal, 2016), while rural areas are not mainstream of interest. Not only IoT but multiple-layers telemetry technologies are introduced in this area – usually when a mobile phone is used as a concentrator (Granulo et al., 2016)[or GSM (Groupe Spécial Mobile – European standard for digital mobile networks) module (Sarri et al., 2017). But those areas are quite different from previously mentioned in terms of distances, power availability, hostile environment on fields (Parada et al., 2017) - so different approaches and technologies may or should be used. What is common for the smart city concept (Mikhaylyuk et al., 2018) are short span distances (100s of meters) (Centenaro et al., 2016), high or extreme high density of end devices within the premises and expect a lot of interference and background radio noise. On contrary, for smart agriculture, there is expected a much longer span distance of the links between the base station (concentrator) and measurement nodes (kilometres and more), low density of installations and less artificial electromagnetic interference. For both situations, wireless communication is used, using advantages such as instantaneous network build-up, no need to gain access to the premises between the nodes, nomadic or even mobile nature of devices. But without physical media, those networks suffer from disadvantages including, but not limited to, uncontrolled environment, extreme energy attenuation during transport, interference both natural and artificial.

For wireless data transmission, various frequencies can be used (Akpakwu et al., 2018), with different nature of different bands – ranges of frequencies with the common usage and/or behaviour. Those bands are co-originated worldwide by ITU (International Telecommunication Union) and regionally by national regulators. The lowest usable band for telemetry applications is VHF (very-high frequency) 160 MHz, which was widely used even in the analogue era in the 80´s-90´s of the 20th century. Such frequencies are capable of non-LOS (line-of-sight) applications because they can penetrate solid objects with still reasonable attenuation. Also, the construction of the high rf (radiofrequency) power output devices is possible using standardized components. The main problem with this band is in all developed countries caused by overloading shared frequencies by so many existing devices both legacy and digital from the pre-IoT era.

The second usable frequencies are in the “70cm” UHF (ultra-high frequency) band neighbouring 430-450 MHz local communication networks at the lower end of the existing television IV band. In this band, typically remote controllers, signalling devices with low reach and walkie-talkies. In this band, the uninterrupted LOS is required while those frequencies are way more attenuated when penetrating solid objects. On contrary, more bandwidth is available and almost no analogue co-existence is expected.

The last considered band is 900 MHz, close to the original GSM mobile band. Channels around 868 MHz were recently adopted for IoT usage and thus the main expected advantage was the lack of interfering and competitive appliances since the key-ratio (% of time used for transmission vs % of the time without transmission) is limited to 1% according to the ERC-REC 70-03 (CEPT Electronics Communication Committee recommendation). Due to the nature of such high frequencies, also antennas dimensions can be shorter and for end nodes (sensors) devices omnidirectional antennas with a gain of 0 can be used.

One of the differences from well-known RLANs (Radio Local Area Network), 802.11, GSM, and LTE are very low power transmitters, working at +14dBm (Europe) or +20dBm (North America) and extremely narrow bandwidth at 125 kHz (LoRaWAN) or 200 kHz (SixFox). A shared (ISM) band is always used for IoT regarding the regional specifics. The typical and most used band is 867-869 MHz in Europe, 902-928 MHz in North America. But not only are those intended to be used for the IoT. According to the ITU following bands are expected to be used for the "dedicated wide-area technologies" – 169, 420, 460 MHz which are legacy bands used for analogue and direct digital telemetry in the past. So there are more options available for the same purposes (telemetry) and for all of them, the IoT is one of the possibly used technology. Despite this, only one band is used in real applications and other options are usually even not taken into consideration.

Therefore, the main objective of this paper is to theoretically calculate and by a practical measurement check compare, which frequency bands are suitable for telemetry in smart agriculture – precision farming, where specific conditions with large distances and low device density exist.

Materials and methods

The authors firstly calculated the estimated maximum link distance for different frequencies. Due to the nature of radio waves distribution, a span distance for each radio-hop (the link between two points) differs according to the exact frequency used. The higher frequency is used, more electromagnetic energy is attenuated by the environment during propagation. This is caused by different energy spread and absorption of energy in materials, including molecules of air gases, for different frequencies. Following those estimations, an experiment was made in terrain, to measure typical background noise levels in different frequency bands in the rural area and on university campus within the city.

Theoretical calculations

For the calculation of theoretical link length, an FSPL (Free Space Path Loss) can be calculated using Formula 1 (Oluseun et al., 2020):

$$FSPL = 20\log_{10}(d) + 20log_{10}(f) + 20log_{10}\left(\frac{4\pi}{c}\right) \quad (1)$$

Where "*d*" stands for link length, *f* is the frequency [MHz] of a transmitted signal and "*c*" is the speed of light.

This formula can be, however, used also to calculate the theoretical maximum distance for radio links when the frequency and FSPL value are known. The FSPL value is calculated from the known maximum power output of the device (given by the regulatory) and the total gain of all passive parts of the radio link – in Formula 2:

$$d = \sqrt[20]{10^{FSPL-20log_{10}(f)-20log_{10}\left(\frac{4\pi}{c}\right)}} \quad (2)$$

With results in meters for ideal radio link conditions without interference (artificial or natural). In the real environment, those conditions are usually degraded by an object near and/or within the Fressnell's zone.

Also, for any data transmission technology, the theoretical bitrate can be calculated using the Shannon–Hartley Formula 3 (S-H) (Rioul and Magossi, 2015):

$$C = B\ log_2\left(1 + \frac{S}{N}\right) \quad (3)$$

Where "*B*" stands for the bandwidth needed for successful data transmission of desired speed (*C* in bits per second) in current noise conditions (signal "*S*" to nosise "*N*" ratio). This ratio is, as shown, unitless and both values can be measured either in dBu or dBm units.

For the first part of the study, theoretical calculations were made with known values and expectations of the noiseless environment – as the "*N*" value for the S-H formula is very low. While measured levels of signals are usuallyin ranges of -10s dBms (typically -90 dBm) the noiseless environment was simulated by the level of -200 dBm. The "*S*" parameter was replaced with the sensitivity parameter of the receiver and the only unknown

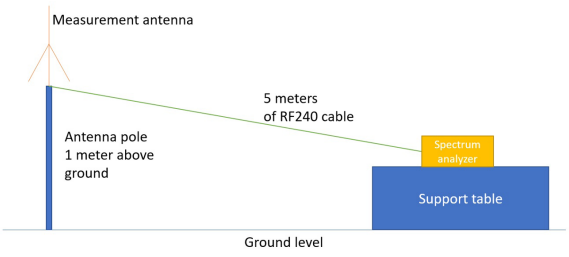
value left was the "*d*" parameter from Formula 2 – resulting in the wanted theoretical link distance for each technology and frequency band.

In the radio-link chain, calculations of the parameters of antennas must be taken into an account too when the most interesting parameter is the antenna gain. This gain is given by the physical dimensions and design of the antenna and is displayed either in dBi or dBD units. The dBi value compares (because all dB-based units are a relative type) the amount of energy radiated or received in the "main radiation direction" compared to the "isotropic" theoretical antenna, where all energy is radiated from the theoretical point in the space equally to all the directions. The dBD value is valid for the same antenna when energy levels are compared to the "dipole" type of antenna, which is a practical open-wire antenna with a length of 1/2 lambda (wavelength) split into two parts. The dBD value of the same antenna is approximately 2.15 dB higher than the dBi value.

To increase the gain of the antenna, the radiation diagram must be altered either in a vertical or horizontal direction. For the IoT applications mostly 0 dBD antennas are used on end-devices (terminals) and higher gain antennas are installed at base stations. The actual gain of the antennas depends on frequencies used while the omnidirectional characteristics (at horizontal level) is expected not to be altered. By extending the physical size (length) of the antenna, a higher gain can be reached but the reduction of the vertical radiation diagram as a result too. For the calculations, selected antennas are shown in Table 1, together with threshold sensitivity parameters of selected IoT terminal devices, calculated as the median of values from products datasheets of the IoT modules available at the European markets for respective bands (LPWAN SX1278, RA-01 SX1278, LPWAN SX1276, LoRa32 GPS NEO-6M, Semtech SX1276RF1IAS). While all IoT base stations and terminals use antennas directly connected to the transmitter (or integrated units) there is no need to take attenuation of the cable into account. The calculation for each frequency starts with the power of the transmitter in the worst scenario – the terminal unit, which is battery powered and its output power is limited by requirements for the long-live duty cycle. The typical power outputs for different bands are summed up in Table 1 while limits are governed by the previously mentioned ERC REC 70-03. Then the gain of one (base) antenna is added and with the knowledge of sensitivity threshold maximum allowed FPSL is calculated. From this result, limit span distance is calculated as a result of each frequency band.

Experimental measurements

In the second part, the real "N" parameter in the Shannon–Hartley formula was measured and calculated. Measurement of the background noise was performed in real conditions, while the university environment provided usable examples of both "urban" and "rural" environments. The university campus (WGS84: 50.1283828N, 14.3733025E) is located in Prague city, the capital of the Czech Republic. The second location (WGS84: 50.0694042N, 13.8861089E) was a field near Požáry village within Křivoklátsko protected landscape area, which is a typical European rural area. Field measurements were performed on the 16th and 17th of October 2020, each day during midday (11-12 hours) and evening (18-19 hours) on both sites for 30 minutes of continuous measurement. During all measurements, the weather was clear, without rain, temperatures from 18 to 22 Celsius. Values used in calculations were calculated as a median of measured values. Measurements in the field were made using a standardized set-up (Figure 1) with the ultra wide-band measurement antenna Sirio SD 2000 U / N which is capable of receiving in bands 130-160, 221-445, 610-682, 60-960, 1075-1500, 1610-2000 MHz and equal gain of 2dBi for all ranges below 1 GHz. An antenna was connected by a low-noise Belden RF240 PE cable of length 5 meters. Attenuation of the cable is previously checked and measured using the precise generator and obtained correction factors as in Table 2. This setup is connected to the spectrum analyzer FSL6-06 (1300.2502.06) by Rohde and Schwarz and is displayed in Figure 1. The whole set was battery-powered.



Source: own work

Figure 1: Measurement set-up

In this configuration the IoT base station (data collector) were simulated, while it is expected, that background noise would affect mostly this device and not the end nodes. Also, several IoT applications use only one-way communication where the receiving party is a base station.

According to the measured "*N*" parameter, a fixed SNR (signal-to-noise ratio) of 10 dB was added, the typical required capacity of 10 kbit/s is used and the resulting minimum received level is calculated. 15 dB reserve is set from the catalogue parameters of the IoT devices where required SNRs for different spreading factor varies from 7.5 to 20 dB.

From the known required level and known equipment parameters (tx power, antenna gain) maximum real link distance was calculated and real coverage for the selected technology was revealed.

On each location, the antenna was mounted to stand at a height of 1 meter above ground and measurements of the received energy in a 200 kHz window surrounding the centre frequency were made with an analyzer set to measure the maximum value of 1000 independent measures. This allowed authors to calculate with the pessimistic values and simulate "worst conditions".

Results and discussion

Calculations

In theoretical calculations, the FSLP was calculated from existing values of frequency, power output limit and typical sensitivity of devices using Formula 1, from such values a „d" parameters (Formula 2) were deduced and the length of theoretical maximal span distance for noiseless conditions was calculated (Table 1).

Those calculations clearly show that sensitivity levels, provided by the manufacturers of the IoT devices, selected as typical products available on market and mentioned above, cannot be taken as a valid parameter for the planning of the network. And for real span distance limits a real measurement had to be made. The reason for such extreme results (tens of kilometres) is also caused by not mentioned (in the datasheets) predicted reserve for the fade of 30 dB. For theoretical data bitrate, in a noiseless environment, noise level -200 dBm is used and bandwidth od 125 kHz (Table 2).

Measurements

Experimental measurement results started with the cable calibration, where exact attenuation of antenna-analyzer cable for different frequencies was to be later used as a correction. A well-known power level was applied to the cable, while the exit level was measured (Table 3).

An experimental set-up was established on both sites and the noise level was measured, cable attenuation from Table 4 was added as a correction.

For all bands, the rural area noise level is significantly lower than the urban one.

From measured levels and already known parameters of devices, expected link (hop) distance is calculated in Table 5 (pessimistic estimation for 30 dB fade reserve).

Centre frequency (band)	Transmitter output	Typical small device antenna gain	Typical device sensitivity	Available energy for FSLP	Theoretical span in noiseless conditions
169 MHz	+27 dBm	3 dBi	-129 dBm	159 dB	12 581m
433 MHz	+10 dBm	3 dBi	-132 dBm	145 dB	9 797m
867 MHz	+20 dBm	7 dBi	-136 dBm	163 dB	38 867m

Note: Transmitter outputs are regulated by international rules, used values are maximums defined by CEPT regulatory for respective ISM bands - ETSI 300 220-1 V2.4.1.

Antenna gain is used for antennas typical for small size devices, such as field sensor setups.

Typical device sensitivity is a mode of commercially available sets of rf modules capable of IoT (LoRa) transmissions at the time of the paper preparation. For 169 and 433 MHz bands, only universal rf modules were available.

Source: own calculations

Table 1: Calculated signal attenuation and maximal hop distance for the noiseless environment.

Frequency band	Bitrate available for the noiseless environment at the edge of coverage
169 MHz	86.6 kbit/s
433 MHz	89.3 kbit/s
867 MHz	91.4 kbit/s

Source: own calculations

Table 2: Theoretical bitrate for noiseless environment is sufficient for all expected purposes.

Frequency used	Generator power	Measured energy	Cable attenuation
169 MHz	-70 dBm	-70.48 dBm	0.48 dBm
433 MHz	-70 dBm	-70.82 dBm	0.82 dBm
867 MHz	-70 dBm	-71.15 dBm	1.15 dBm

Source: own calculations

Table 3: Cable calibration values (attenuation of the signal in measurement cable) measured before experimental measurement on sites.

Measured frequency	Urban area	Rural area	Cable attenuation
169 MHz	-84 dBm	-91 dBm	0.48 dBm
433 MHz	-87 dBm	-94 dBm	0.82 dBm
867 MHz	-92 dBm	-97 dBm	1.15 dBm

Source: own calculations

Table 4: Results of experimental measurements- background noise levels in terrain for three different bands in different areas.

Frequency used	Urban area	Rural area	Cable attenuation
169 MHz	1 258m	2 816m	0.48 dBm
433 MHz	693m	1 552m	0.82 dBm
867 MHz	616m	1 095m	1.15 dBm

Source: own calculations

Table 5: Calculated maximal hop distances for different bands in noisy conditions.

The table compares the theoretical span distance of radio hop with assured reliability for three studied radio bands in urban and rural areas.

Calculated results proved, that all frequency bands available for the IoT telemetry devices can be theoretically used for extreme distances (Table 1), corresponding to the manufacturer's datasheets. But when used in the real environment, when existing background noise must be taken into consideration, those span distances are limited and for the city-wide use one kilometre or less (Table 5). In the rural environment, where less noise is present, usable distance extends to kilometres, which are fully suitable for standalone is-land-type IoT installations. Since VHF band (169 MHz) devices are practically nonexistent at the market (even in kit or modules), from remaining, the 433 MHz, seems to be the best solution when an independent network is built, while the 860-870 MHz band is currently occupied by commercial and country-wide networks. Unfortunately, no producer of commercial IoT solutions focuses on the EU433 standards, while it would be usable in the smart agriculture and users of IoT in this area of application are forced to rely on the 900 MHz band, NB or even C-band solutions from country-wide providers. Results are focused mostly on European theatre as for the exact frequencies used (CEPT/ETSI) and power output limits.

Still, all mentioned bands for the IoT are well suitable for agricultural use with benefits of the IoT principles – small independent devices, used in régime „install and forget“. When comparing those bands, the main difference of agriculture use from smart cities concept is larger distances which need to be covered, thus even slightly better reach, shown in Table 6 as an increase of 50% in favour of 433 MHz, should be taken in consideration when projecting a new isůand-type IoT installation.

Frequency used	Theoretical span distance	Real span distance
169 MHz	12 581m	2 816m
433 MHz	9 797m	1 552m
867 MHz	38 867m	1 095m

Source: own calculations

Table 6: Comparison of theoretical calculated distances and distances calculated for the real environment.

Future research should focus on the creation of an experimental 433 MHz+867 MHz dual-band IoT island-. type installation in rural areas and comparison of the real coverage and reliability to a commercial solution. This would allow the researcher a continual measurement of signal parameters for a longer period and include the influence of weather conditions, such as temperature, air humidity on results. Those influences may cause different results, while

weather situation is also a possible aspect of signal (including noise) attenuation.

Conclusion

In the paper, the authors show that not only 900 MHz band is available for the IoT applications and despite most authors nowadays planning and implementing new IoT solutions at higher UHF bands (900MH and above), the 70cm band (433 MHz) is an attractive alternative, with usability limited by the unavailability of commercial devices and lack of commercial coverage. But for self-managed island systems, made of modules it is promising to use this band for agricultural applications. Even when lower allowed power output, a better propagation of lower frequencies was shown in theoretical calculation using FSPL attenuation. When a background noise level was experimentally measured, the difference in favour to the 70cm band even increased. Those results should be confirmed by a longer continuous study with on-site installation in the future.

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