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CONTENTS

ANALYSES

INFORMATION

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How Do Changes in the Minimum Wage Affect Household Consumption?

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Abstract

Minimum wage hikes increase the consumption of affected households. This paper studies the structure of the additional consumption across various low-income household types. Using a unique set of cross-sectional data at the household level in the Czech Republic, I simulate the impact on consumption categories of additions to disposable income due to minimum wage increases between 2011 and 2019. My findings suggest that the additional income is predominantly allocated to essentials, despite a drop in their budget share. Consumption of addictive goods represents a luxury for low-income households, among whom the demand is even more elastic for those with children. Similarly, health and education expenditures are substantially income sensitive for households with children.

Keywords	***DOI***	***JEL code***
Minimum wage, income elasticity, household consumption, low-income households, household data	*https://doi.org/10.54694/stat.2022.23*	*D12, D30, J38*

INTRODUCTION

The minimum wage has attracted the attention of labour market researchers for decades. An extensive literature focuses on the impact of minimum wage increases on labour market outcomes, while the literature on the impact of minimum wage changes on consumption is limited. But the main goal of wage floors is not to support employment but to increase the welfare of low-income employees (ILO, 2015), genuinely realised through increasing their consumption.

This paper relates to the only four studies examining the direct relationship between the minimum wage and consumption. Aaronson et al. (2012) find a positive effect of minimum wage increases on US household aggregate consumption, where the effect is concentrated on durable consumption, especially vehicles purchased by a few households. The effect on durables is not accompanied by any impact on nondurables or services. However, Alonso (2016), using a double-log model and US retail sales data, finds that the minimum wage does increase consumption of nondurable goods. This relationship is stronger in cases in which minimum wage changes affect more employees. Alonso focuses only

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on nondurable consumption, leaving unexamined the consumption structure as a whole. Arpaia et al. (2017) examine the direct relationship between the minimum wage and total consumption across the income distribution. The result of their regression analysis using Eurostat experimental data is the theoretically expected positive effect on the consumption of low-income groups. Finally, according to Dautović (2017), Chinese households with at least one child consume all the additional income due to minimum wage increases. The consumption categories most affected by the income change are health and education expenditures.

From the theoretical perspective, a minimum wage increase can be considered a permanent positive income shock. The distinction between one-off and permanent income changes stems from the life-cycle hypothesis and the related permanent-income hypothesis, both of which predict the smoothing of consumption over a lifetime (Modigliani and Brumberg, 1955; Friedman, 1957). According to several surveys, people are more likely to reduce consumption after a negative income shock than to increase consumption after a positive shock (Fuster et al., 2018; Christelis et al., 2019). The degree to which a change in a person's disposable income is reflected in consumption depends on their marginal propensity to consume (Keynes, 1936). The marginal-propensity-to-consume hypothesis predicts that people with lower income consume more of the additional income (Carroll et al., 2017). Similarly, the model of hand-to-mouth consumers predicts such people spend most of their additional income because they face restricted liquidity and have unsatisfied basic needs (Ben-David and Bos, 2017; Baugh et al., 2018; Agarwal et al., 2020). This paper examines only low-income households whose marginal propensity to consume is presumably high (Carroll et al., 2017), because high share of their total expenditures covers subsistance level of consumption. Subsistance in consumption is a concept descibing the consumption required for satisfaction of basic needs (Steger, 2000). The subsistance requierement relates to poverty and directly affects consumption behaviour (Baumgärtner et al., 2013).

The aggregate positive income shock due to a minimum wage increase is higher when the undesirable labour market outcomes – disemployment, the price effect, and a drop in profit margins – are smaller. Eriksson and Pytliková (2004) examine an increase in the minimum wage in the Czech Republic and conclude that it led to a rise in the wages of low-income employees and had little or no effect on their employment. Grossmann et al. (2019) come to the same results when examining the period between 2013 and 2017, which overlaps with the period studied in this paper. The price effect, if any, occurs primarily in sectors whose workforce is disproportionately affected by the minimum wage (Lemos, 2006; Aaronson et al., 2008; MaCurdy, 2015; Cooper et al., 2017). But multiple studies find no direct price effect (Katz and Krueger, 1992; Machin et al., 2003; Draca et al., 2011). Notably, only 3.1% of employees in the Czech Republic earned less than 105% of the minimum wage in 2018, making the Czech minimum wage among the least restrictive in the European Union (Eurostat, 2022). As for the possibility of reduced profits, one of the few empirical studies – Draco et al. (2011) – finds only a short-term effect.

This paper builds on the rich empirical literature on income elasticity for twelve consumption categories, as defined by the COICOP (Classification of Individual Consumption According to Purpose), and the broader categories of nondurables, semidurables, durables, and services (*CZ-COICOP, n.d.*). A consumed good or service's income elasticity, which is the primary basis for empirically examining the income – consumption link, is *normal* (with positive income elasticity), *necessary* (with elasticity between zero and one), *luxury* (with elasticity above one), or *inferior* (with negative elasticity) (Hal R. Varian, 1992). Many empirical studies find food and nonalcoholic beverages to be necessary goods (Murty, 1981; Ogundari and Abdulai, 2013; Santeramo and Shabnam, 2015; Ogundari et al., 2016); the category's elasticity is 0.47 on average for Czech households (Malá and Červená, 2012). Additionally, low-income households' food consumption structure seems to be remarkably sensitive to changes in total consumption (Huang and Gale, 2009). Though household size (Houthakker, 1957; Massell, 1969), number of children (Pellerano

et al., 2020), number of adults (Horton and Hafstrom, 1985), and number of parents (Abdel-Ghany and Schwenk, 1993) affect consumption behaviour, there might not be any significant difference between households with and without children nor between households whose workers are employees and those whose workers are self-employed (Benda-Prokeinová et al., 2017).

The income elasticity of alcohol consumption for total population is inelastic (Fogarty, 2010; Laković et al., 2019) and varies around 0.6 (Nelson, 2013). Syrovátka et al. (2015) find similar estimates among Czech households, although the authors examined only beer and wine which tend to be less elastic than spirits (Nelson, 2013).The inelastic demand applies also to the tobacco consumption (Matsuda et al., 1999; Martinez et al., 2015), while low-income households tend to be more sensitive to income increases (Franks et al., 2007). To the contrary, Heboyan and Hovhannisyan (2019) find that income explains tobacco consumption only among light smokers with high income. The authors' interpretation relates to the addictive nature of tobacco being more potent driver of smoking than income.

The housing category, which is necessary, takes up a significant share of households' budget (Åkerman, 1957; Goodman, 1988; Hansen et al., 1996; Fernández-Kranz and Hon, 2006; Tandoh and Tewari, 2016). Associated parts of the housing category such as water (Dalhuisen et al., 2003; Ščasný and Smutná, 2019; Bruno and Jessoe, 2021) and energy (Tse and Raftery, 1999; Salotti et al., 2015; Vesterberg, 2016) make the whole category inelastic. Schulte and Heindl (2017) estimate that among German households, housing is relatively inelastic only for low-income households.

Transport is necessary for getting to work, school, and other places. It counts as a necessity in the cases of public transport services (Fouquet, 2012) and fuel (Graham and Glaister, 2002; Dahl, 2012). However, the transport category as a whole can be dominated by vehicle purchases, which have elastic demand (McCarthy, 1996; Linn and Shen, 2021). The remaining items in the category – such as air transport, which is very elastic (Gallet and Doucouliagos, 2014) – have much less weight.

Regarding countries with broad public provision of certain services, health care (Salotti et al., 2015; Mien and Said, 2018) and education (Abdel-Ghany and Schwenk, 1993; Matsuda et al., 1999) generally appear to be luxuries. But while demand for education among low-income households is elastic, education is even an inferior service for high-income households (Hashimoto and Heath, 1995).

The clothing-and-footwear category falls under the heading of luxuries (Jones, 1994; Kim, 2012), as do the categories of furnishings and household equipment (Salotti et al., 2015) and recreation services (Ghalwash, 2008), the latter of which includes highly elastic subcategories such as tourism (Bernini and Cracolici, 2016) and travelling (Zheng and Zhang, 2013) and less elastic ones such as cultural activities (Zieba, 2009). Households with low total expenditures display high income elasticity for international leisure travel (Stråle, 2021) and hotels (in the category of restaurants and accommodation services) (Davies and Mangan, 1992). In contrast, both access to the internet and mobile phones are becoming more and more essential in digitalised developed countries, which is reflected in the less than unitary elasticity for the category of information and communication goods and services (Salotti et al., 2015).

Regarding the broader COICOP categories, increasing the durability of a given item decreases income elasticity because consumer spending patterns are more flexible in the long run. Services range from inelastic passenger-transport and housing services to relatively elastic financial services (Wong and John McDermott, 1990; Salotti et al., 2015).

While building on the empirical literature on elasticity, this paper also enhances the literature on the impact of the minimum wage. My main objective is to explore how yearly changes in the minimum wage affect the structure of minimum wage earners' household consumption. For this purpose, I employ household-level microdata from the Household Budget Survey in the Czech Republic between 2011 and 2019 and carry out ex post simulations of the country's minimum wage hikes.

Section 1 describes my datasets. Section 2 presents my methodology. Section 3 presents the results, followed by Discussion in Section 4 and a final Conclusion.

1 DATA

This section presents the data in three segments: disposable-income changes due to an increase in the minimum wage, consumption expenditures, and a combination of net household income and related consumption structure.

1.1 Minimum wage

The period under review partly overlaps with six years of the frozen minimum wage, which was not increased until August 2013.[2] During these six years, the minimum wage fell from 36% to 31% of the average wage and from 42% to 37% of the median wage. This was followed by a period in which the minimum wage rose, including in relation to the average and median wages. In 2019 the minimum wage reached 37% of the average wage and 43% of the median wage. Czechia is one of the OECD countries with the lowest minimum wage. Comparing the minimum wage's relation to the average wage in the reviewed period, Czechia ranked twenty-eighth or twenty-seventh out of the thirty-one countries that set a statutory minimum wage (Eurostat, 2022). To study the minimum wage's impact on consumption, the year-on-year change of the gross minimum wage needs to be expressed as the change of household disposable income. For such purpose, I compute the yearly net minimum wage change showed in Table 1.

1.2 Consumption expenditures

I employ for my sample the Czech Republic's Household Budget Survey (HBS or "Statistika rodinných účtů"), commonly used for demand analysis in the country (Syrovátka, 2007; Janda et al., 2010; Dybczak et al., 2014; Jánský, 2014). The HBS contains detailed data on the amount and structure of consumption according to COICOP (*CZCOICOP, n.d.*) The studied consumption categories and their abbreviations are listed in Table A1 in the Appendix 1.

The goal is to create a dataset covering only households potentially affected by minimum wage changes. Therefore, I include only households with at least one employed person. I apply a condition of nonzero income from the employment activity while not excluding the income from self-employment, as it can provide ancillary income for employees' households. I exclude households with nonworking pensioner members.

I narrow the dataset to low-income households on the assumption that such households include minimum wage earners or share similar consumption patterns. I am unable to directly target households with minimum wage earners because there are too few of them. A household is considered low income when its income falls in the first quartile of households in the examined period (defined below). Thus, I obtain a unique sample of households whose dominant source of income is dependent activity (91% of total income). The mean income from self-employment is only supplementary and 83% of households have no such income.

Some households take part in the survey repeatedly. To ensure the observations are random, I keep each household only once, when it first appeared in the survey.

1.3 Household types: net disposable income and consumption structure

The impact of minimum wage changes varies according to the composition, total income, and consumption structure of a household. Therefore, I distinguish three types of households by the presence of children (with mediating effect on elasticity) and the number of adults (which affects net household income through variations in taxes and benefits):

[2] In 2013 the minimum wage increase took effect not in January, as in other years, but in August. Since I analyse the monthly minimum wage, I work with this year the same way as the others, taking into account that the year-round effect on consumption was only half.

(i) Single minimum wage earner without children (denoted 1 + 0).
(ii) Single minimum wage earner with two children (denoted 1 + 2).
(iii) Minimum wage earner with a nonworking partner and two children (denoted 2 + 2).

I take data on net household income from the OECD. The data are based on the TaxBEN model and combine the gross statutory minimum wage (income from employment) with family and in-work benefits. When applicable, the net income also includes social assistance and housing benefits. Table 1 presents the percentage change of disposable income calculated by dividing the change of the net minimum wage by the total disposable income of each household type.

Table 1 Minimum wage (in CZK per month) and the relative change of the disposable income

	2010	2011	2012	2013*	2014	2015	2016	2017	2018	2019
Minimum wage (MW)										
Gross MW	8 000	8 000	8 000	8 500	8 500	9 200	9 900	11 000	12 200	13 350
Change in gross MW	–	0	0	500	0	700	700	1 100	1 200	1 150
Change in net MW	–	0	0	445	0	623	623	829	828	799
% change of income										
1+0	–	0%	0%	4.4%	0%	5.6%	5.3%	6.6%	6.2%	5.7%
1+2	–	0%	0%	2.7%	0%	3.5%	3.5%	4.4%	3.9%	3.6%
2+2	–	0%	0%	2.7%	0%	3.5%	3.4%	4.2%	3.8%	3.5%

Note: % change of income represents the year-on-year relative change of net disposable income due to the minimum wage change.
* The minimum wage (MW) has changed since August.
Source: MoLSA, own calculations

The consumption structures of the household types are derived for each year from the HBS dataset as the mean shares of each consumption category of single childless households, single parents, and households with two parents with children. Table A2 in the Appendix 1 summarises the disposable income of each household type in each year and the structure of their consumption.

2 METHODS

I estimate the income elasticities of consumption categories to carry out ex post simulations of how minimum wage changes affect various household types. It further allows me to explore where such households allocate the additional disposable income, what they spend more and less on, and how the minimum wage changes transform the consumption pattern.

I use the HBS dataset to estimate the income elasticities of consumption categories. However, the HBS surveys a relatively small sample: 14 123 unique households between 2011 and 2019, only 2 967 of which remain after the above-described restrictions. Therefore, for the estimate of income elasticity of consumption, I divide the period into three-year periods, in which prices and wages remain reasonably stable. In other words, I group three consecutive years when creating the cross-sectional datasets. I obtain 1 443 observations in the first period (2011–2013), 1 223 observations in the second period (2014–2016), and 301 observations in the last period (2017–2019). The change in the data-collection method causes the number of observations in the third period to be relatively low.

I study a small subpopulation whose income range is narrow enough that we can assume its income elasticities remain unchanged with additional income. Thus, I employ the following model created by Houthakker (1957) and widely used for consumption analysis (Abdel-Ghany and Foster, 1982; Salotti et al., 2015; Ščasný and Smutná, 2019; Stråle, 2021):

$$ln(c_i) = \alpha_i + \beta ln(M_i) + \sum_{j=1}^{n} \gamma_j X_j + \epsilon\,. \tag{1}$$

Here, *i* stands for a time period, *c* corresponds to the consumption expenditure of an examined category, *M* is total consumption expenditure, X_j stands for the demographic control variables, α indicates the level constant, and ϵ represents the random error. I use the OLS estimation method with robust errors. Putting both the dependent variable $ln(c_i)$ and the main independent variable $ln(M_i)$ in the form of natural logarithms leads to a straightforward interpretation of the β coefficient as income elasticity (Houthakker, 1957). Because of the potential loss of observations from deriving the logarithm of zero values, I replace zero values with consumption of 1 CZK, following Stråle (2021). Given the data-related issues causing a mismatch between net income and total consumption, I use total consumption expenditure as a proxy for household income (Massell, 1969). Assuming low-income households' savings rate is close to zero, total expenditures serve as an accurate proxy for net disposable income.

I include multiple demographic characteristics as control variables, following the literature (Currie and Thomas, 1972; Harmon, 1988; Vesterberg, 2016): *dwelling* is the dummy variable for the type of dwelling; it equals 0 if a household lives in its own, in a cooperative, or in a privately owned flat or house, and it equals 1 if the household rents or resides for free (with relatives or friends). The variable *size* stands for the size of the municipality (ranging from 1 for villages below five hundred inhabitants to 8 for cities with more than one hundred thousand inhabitants).[3] Finally, since household composition influences consumption behaviour, I include a dummy variable indicating the presence of at least one child (*child*). Measuring the impact of a child on household consumption requires extending the model to determine whether the number of dependent children moderates the consumption–income relationship:

$$ln(c_i) = \alpha_i + \beta ln(M_i) + \sum_{j=1}^{n} \gamma_j X_j + \delta ln(M_i) \times child + \epsilon\,. \tag{2}$$

Here, the coefficient δ in front of the cross variable indicates whether the interaction of M_i and *child* strengthens or weakens consumers' sensitivity to the income change. When the moderation effect is significant, I use the corresponding β estimates for childless households and the sum $\beta + \delta$ for households with children.

Additionally, I add a price variable in the form of the consumer price index for individual consumer categories from the Czech Statistical Office (CZSO, 2022) to adjust income elasticity for the potential impacts of price changes during the three-year periods. However, adding the price index to the models leads to neither significant estimates nor better results, which I evaluate according to the coefficient of determination and using the Akaike's Information Criteria (AIC) and Bayesian Information Criteria (BIC). Hence, I do not continue to use those extended models.

For the subsequent simulation, I use the year-on-year change in disposable income due to the minimum wage change, the estimated income elasticity of consumption, and the amount and structure of consumption of typical households. The income elasticity of a specific consumption category *c* is defined as follows:

$$e_c = \frac{\Delta c}{\Delta M} \times \frac{M}{c}\,. \tag{3}$$

By a simple transformation, I calculate the relative change in expenditures by consumption category. By doing so, I simulate the new consumption structure after the change in the minimum wage.

[3] 1 = 499 inhabitants or fewer; 2 = 500–999; 3 = 1 000–1 999; 4 = 2 000–4 999; 5 = 5 000–9 999; 6 = 10 000–49 999; 7 = 50 000–99 999; 8 = 100 000 or more.

3 RESULTS

This section presents the income-elasticity estimates and then the results of simulations. Table A3 in the Appendix 1 displays the descriptive statistics by period. The coefficient estimates representing the elasticities are positive and statistically significant, except for educational expenditures in the third period.

The most elastic category is clothing and footwear in the third period, with elasticity of 3.6. Based on the estimates, transport (*c07*), alcoholic beverages and tobacco (*c02*), and restaurants and accommodation services (*c11*) fall under the luxury category. In contrast, food and nonalcoholic beverages (*c01*), housing, water, electricity, gas and other fuels (*c04*; except for the second period), and education services (c10) can be considered as necessities. Regarding the broader categories, nondurable goods (*c_nd*) fall under the heading of necessities. At the same time, the results indicate high elasticity of durable goods (*c_d*), lower elasticity for semidurables (*c_sd*), and approximately unitary elasticity for services. Table A4 in the Appendix 1 shows those results for the twelve consumption categories, and Table A5 presents the regression estimates for broader categories according to durability.

Following the outlined methodology, I run the second set of regressions, which tests whether the relationship between income and consumption is moderated by having children. The cross variable's positive and statistically significant coefficient indicates a strengthening mediation effect of having children. In other words, having at least one child raises a household's income elasticity. The regression results are presented in the Appendix 1 in Tables A6 and A7. In the first period, I found a sign of mediation effect in the case of health (*c06*) and education (*c10*); the *ln(M)* estimate for childless households was insignificant, and education was highly elastic for households with children. The income elasticity of other goods and services (*c12*) was mediated by children's presence. The potential mediation effect

Table 2 Income elasticities of consumption by period and household type

Consumption categories	2011–2013			2014–2016			2017–2019		
	1 + 0	1 + 2	2 + 2	1 + 0	1 + 2	2 + 2	1 + 0	1 + 2	2 + 2
c01	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8
c02	2	2	2	2	2	2	1.6	1.6	1.6
c03	1.4	1.4	1.4	1.7	1.7	1.7	3.6	3.6	3.6
c04	0.6	0.6	0.6	1.1	1.1	1.1	0.7	0.7	0.7
c05	1.8	1.8	1.8	1.4	1.4	1.4	2.1[a]	0.4[a]	0.4[a]
c06	1.1[a]	2.1[a]	2.1[a]	1.3	1.3	1.3	2.4	2.4	2.4
c07	2.2	2.2	2.2	1.1[a]	2[a]	2[a]	2.3	2.3	2.3
c08	1.1	1.1	1.1	1.1	1.1	1.1	0.9	0.9	0.9
c09	1.5	1.5	1.5	1.4	1.4	1.4	1.3	1.3	1.3
c10	0.2[a]	2.6[a]	2.6[a]	0.3[a]	2.5[a]	2.5[a]	0.4	0.4	0.4
c11	2.2	2.2	2.2	2.8[a]	1.6[a]	1.6[a]	1.5	1.5	1.5
c12	1.1[a]	1.5[a]	1.5[a]	1.3	1.3	1.3	1.6	1.6	1.6
c_nd	0.9	0.9	0.9	0.8	0.8	0.8	0.9	0.9	0.9
c_sd	1.3	1.3	1.3	1.3	1.3	1.3	2.3[a]	1.1[a]	1.1[a]
c_d	4.3	4.3	4.3	3.5	3.5	3.5	2.7	2.7	2.7
c_s	1	1	1	1.1	1.1	1.1	0.8[a]	1.4[a]	1.4[a]

Note: [a] the altered elasticities with mediation effect. For abbreviations, see Table A1 in the Appendix 1.
Source: Own calculations

on transport (*c07*) weakened the impact of income change on restaurants and accommodation services (*c11*) in the second period and on furnishings, household equipment, and routine household maintenance (*c05*) in the third period. Regarding the broader categories, I found a mediation effect only in the third period: a weakening effect on consumption of semidurables (driven by household equipment) and a strengthening effect on services (with rents, communication, and financial and recreation-related services as the main items). The diagnostics for the regressions are presented in the Appendix 2.

I present the final income elasticities in Table 2. I use the same estimated elasticities for each year in the given period and for both household types with children. But I differentiate the elasticities between the types of households for cases in which I found a potential moderation effect. I distinguish the latter cases with an index.

I do not report the years with no minimum wage change in the rest of the paper. By combining a relative change of income with the estimated elasticities, I obtain the relative change of expenditures on each consumption category (Table 3). By definition, the higher the income elasticity, the higher the relative consumption change. The major relative changes concern luxuries, such as clothing and footwear (*c03*) and durable goods in general. In contrast, the insensitive reaction relates to the consumption of food (*c01*), housing (*c04*), and nondurables.

However, to present the whole picture, the relative importance of each expenditure needs to be considered. For example, the extreme response of consumption of durables plays a minor role because its mean share in the household budget lies between 1% and 3%, depending on the type of household. I thus present the decomposed change of total expenditures in Table 4. The table shows

Table 3 The relative change of expenditures on each consumption category due to change in the minimum wage by year and type of household

Consumption categories	1 + 0						1 + 2						2 + 2					
	2013	2015	2016	2017	2018	2019	2013	2015	2016	2017	2018	2019	2013	2015	2016	2017	2018	2019
c01	3%	4%	4%	6%	5%	5%	2%	3%	3%	4%	3%	3%	2%	3%	2%	4%	3%	3%
c02	9%	11%	11%	11%	10%	9%	5%	7%	7%	7%	6%	6%	5%	7%	7%	7%	6%	6%
c03	6%	9%	9%	24%	23%	20%	4%	6%	6%	16%	14%	13%	4%	6%	6%	15%	14%	13%
c04	3%	6%	6%	4%	4%	4%	2%	4%	4%	3%	3%	2%	2%	4%	4%	3%	3%	2%
c05	8%	8%	8%	14%	13%	12%	5%	5%	5%	2%	1%	1%	5%	5%	5%	2%	1%	1%
c06	5%	8%	7%	16%	15%	14%	6%	5%	5%	11%	9%	9%	6%	5%	5%	10%	9%	9%
c07	10%	6%	6%	15%	14%	13%	6%	7%	7%	10%	9%	8%	6%	7%	7%	10%	9%	8%
c08	5%	6%	6%	6%	5%	5%	3%	4%	4%	4%	3%	3%	3%	4%	4%	4%	3%	3%
c09	7%	8%	7%	8%	8%	7%	4%	5%	5%	6%	5%	5%	4%	5%	5%	5%	5%	5%
c10	1%	2%	2%	3%	2%	2%	7%	9%	9%	2%	2%	1%	7%	9%	8%	2%	1%	1%
c11	10%	16%	15%	10%	10%	9%	6%	6%	6%	7%	6%	6%	6%	6%	6%	7%	6%	6%
c12	5%	7%	7%	10%	10%	9%	4%	5%	5%	7%	6%	6%	4%	5%	4%	7%	6%	6%
c_nd	4%	5%	4%	6%	6%	5%	2%	3%	3%	4%	4%	3%	2%	3%	3%	4%	4%	3%
c_sd	6%	8%	7%	15%	14%	13%	4%	5%	5%	5%	4%	4%	4%	5%	5%	4%	4%	4%
c_d	19%	20%	19%	18%	17%	15%	11%	12%	12%	12%	10%	10%	11%	12%	12%	11%	10%	9%
c_s	5%	6%	6%	5%	5%	4%	3%	4%	4%	6%	5%	5%	3%	4%	4%	6%	5%	5%

Note: %ΔM represents a percentage change of disposable income. Unitary elasticity would change the consumption expenditure by the same rate.
Source: Own calculations

that households spend the vast majority of the additional income on nondurables and services. In more detail, the minimum wage earner with two children allocates more additional income to food (*c01*) and housing (*c04*). Two-adult households spend relatively less on housing.

The final point of view presented in Table 5 compares the original and the new consumption structure and highlights the shift in the importance of the categories in the consumption mix. Across household types, food (*c01*), housing (*c04*), and nondurables become less important – falling by more than 100 basis points (1 percentage point) – after the minimum wage increases. All household types consistently, though fractionally, increase their share of the following consumption categories: alcohol, beverages, tobacco and narcotics (*c02*), clothing and footwear (*c03*), restaurants and accommodation services (*c11*), other goods and services (*c12*), and durables.

Table 4 Decomposition of total expenditure change (separately for the twelve consumption categories and the four broader categories)

Consumption categories	1 + 0						1 + 2						2 + 2					
	2013	2015	2016	2017	2018	2019	2013	2015	2016	2017	2018	2019	2013	2015	2016	2017	2018	2019
c01	13%	11%	11%	15%	14%	14%	15%	14%	15%	18%	20%	15%	16%	15%	18%	20%	18%	20%
c02	5%	6%	5%	7%	5%	5%	3%	3%	3%	2%	5%	3%	5%	3%	2%	6%	5%	2%
c03	6%	7%	6%	12%	13%	13%	6%	7%	7%	21%	13%	11%	4%	7%	9%	9%	17%	12%
c04	16%	24%	25%	17%	14%	17%	18%	27%	26%	17%	15%	22%	13%	22%	15%	16%	10%	14%
c05	7%	5%	5%	6%	7%	7%	5%	4%	4%	1%	2%	1%	4%	4%	3%	2%	1%	1%
c06	2%	2%	2%	2%	4%	5%	3%	2%	2%	3%	2%	4%	2%	1%	1%	1%	2%	6%
c07	14%	7%	7%	11%	12%	9%	11%	11%	10%	12%	12%	10%	21%	15%	16%	15%	19%	14%
c08	5%	5%	4%	4%	3%	4%	6%	5%	5%	4%	6%	5%	6%	6%	5%	4%	4%	4%
c09	11%	10%	9%	8%	8%	9%	9%	8%	7%	7%	8%	8%	7%	6%	5%	8%	10%	8%
c10	0%	0%	0%	0%	0%	0%	2%	2%	2%	1%	0%	0%	1%	2%	1%	0%	1%	0%
c11	9%	11%	12%	10%	9%	7%	9%	8%	8%	7%	8%	9%	6%	6%	8%	4%	8%	11%
c12	12%	13%	13%	10%	10%	9%	12%	10%	10%	7%	9%	11%	15%	13%	16%	14%	6%	9%
c_nd	37%	35%	36%	52%	46%	42%	42%	40%	40%	40%	48%	29%	49%	42%	46%	47%	51%	50%
c_sd	12%	13%	12%	20%	24%	21%	12%	13%	13%	13%	10%	7%	13%	15%	17%	10%	12%	11%
c_d	13%	10%	10%	2%	6%	8%	9%	7%	9%	3%	6%	5%	5%	6%	3%	2%	1%	1%
c_s	37%	42%	42%	25%	25%	29%	37%	41%	38%	45%	36%	59%	33%	37%	34%	41%	37%	39%

Source: Own calculations

Table 5 Change of the share in total consumption expenditure (basis points)

Consumption categories	1 + 0						1 + 2						2 + 2					
	2013	2015	2016	2017	2018	2019	2013	2015	2016	2017	2018	2019	2013	2015	2016	2017	2018	2019
c01	–32	–53	–49	–49	–53	–42	–23	–38	–40	–36	–27	–17	–31	–42	–49	–30	–43	–32
c02	11	15	13	14	8	8	4	5	5	2	7	4	7	5	3	8	5	3
c03	5	11	10	58	62	55	3	8	9	70	37	28	2	8	9	29	51	32
c04	–61	–22	–22	–107	–100	–97	-42	–12	–11	–68	–43	–56	–36	–12	–7	–51	–46	–43
c05	13	5	5	17	21	20	6	2	3	–12	–17	–9	4	3	2	–15	–6	–10

Table 5 (continuation)

Consumption categories	1 + 0						1 + 2						2 + 2					
	2013	2015	2016	2017	2018	2019	2013	2015	2016	2017	2018	2019	2013	2015	2016	2017	2018	2019
c06	0	1	1	6	14	15	4	1	1	8	4	9	3	0	0	3	3	12
c07	32	–3	–3	39	39	26	16	19	16	28	25	20	29	26	26	35	40	27
c08	0	–5	–4	–11	–12	–10	0	–3	–3	–7	–7	–5	–1	–3	–3	–5	–9	–6
c09	12	6	5	3	0	2	6	4	4	3	4	4	4	3	2	4	0	2
c10	–1	–1	–1	–1	–4	0	3	3	3	–6	–3	–1	2	3	2	–2	–6	–3
c11	20	40	41	15	11	10	14	9	9	9	10	10	9	6	8	5	6	10
c12	0	5	4	16	14	13	9	3	4	9	10	13	10	3	4	18	5	9
c_nd	–46	–66	–62	–31	–43	–32	–24	–39	–42	–43	–42	–39	–21	–38	–34	–41	–35	–33
c_sd	11	15	14	71	78	63	8	10	10	–4	–2	–4	9	13	14	–2	–1	–1
c_d	45	41	37	9	22	25	18	17	22	7	14	11	9	14	7	5	3	2
c_s	–10	11	11	–49	–58	–57	–1	11	9	40	30	32	2	12	13	38	33	32

Source: Own calculations

4 DISCUSSION

Increases in the minimum wage increase the consumption expenditures of affected households. This effect is driven by the inelastic subcategories within the broad categories of nondurables and services, such as food and housing. Low-income households spend a substantial share of income on those essentials, yet their sensitivity to income shocks remains relatively high. Therefore, more than three-quarters of the additional income is allocated to nondurables and services. This is consistent with Alonso's (2016) finding of a positive effect on nondurables. The affected households decrease the share of nondurables, and single childless households also reduce the share of services. Yet the importance of services remains profound.

Take the housing category as an example. Its income elasticity exceeds one in the second period, even though the existing literature uniformly considers housing necessary (Harmon, 1988; Hansen et al., 1996). Such a finding suggests that low-income households have not sufficiently satisfied their housing needs, be they electricity, heating, water, or dwellings. Also, consistently with Engel's law (Houthakker, 1957) and a rich empirical literature (Murty, 1981; Ogundari and Abdulai, 2013; Santeramo and Shabnam, 2015; Ogundari et al., 2016), expenditures on food and nonalcoholic beverages are income inelastic. The minimum wage change decreased the proportion of food expenditures up to 50 basis points. This impact is similar for all household types and in all periods. Nonetheless, a more detailed analysis might detect significant changes within the food category as suggested by Huang and Gale (2009).

Aaronson et al. (2012) argue that the minimum wage's impact on consumption is driven by spending on durables. Durables indeed do record the most significant increase in consumption: up to one-fifth of the total increase. Still, durables occupy a negligible part of low-income households' budgets. Nevertheless, many households who purchased a vehicle were filtered out of the dataset because such outliers significantly distorted the consumption structure in the year the purchase was made, so interpreting the result requires caution.

The sensitivity of childless households' consumption sometimes differs from that of households with children. This difference is manifested mainly in semidurables, whose budget share increased by up to 78 basis points for childless households whereas its share fell among households with children. This category includes consumer goods, which may still be an unaffordable luxury for poorer parents.

The opposite effect can be observed in services, the importance of which decreases significantly in childless households and increases in households with children.

The high sensitivity of health expenditures is expected given the comprehensive coverage by the public sector. Childless households may be older and have higher mean share of health expenses which is directly connected to the potential strengthening mediation effect. The same applies to education: though it is a marginal category of consumption, I found a strong positive mediation effect. Offspring may require extra educational costs not covered by the public system, such as tuition, tutoring, and kindergarten. The higher elasticity may indicate a willingness of parents to incur these expenses, yet their willingness is constrained by disposable income. Both effects are supported by Dautović (2017), who considers health and education the drivers of consumption increases among households with children.

Low-income households spend limited resources on addictive goods, such as alcohol, tobacco, and narcotics. I found that households consistently spend a higher share of their budget on those items following a positive income shock. The effect is driven by the goods' high elasticity, indicating these goods are non-essentials for low-income households. Similarly, Franks et al. (2007) find higher income elasticity of tobacco among low-income households relative to higher-income groups. The corresponding increase in the budget share of households with children is much lower. Clearly, only a marginal amount of additional income due to minimum wage hikes is allocated to alcohol and tobacco.

Consumption of furnishings, household equipment, and routine household maintenance seems inelastic among households with children in the third studied period. Their insensitive reaction to an income shock may relate to their prioritising of other categories over inessential equipment. Increased purchasing power between the second and the third period given by the fastest growth of the minimum wage increased spending on the categories of clothing and footwear and of recreation, sport, and culture. Overall, these categories do not affect the consumption structure much.

According to both the existing literature and my findings, restaurants and accommodation services are considered nonessentials. Because of its higher share in the budget, the category gains considerably higher share after the minimum wage increases in 1 + 0 households, especially in 2012 and 2013. The proportion of transport expenditures grows with minimum wage hikes and constitutes up to a fifth of additional spending. The category of information and communication goods and services mostly loses share in the consumption structure but has close to unitary elasticity regardless of time period and household type. Other goods and services increase their share by up to 18 basis points in response to minimum wage hikes. The mediation effect is significant, but it does not change the nature of those expenditures.

CONCLUSION

In this paper, I examined the relationship between minimum wage changes and consumption structure in the Czech Republic. My findings suggest that the growth of households' working income is associated with a general shift in consumption structure from necessary nondurable goods to luxury durable goods, especially in one-member households. Yet the share of essentials in the family budget remains substantial. Moreover, health and education spending are very sensitive to income shocks in households with children, and parents in those households consider alcohol and tobacco luxuries.

The HBS dataset is commonly used for demand analysis. Narrow focus of this paper on the low-income households required to merge multiple years into one period. Using a different dataset with more observations or defining the low-income threshold less restrictively might offer more robust estimates. It could also allow for more detailed analysis beyond the general COICOP categories.

Further investigation may offer more profound insight into what happens within the general categories, especially in the case of so-called sin consumption. My results for the category of alcohol, tobacco, and narcotics contradict the standard finding that addictive goods are inelastic, and they may contribute

to the academic and policy discussion about regressivity of excise taxes. A policy application, however, requires more detailed analysis of consumption items. Empirical studies focused on low-income households could take advantage of my dataset construction to study other specified subgroups of households in more detail. Comparative research of various regions with more restrictive wage policies or with different minimum wage policy-making regimes may shed more light on the role of the type of income shock. My results represent a substantial input for shaping public policies targeting the working poor.

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APPENDIX 1

Table A1 COICOP classification

Abbrev.	Name of the category
c01	Food and nonalcoholic beverages
c02	Alcoholic beverages, tobacco and narcotics
c03	Clothing and footwear
c04	Housing, water, electricity, gas and other fuels
c05	Furnishings, household equipment and routine household maintenance
c06	Health
c07	Transport
c08	Information and communication
c09	Recreation, sport and culture
c10	Education services
c11	Restaurants and accommodation services
c12	Other goods and services
c_nd	Nondurable consumption
c_sd	Semidurable consumption
c_d	Durable consumption
c_s	Services

Source: CZ-COICOP (n.d.)

Table A2 Net disposable income and shares of consumption categories by household type

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Household type 1 + 0									
Income	9 847	10 026	10 015	10 473	11 075	11 746	12 576	13 261	14 121
c01	19%	20%	20%	20%	20%	19%	21%	21%	21%
c02	3%	3%	3%	3%	4%	3%	6%	4%	4%
c03	5%	5%	5%	5%	5%	5%	4%	5%	4%
c04	29%	29%	29%	28%	27%	29%	31%	28%	32%
c05	4%	4%	4%	4%	4%	5%	3%	5%	4%
c06	3%	2%	2%	2%	2%	2%	1%	2%	2%

Table A2 (continuation)

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Household type 1 + 0									
c07	7%	7%	7%	7%	7%	7%	6%	7%	5%
c08	5%	5%	5%	5%	5%	5%	5%	5%	5%
c09	9%	9%	8%	8%	9%	8%	8%	8%	9%
c10	0%	0%	0%	0%	0%	0%	0%	1%	0%
c11	5%	4%	4%	5%	5%	5%	8%	7%	6%
c12	11%	12%	12%	12%	13%	12%	8%	8%	7%
c_nd	47%	48%	47%	47%	47%	47%	57%	53%	48%
c_sd	10%	10%	10%	10%	10%	10%	9%	11%	10%
c_d	3%	3%	3%	3%	3%	3%	1%	2%	3%
c_s	40%	39%	39%	40%	40%	40%	33%	34%	40%
Household type 1 + 2									
Income	14 696	16 644	16 634	17 091	17 843	17 798	18 902	21 209	22 127
c01	24%	24%	23%	23%	24%	25%	26%	27%	20%
c02	2%	2%	2%	1%	2%	2%	1%	4%	2%
c03	5%	5%	5%	5%	5%	5%	7%	4%	3%
c04	30%	31%	32%	30%	30%	28%	31%	25%	37%
c05	3%	3%	3%	3%	3%	4%	4%	6%	4%
c06	2%	2%	2%	2%	2%	2%	2%	1%	2%
c07	5%	5%	6%	7%	7%	6%	6%	6%	5%
c08	6%	6%	6%	6%	6%	6%	5%	7%	6%
c09	8%	7%	7%	8%	7%	7%	6%	7%	6%
c10	1%	1%	1%	1%	1%	1%	2%	1%	0%
c11	5%	5%	5%	5%	6%	6%	6%	6%	7%
c12	9%	9%	9%	10%	10%	10%	6%	6%	8%
c_nd	49%	50%	51%	49%	51%	52%	49%	58%	38%
c_sd	11%	10%	9%	10%	10%	10%	14%	10%	9%
c_d	2%	3%	2%	2%	2%	3%	1%	2%	2%
c_s	39%	37%	37%	39%	37%	35%	36%	29%	51%
Household type 2 + 2									
Income	14 696	16 644	16 634	17 091	17 843	18 575	19 778	21 563	22 587
c01	27%	26%	26%	25%	25%	31%	27%	28%	29%
c02	4%	4%	3%	2%	2%	1%	4%	4%	2%
c03	4%	4%	4%	4%	5%	6%	3%	6%	4%
c04	26%	28%	24%	28%	24%	17%	27%	20%	24%
c05	3%	3%	3%	4%	4%	3%	5%	2%	4%
c06	2%	1%	1%	2%	1%	1%	1%	1%	3%

Table A2 (continuation)

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Household type 2 + 2									
c07	7%	8%	12%	11%	9%	10%	8%	11%	7%
c08	5%	5%	7%	6%	6%	6%	5%	6%	5%
c09	6%	7%	6%	5%	6%	5%	7%	10%	7%
c10	1%	1%	0%	0%	1%	1%	1%	2%	1%
c11	4%	5%	3%	4%	5%	6%	3%	7%	8%
c12	10%	9%	12%	10%	12%	15%	10%	5%	7%
c_nd	58%	58%	57%	54%	53%	56%	57%	59%	59%
c_sd	10%	10%	10%	10%	11%	13%	10%	12%	11%
c_d	2%	1%	1%	2%	2%	1%	1%	1%	0%
c_s	30%	31%	32%	33%	34%	31%	33%	28%	30%

Note: Net disposable income is expressed in CZK per month and represents the net family income.
Source: Own calculations, OECD (2022)

Table A3 Descriptive statistics by period (mean in CZK per month)

	2011–2013			2014–2016			2017–2019		
	Mean	sd	Mean share	Mean	sd	Mean share	Mean	sd	Mean share
Total	13 812	2 600	–	14 204	2 696	–	17 063	3 824	–
c01	2 938	1 060	21%	2 987	1 057	21%	4100	1 724	24%
c02	401	553	3%	426	615	3%	719	837	4%
c03	636	442	5%	683	462	5%	763	859	4%
c04	3 941	1 606	29%	3 886	1 645	28%	4 902	2 139	29%
c05	559	506	4%	569	499	4%	733	810	4%
c06	285	307	2%	286	306	2%	302	397	2%
c07	983	900	7%	1 088	930	8%	1 086	1 194	6%
c08	764	431	6%	750	388	5%	932	565	6%
c09	1 122	801	8%	1 106	798	8%	1 223	948	7%
c10	62	229	0%	47	149	0%	75	289	0%
c11	602	552	4%	680	647	5%	1 015	1 041	6%
c12	1 520	828	11%	1 698	963	12%	1 216	1 075	7%
c_nd	6 848	2 038	50%	6 941	2 098	49%	9 463	3 236	56%
c_sd	1 351	774	10%	1 432	805	10%	1 767	1 326	10%
c_d	413	592	3%	419	572	3%	321	737	2%
c_s	5 200	1 951	38%	5 413	2 069	38%	5 512	2 748	33%

Note: Total represents total consumption expenditures, mean is in CZK per month, sd represents standard deviation, mean share indicates mean share of the consumption category of total spending.
Source: Own calculations

Table A4 Regression-parameter estimates of the twelve consumption categories

Independent variables	*ln(c01)*	*ln(c02)*	*ln(c03)*	*ln(c04)*	*ln(c05)*	*ln(c06)*	*ln(c07)*	*ln(c08)*	*ln(c09)*	*ln(c10)*	*ln(c11)*	*ln(c12)*
2011–2013												
ln(M)	0.738***	2.023***	1.386***	0.631***	1.827***	1.343***	2.170***	1.142***	1.469***	0.774***	2.196***	1.220***
	(17.85)	(8.02)	(9.85)	(6.47)	(17.13)	(8.27)	(10.14)	(8.41)	(16.44)	(3.34)	(8.52)	(15.54)
Child	0.218***	−0.857***	0.0820	0.0523	−0.257***	−0.201**	−0.114	0.168***	−0.156***	1.974***	0.323***	−0.210***
	(12.41)	(−7.46)	(1.34)	(1.40)	(−5.59)	(−2.65)	(−1.36)	(3.34)	(−4.25)	(14.50)	(3.50)	(−6.29)
Size	−0.0214***	−0.114***	−0.0166	0.0993***	−0.0291**	0.0398*	−0.173***	−0.0423***	0.00570	0.0459*	−0.0894***	−0.0530***
	(−5.62)	(−5.07)	(−1.27)	(10.78)	(−2.79)	(2.44)	(−11.92)	(−4.02)	(0.66)	(2.01)	(−4.01)	(−7.01)
Dwelling	−0.115***	0.425***	−0.169*	−0.0543	−0.229***	−0.333***	0.0854	0.0138	−0.153***	0.135	0.263*	−0.176***
	(−6.07)	(4.04)	(−2.57)	(−0.98)	(−4.55)	(−4.28)	(1.05)	(0.26)	(−3.61)	(1.17)	(2.57)	(−4.94)
Constant	0.992*	−13.58***	−6.930***	1.586	−11.12***	−7.779***	−13.36***	−4.265***	−7.134***	−7.208**	−14.93***	−4.047***
	(2.53)	(−5.67)	(−5.16)	(1.68)	(−11.05)	(−5.06)	(−6.57)	(−3.32)	(−8.42)	(−3.28)	(−6.07)	(−5.40)
N	1 443	1 443	1 443	1 443	1 443	1 443	1 443	1 443	1 443	1 443	1 443	1 443
adj. R-sq	0.297	0.088	0.081	0.124	0.176	0.059	0.127	0.083	0.172	0.196	0.083	0.186
AIC	705.0	5 756.8	4 033.7	2 821.3	3 506.7	4 716.6	5 110.4	3 713.4	2 845.7	5 877.7	5 712.3	2 492.2
BIC	731.4	5 783.2	4 060.1	2 847.7	3 533.1	4 743.0	5 136.7	3 739.7	2 872.1	5 904.1	5 738.6	2 518.5
2014–2016												
ln(M)	0.710***	2.017***	1.674***	1.072***	1.437***	1.328***	2.550***	1.056***	1.356***	0.746**	2.599***	1.294***
	(16.04)	(7.28)	(10.97)	(5.95)	(10.66)	(7.08)	(10.65)	(8.30)	(14.21)	(3.20)	(8.67)	(14.40)
Child	0.229***	−1.018***	0.0886	0.0931*	−0.205***	−0.135	−0.200*	0.187**	−0.199***	2.164***	0.323**	−0.231***
	(12.03)	(−7.70)	(1.41)	(2.19)	(−3.75)	(−1.45)	(−2.13)	(3.22)	(−4.46)	(13.92)	(2.94)	(−5.92)
Size	−0.0170***	−0.119***	0.00241	0.104***	−0.0366**	0.0122	−0.197***	−0.0361***	0.00423	0.0185	−0.0720**	−0.0498***
	(−4.31)	(−4.90)	(0.17)	(8.84)	(−2.88)	(0.62)	(−12.41)	(−3.36)	(0.46)	(0.81)	(−3.01)	(−5.95)
Dwelling	−0.0917***	0.262*	−0.0791	−0.148	−0.300***	−0.278**	0.0948	0.111*	−0.121*	0.344**	0.117	−0.248***
	(−4.97)	(2.18)	(−1.25)	(−1.90)	(−4.54)	(−2.77)	(1.10)	(2.32)	(−2.49)	(2.83)	(0.97)	(−6.09)

Table A4 (continuation)

Independent variables	*ln(c01)*	*ln(c02)*	*ln(c03)*	*ln(c04)*	*ln(c05)*	*ln(c06)*	*ln(c07)*	*ln(c08)*	*ln(c09)*	*ln(c10)*	*ln(c11)*	*ln(c12)*
2014–2016												
Constant	1.235**	−13.52***	−9.765***	−2.677	−7.377***	−7.581***	−16.79***	−3.532**	−6.112***	−6.933**	−18.84***	−4.697***
	(2.93)	(−5.11)	(−6.64)	(−1.56)	(−5.75)	(−4.27)	(−7.33)	(−2.95)	(−6.75)	(−3.14)	(−6.57)	(−5.46)
N	1 223	1 223	1 223	1 223	1 223	1 223	1 223	1 223	1 223	1 223	1 223	1223
adj. R-sq	0.317	0.086	0.118	0.124	0.118	0.040	0.177	0.099	0.143	0.245	0.094	0.206
AIC	457.5	4 963.4	3 333.7	2 969.5	3 161.9	4 262.8	4 242.7	2 854.5	2 504.9	4 808.1	4 943.3	2 184.1
BIC	483.0	4 989.0	3 359.3	2 995.0	3 187.4	4 288.4	4 268.3	2 880.0	2 530.4	4 833.7	4 968.8	2 209.6
2017–2019												
ln(M)	0.846***	1.639**	3.612***	0.657***	1.872***	2.414***	2.271***	0.858*	1.279***	0.375	1.547*	1.569***
	(9.88)	(3.26)	(5.84)	(6.91)	(7.58)	(4.37)	(3.79)	(2.24)	(7.34)	(0.98)	(2.28)	(5.95)
Child	0.249***	−0.160	−0.300	0.0434	−0.0647	−0.476	−0.639	0.151	−0.197	2.162***	0.0446	0.0788
	(5.66)	(−0.75)	(−0.86)	(0.78)	(−0.48)	(−1.43)	(−1.83)	(0.76)	(−1.94)	(6.45)	(0.14)	(0.65)
Size	−0.0297**	−0.0325	0.103	0.0413***	−0.0232	−0.0618	−0.101	0.0639	−0.00782	0.0286	0.101	−0.0181
	(−2.99)	(−0.68)	(1.48)	(3.65)	(−0.80)	(−0.93)	(−1.53)	(1.50)	(−0.39)	(0.61)	(1.63)	(−0.66)
Dwelling	−0.0662	0.361	−0.191	0.309***	−0.183	−0.517	−0.896*	−0.204	−0.193	−0.151	0.288	−0.415**
	(−1.42)	(1.62)	(−0.57)	(5.52)	(−1.32)	(−1.47)	(−2.46)	(−0.93)	(−1.71)	(−0.72)	(1.02)	(−3.05)
Constant	0.0959	−10.17*	−30.33***	1.725	−11.94***	−18.69***	−15.54**	−2.206	−5.475**	−3.481	−9.745	−8.432**
	(0.12)	(−2.07)	(−5.07)	(1.85)	(−4.95)	(−3.48)	(−2.67)	(−0.58)	(−3.23)	(−0.93)	(−1.50)	(−3.30)
N	301	301	301	301	301	301	301	301	301	301	301	301
adj. R-sq	0.370	0.039	0.099	0.227	0.169	0.055	0.066	0.026	0.142	0.222	0.025	0.146
AIC	240.1	1 219.3	1 424.5	329.9	870.0	1 390.8	1 412.7	1 082.5	691.1	1 219.5	1 364.6	888.3
BIC	258.6	1 237.8	1 443.1	348.4	888.6	1 409.3	1 431.3	1 101.0	709.6	1 238.0	1 383.2	906.8

Note: ***, ** and * indicate significance at 0.1%, 1%, and 5% respectively, robust standard deviation is in parentheses.
Source: Own calculations

Table A5 Regression-parameter estimates of broad consumption categories

	2011–2013				2014 –2016				2017–2019			
	ln(c_nd)	*ln(c_sd)*	*ln(c_d)*	*ln(c_s)*	*ln(c_nd)*	*ln(c_sd)*	*ln(c_d)*	*ln(c_s)*	*ln(c_nd)*	*ln(c_sd)*	*ln(c_d)*	*ln(c_s)*
ln(M)	0.856***	1.348***	4.261***	1.025***	0.810***	1.348***	3.496***	1.125***	0.908***	2.121***	2.671***	0.835***
	(26.77)	(17.44)	(14.96)	(21.26)	(23.45)	(15.68)	(11.07)	(22.06)	(12.98)	(7.65)	(4.09)	(7.14)
Child	0.0820***	0.0545	−0.613***	−0.0667***	0.0938***	0.0423	−0.763***	−0.0963***	0.0342	−0.0133	0.0368	0.0411
	(6.30)	(1.54)	(-4.75)	(−3.48)	(6.10)	(1.11)	(−5.21)	(−4.12)	(1.02)	(−0.12)	(0.09)	(0.63)
Size	−0.0402***	−0.0117	0.0284	0.0536***	−0.0398***	−0.00764	0.0133	0.0506***	−0.0568***	0.00902	0.0469	0.0900***
	(−14.47)	(−1.47)	(1.06)	(13.03)	(−13.11)	(−0.89)	(0.45)	(12.10)	(−7.59)	(0.33)	(0.62)	(5.63)
Dwelling	−0.200***	−0.0782*	−0.231	0.219***	−0.202***	−0.0565	−0.129	0.227***	−0.128***	−0.129	−0.0311	0.209**
	(−12.34)	(−2.09)	(−1.83)	(11.93)	(−11.65)	(−1.41)	(−0.95)	(11.89)	(−3.36)	(−0.96)	(−0.08)	(2.74)
Constant	0.899**	−5.725***	−35.83***	−1.624***	1.318***	−5.721***	−28.45***	−2.541***	0.564	−13.55***	−23.20***	−0.126
	(2.98)	(−7.79)	(−13.20)	(−3.55)	(4.02)	(−6.97)	(−9.42)	(−5.25)	(0.83)	(−5.06)	(−3.67)	(−0.11)
N	1443	1443	1443	1443	1223	1223	1223	1223	301	301	301	301
adj. R-sq	0.459	0.178	0.143	0.405	0.463	0.183	0.107	0.430	0.517	0.203	0.042	0.262
AIC	−64.92	2 573.8	6 217.2	786.7	−62.76	2 160.1	5 248.7	655.0	56.50	875.3	1 486.5	434.8
BIC	−38.55	2 600.2	6 243.6	813.1	−37.22	2 185.6	5 274.3	680.5	75.03	893.9	1 505.0	453.3

Note: ***, ** and * indicate significance at 0.1%, 1%, and 5% respectively, robust standard deviation is in parentheses.
Source: Own calculations

Table A6 Regression-parameter estimates of the twelve consumption categories with a mediation effect

Independent variables	*ln(c01)*	*ln(c02)*	*ln(c03)*	*ln(c04)*	*ln(c05)*	*ln(c06)*	*ln(c07)*	*ln(c08)*	*ln(c09)*	*ln(c10)*	*ln(c11)*	*ln(c12)*
2011–2013												
log(M)	0.718***	1.843***	1.406***	0.695***	1.845***	1.117***	2.106***	1.193***	1.473***	0.225	2.302***	1.125***
	(14.72)	(6.81)	(8.90)	(6.06)	(14.60)	(6.22)	(8.96)	(7.83)	(14.13)	(1.01)	(7.47)	(13.05)
Child	−0.627	−8.317	0.907	2.691	0.455	−9.529*	−2.768	2.279	−0.00606	−20.72**	4.691	−4.136*
	(−0.72)	(−1.30)	(0.27)	(1.33)	(0.21)	(−2.51)	(−0.52)	(0.71)	(−0.00)	(−3.11)	(0.91)	(−2.20)
*ln(M)*child*	0.0885	0.781	−0.0864	−0.276	−0.0745	0.977*	0.278	−0.221	−0.0157	2.376***	−0.457	0.411*
	(0.96)	(1.17)	(−0.24)	(−1.30)	(−0.33)	(2.47)	(0.50)	(−0.67)	(−0.08)	(3.41)	(−0.85)	(2.09)
Size	−0.0212***	−0.113***	−0.0167	0.0989***	−0.0292**	0.0412*	−0.173***	−0.0426***	0.00568	0.0494*	−0.0901***	−0.0524***
	(−5.55)	(−5.00)	(−1.27)	(10.86)	(−2.79)	(2.54)	(−11.83)	(−4.03)	(0.65)	(2.17)	(−4.03)	(−6.93)
Dwelling	−0.115***	0.424***	−0.169*	−0.0542	−0.229***	−0.333***	0.0853	0.0140	−0.153***	0.133	0.264*	−0.177***
	(−6.07)	(4.04)	(−2.57)	(−0.98)	(−4.55)	(−4.28)	(1.05)	(0.26)	(−3.60)	(1.16)	(2.57)	(−4.95)
Constant	1.185*	−11.87***	−7.119***	0.982	−11.28***	−5.643***	−12.76***	−4.748**	−7.168***	−2.011	−15.93***	−3.148***
	(2.57)	(−4.63)	(−4.74)	(0.89)	(−9.46)	(−3.30)	(−5.72)	(−3.29)	(−7.28)	(−0.95)	(−5.43)	(−3.84)
N	1 443	1 443	1 443	1 443	1 443	1 443	1 443	1 443	1 443	1 443	1 443	1 443
adj. R-sq	0.297	0.088	0.080	0.124	0.175	0.062	0.126	0.083	0.171	0.205	0.083	0.188
AIC	706.2	5 756.9	4 035.6	2 821.5	3 508.6	4 712.4	5 112.0	3 714.7	2 847.7	5 863.2	5 713.6	2 489.0
BIC	737.8	5 788.5	4 067.3	2 853.1	3 540.3	4 744.1	5 143.6	3 746.4	2 879.4	5 894.8	5 745.2	2 520.7
2014–2016												
log(M)	0.701***	2.136***	1.778***	1.175***	1.414***	1.141***	2.252***	0.952***	1.413***	0.304	2.848***	1.206***
	(13.68)	(6.99)	(9.81)	(5.22)	(9.12)	(5.57)	(9.13)	(7.90)	(13.07)	(1.41)	(8.06)	(12.24)
Child	−0.170	4.541	4.963	4.886*	−1.274	−8.838	−14.12*	−4.670	2.433	−18.50*	11.96*	−4.342*
	(−0.18)	(0.67)	(1.72)	(1.99)	(−0.43)	(−1.87)	(−2.07)	(−1.16)	(1.12)	(−2.44)	(2.11)	(−1.96)
*ln(M)*child*	0.0416	−0.580	−0.508	−0.500	0.111	0.907	1.451*	0.506	−0.274	2.155**	−1.214*	0.429
	(0.42)	(−0.82)	(−1.70)	(−1.95)	(0.36)	(1.85)	(2.06)	(1.22)	(−1.22)	(2.73)	(−2.06)	(1.87)

Table A6 (continuation)

Independent variables	*ln(c01)*	*ln(c02)*	*ln(c03)*	*ln(c04)*	*ln(c05)*	*ln(c06)*	*ln(c07)*	*ln(c08)*	*ln(c09)*	*ln(c10)*	*ln(c11)*	*ln(c12)*
2014–2016												
Size	−0.0170***	−0.120***	0.00222	0.104***	−0.0366**	0.0126	−0.196***	−0.0359***	0.00412	0.0194	−0.0725**	−0.0497***
	(−4.30)	(−4.91)	(0.16)	(8.80)	(−2.87)	(0.64)	(−12.42)	(−3.38)	(0.44)	(0.85)	(−3.03)	(−5.93)
Dwelling	−0.0916***	0.260*	−0.0806	−0.149	−0.300***	−0.275**	0.0991	0.112*	−0.121*	0.350**	0.113	-0.247***
	(−4.96)	(2.16)	(−1.27)	(−1.91)	(−4.53)	(−2.74)	(1.15)	(2.35)	(−2.51)	(2.88)	(0.94)	(−6.07)
Constant	1.316**	−14.65***	−10.76***	−3.653	−7.159***	−5.809**	−13.96***	−2.543*	−6.648***	−2.726	−21.21***	−3.860***
	(2.70)	(−5.03)	(−6.17)	(−1.71)	(−4.85)	(−2.99)	(−5.92)	(−2.21)	(−6.47)	(−1.34)	(−6.28)	(−4.10)
N	1 223	1 223	1 223	1 223	1 223	1 223	1 223	1 223	1 223	1 223	1 223	1 223
adj. R-sq	0.317	0.085	0.119	0.126	0.118	0.042	0.183	0.101	0.143	0.252	0.096	0.208
AIC	459.3	4 964.6	3 333.4	2 968.5	3 163.8	4 261.4	4 235.8	2 853.1	2 505.6	4 797.7	4 941.8	2 181.9
BIC	490.0	4 995.3	3 364.1	2 999.1	3 194.4	4 292.1	4 266.4	2 883.7	2 536.2	4 828.4	4 972.4	2 212.6
2017–2019												
log(M)	0.836***	1.552**	3.750***	0.653***	2.082***	2.300***	1.861**	0.809	1.247***	0.168	1.361	1.456***
	(8.89)	(2.78)	(5.71)	(6.45)	(8.13)	(3.94)	(3.04)	(1.93)	(6.72)	(0.52)	(1.88)	(4.98)
Child	−0.552	−7.136	10.83	−0.282	16.89*	−9.650	−33.69	−3.826	−2.752	−14.51	−14.92	−9.040
	(−0.28)	(−0.67)	(0.54)	(−0.10)	(2.21)	(−0.54)	(−1.66)	(−0.44)	(−0.53)	(−0.70)	(−0.69)	(−1.69)
*ln(M)*child*	0.0816	0.711	−1.134	0.0331	−1.728*	0.935	3.367	0.405	0.260	1.699	1.524	0.929
	(0.41)	(0.66)	(−0.55)	(0.11)	(−2.22)	(0.52)	(1.64)	(0.46)	(0.49)	(0.80)	(0.70)	(1.70)
Size	−0.0294**	−0.0301	0.0997	0.0415***	−0.0289	−0.0588	−0.0899	0.0652	−0.00697	0.0342	0.106	−0.0150
	(−2.95)	(−0.63)	(1.40)	(3.61)	(−1.00)	(−0.88)	(−1.38)	(1.53)	(−0.35)	(0.74)	(1.71)	(−0.54)
Dwelling	−0.0663	0.361	−0.189	0.309***	−0.181	−0.518	−0.900*	−0.205	−0.193	−0.153	0.285	−0.416**
	(−1.42)	(1.62)	(−0.57)	(5.51)	(−1.30)	(−1.47)	(−2.50)	(−0.94)	(−1.71)	(−0.74)	(1.01)	(−3.06)
Constant	0.191	−9.342	−31.65***	1.763	−13.95***	−17.60**	−11.63	−1.735	−5.172**	−1.506	−7.973	−7.352**
	(0.21)	(−1.72)	(−5.00)	(1.78)	(−5.57)	(−3.11)	(−1.95)	(−0.42)	(−2.86)	(−0.47)	(−1.14)	(−2.60)

Table A6 (continuation)

Independent variables	*ln(c01)*	*ln(c02)*	*ln(c03)*	*ln(c04)*	*ln(c05)*	*ln(c06)*	*ln(c07)*	*ln(c08)*	*ln(c09)*	*ln(c10)*	*ln(c11)*	*ln(c12)*
2017–2019												
N	301	301	301	301	301	301	301	301	301	301	301	301
adj. R-sq	0.368	0.037	0.097	0.225	0.180	0.052	0.074	0.023	0.140	0.223	0.025	0.148
AIC	242.0	1 221.0	1 426.2	331.9	866.7	1 392.5	1 411.4	1 084.3	692.9	1 219.9	1 365.8	888.9
BIC	264.2	1 243.3	1 448.4	354.1	888.9	1 414.7	1 433.6	1 106.6	715.1	1 242.1	1 388.1	911.1

Note: ***, ** and * indicate significance at 0.1%, 1%, and 5% respectively, standard deviation is in parentheses.
Source: Own calculations

Table A7 Regression-parameter estimates of broad consumption categories with a mediation effect

	2011–2013				2014 –2016				2017–2019			
	ln(c_nd)	*ln(c_sd)*	*ln(c_d)*	*ln(c_s)*	*ln(c_nd)*	*ln(c_sd)*	*ln(c_d)*	*ln(c_s)*	*ln(c_nd)*	*ln(c_sd)*	*ln(c_d)*	*ln(c_s)*
ln(M)	0.855***	1.333***	4.257***	0.988***	0.799***	1.388***	3.284***	1.082***	0.924***	2.270***	3.160***	0.759***
	(22.13)	(14.71)	(13.19)	(18.00)	(20.45)	(14.22)	(9.41)	(20.56)	(12.06)	(7.37)	(4.62)	(5.96)
Child	0.0124	−0.567	−0.761	−1.602	−0.428	1.946	−10.63	−2.124	1.318	12.00*	39.41	−6.087*
	(0.02)	(−0.34)	(−0.12)	(−1.45)	(−0.53)	(0.98)	(−1.36)	(−1.45)	(0.76)	(2.05)	(1.94)	(−1.97)
*ln(M)*child*	0.00729	0.0651	0.0155	0.161	0.0544	−0.198	1.029	0.211	−0.131	−1.224*	−4.012	0.624*
	(0.11)	(0.38)	(0.02)	(1.39)	(0.65)	(−0.97)	(1.27)	(1.39)	(−0.74)	(−2.05)	(−1.93)	(1.99)
Size	−0.0402***	−0.0116	0.0284	0.0538***	−0.0397***	−0.00772	0.0137	0.0507***	−0.0572***	0.00503	0.0338	0.0921***
	(−14.42)	(−1.45)	(1.06)	(13.07)	(−13.08)	(−0.90)	(0.46)	(12.18)	(−7.57)	(0.18)	(0.45)	(5.74)
Dwelling	−0.200***	−0.0782*	−0.231	0.219***	−0.201***	−0.0571	−0.126	0.227***	−0.128***	−0.128	−0.0258	0.208**
	(−12.34)	(−2.09)	(−1.83)	(11.93)	(−11.62)	(−1.43)	(−0.93)	(11.85)	(−3.36)	(−0.95)	(−0.07)	(2.75)
Constant	0.915*	−5.583***	−35.79***	−1.272*	1.424***	−6.109***	−26.44***	−2.128***	0.412	−14.97***	−27.86***	0.600
	(2.52)	(−6.51)	(−11.65)	(−2.45)	(3.85)	(−6.56)	(−7.93)	(−4.26)	(0.55)	(−5.04)	(−4.21)	(0.49)
N	1 443	1 443	1 443	1 443	1 223	1 223	1 223	1 223	301	301	301	301
adj. R-sq	0.458	0.178	0.143	0.405	0.463	0.183	0.108	0.432	0.516	0.207	0.050	0.267
AIC	−62.93	2 575.7	6 219.2	786.2	−61.19	2 161.1	5 248.7	653.4	58.04	874.7	1 484.8	433.8
BIC	−31.29	2 607.4	6 250.8	817.8	−30.53	2 191.8	5 279.4	684.1	80.28	896.9	1 507.0	456.0

Note: ***, ** and * indicate significance at 0.1%, 1%, and 5% respectively, standard deviation is in parentheses.
Source: Own calculations

APPENDIX 2

DIAGNOSTICS

The variance of the residual terms depends largely on observations in nonlogarithmic form. In most cases, I removed heteroscedasticity by the model building because logarithmisation is an effective transformation in the heteroscedastic regressions. However, the problem persisted in a couple of regressions, so I chose OLS estimation with robust errors as the estimation method.

I tested multicollinearity by calculating variance inflation factors (VIF), whose value of 1 or close to zero indicates that the independent variables are not correlated.

I excluded observations that could affect the estimates before estimating the models. I also removed outliers identified as illogical or deviating for methodological reasons.

Despite the prevalence of statistically significant estimates, high variance of consumption among low-income households causes low values of the coefficient of determination – between 0.023 and 0.517. For this reason, I occasionally did not reject the null hypothesis about the informative value of the model only with intercept, using the F-test of overall significance. Nonetheless, I used a unified method for all the regressions rooted in theoretical assumptions and previous empirical studies.

Consumption and Sustainable Development of Polish Metropolitan Cities

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Abstract

The purpose of the study is to determine the level of sustainable development of metropolitan cities in Poland within the basic dimensions of sustainable development. At the same time, the levels of development of cities in terms of consumption were determined, and an attempt was made to identify the relationship of the levels of development of cities and the levels of development of consumption. Three main dimensions of sustainable development were considered: social, economic and environmental-spatial. It was important to find an answer to the question whether consumption can influence the levels of sustainable development achieved by cities, and in what aspects? A taxonomic method was used, which allows organizing the studied territorial units in a hierarchical manner. The levels of their development in each dimension were determined. Identifying the structure of features allows determining at what distance from the ideal structure of features the studied cities are. The research was carried out in dynamic terms by analyzing 2007 and 2020.

Keywords	***DOI***	***JEL code***
Sustainable development, metropolitan cities, consumption, consumption	*https://doi.org/10.54694/stat.2022.39*	*R15, D16, Q01, P25*

INTRODUCTION

Implementing the concept of sustainable development is one of the key challenges facing the European Union. Attempting to transition to a low-carbon economy, increasing energy efficiency, fighting poverty, but also new trends and patterns in consumption, are among the areas in which member states are implementing initiatives and activities aimed at achieving the 17 global sustainable development goals. In the case of consumption, it is important to focus on large urbanized areas such as metropolitan areas. This is because it is in them that the largest percentage of the country's population lives, which significantly influences

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the development of the area and, through its consumption decisions, influences to a greater or lesser extent the realization of the principles of sustainable development.

The concept of sustainable development is becoming increasingly important in the development of urban areas, especially large cities. The most frequently cited definition is that contained in the Brundland Report (1987), according to which sustainable development is considered to be development that consists in satisfying the needs of present generations without compromising the ability of future generations to satisfy their needs. In this case, the goal is to make the most efficient use of limited resources that have alternative uses in the present as well as in the future. The literature draws attention to three basic aspects of sustainable development: economic, environmental and social. The essence of the concept is to not significantly and irreversibly violate the human environment and to reconcile the laws of nature with the laws of economics (Kozlowski, 1997) The concept has evolved over many years and is now considered a paradigm of 21st century development. An important event that strengthened and popularized its importance was the United Nations Conference on Environment and Development, held in Rio de Janeiro in 1992, when important documents were adopted, i.e. Agenda 21 and the Rio Declaration.

The importance of consumption for achieving sustainable development is increasingly highlighted in the literature. Researchers from various countries are addressing topics related to sustainable consumption of, for example, foodstuffs and its impact on achieving sustainable development goals (Böhm et. al., 2016; Hirsch and Terlau, 2015, Hwang et al., 2010). It is important to remember that consumption is not only limited to the consumption of goods and services, but also affects the consumption of resources during their production or the provision of these services. The entire life cycle of products is important. Here it is worth noting the consumption of energy both directly and indirectly. Its importance is pointed out by Matthew Cole and Andrea Lucchesi, among others. The authors emphasize the roles of energy consumption and energy policy-making in the possibility of reducing environmental pollution (Jackson, 2014). As Akenji and Bengtsson (2014) emphasize. Conference in Rio de Janeiro (1992), unsustainable consumption patterns were also identified as a major cause of environmental degradation. Akenji and Bengtsson prove the relationship between a country's level of development and ecological footprint in their study. The results of their study show a correlation that the higher the level of economic development a country achieves, the larger the ecological footprint it leaves. Often the incentive to decouple economic growth from resource consumption and environmental degradation is one of the key ways to achieve sustainable development goals (Jackson, 2009). However, few countries succeed in doing so (Akenji and Bengtsson, 2014).

The concept of sustainability is particularly important in cities which, in a way, constitute a kind of ecological-social-economic system and in which the disruption of one of its components causes a burden on others (Rzeńca, 2018). In this context, it is important to maintain self-regulation. It is essential that any economic activity be adapted to natural conditions, and that the social activities undertaken take place within the limits of the adaptive capacity of the environment. A significant role in this context is played by the local community of a given city. Its environmental awareness, behavior and consumption. Referring to the basic definition of sustainable development, which draws attention to development involving, among other things, meeting the needs of present and future generations without diminishing access to non-renewable resources, clean environment, sustainable consumption is important. If the satisfaction of human needs is considered as a direct act involving the use of a particular material good or service we define it as consumption (Bywalec, 2010). Sustainable consumption, on the other hand, is considered to be such a shape of its processes that enables the realization of sustainable development goals (Kielczewski, 2008). Due to the scant availability of statistical data in this regard for cities, it is difficult to study this issue comprehensively. Nevertheless, such an attempt has been made using basic indicators, complete, reliable and available, which determine the level of consumption.

1 LITERATURE REVIEW

The literature review conducted by Quoquab, Jihad, Sukari shows that most of the research on sustainable consumption is at a conceptual level and does not emerge a synthetic measure that would measure sustainable consumption. Existing measurement scales are mainly concerned with ethical consumption presented by the consumer and his desire to care for the environment . One of the most widely used methods of consumption research is the survey. Surveys in this area have been conducted by, among others Fiore (Fiore et al., 2022), Széchy (Széchy et al., 2011).

When determining the consumer's impact on the environment, various indicators of measurement are pointed out. However, many studies most often consider five critical areas of household consumption: housing, mobility, food, household goods and appliances (Castellani and Sala, 2019; Comin et al., 2007). In selecting indicators of sustainable consumption, an effort was made to include these five areas, with the principle of accessibility and completeness of indicators. An analysis of the literature and policy documents made it apparent that the vast majority of studies are conducted on a macro or regional scale, and sometimes they involve entire countries, e.g. Indicators and assessment of the environmental impact of EU consumption (Publication Office…,2019) or the publication by Bentley and Leeuw (2003). The availability of a suite of indicators at the local level is very limited.

There are also studies in the literature on the impact of consumption that are based on life cycle assessment (LCA) conducted for specific representative products. However, these studies only deal with the macro scale (e.g. Goralczyk and Manfredi, 2013; Althaus et al., 2013; Heijungs et al., 2022; Hertwich, 2005) and it is difficult to relate them to the local scale which concerns cities. In the case of sustainable consumption, the importance of consumer footprint is emphasized, which is often based on the use phase study in the LCA (Castellani et al., 2017).

Other studies of sustainable consumption are based on an analysis of consumer lifestyles in terms of consumption patterns (Birkved et al., 2016; Kočí and Matuštík, 2019).

When it comes to researching sustainable consumption in urban areas, there are attempts to study and identify the indicators needed to measure it. However, these are often limited to only a selected aspect of sustainability. An example is the study by Hoff et al. concerning the water footprint of cities (Döll et al., 2014). The authors focused their considerations on the consumption of goods such as food and its relation to the amount of water required for their production and the impact of this water consumption in regions. Another example of the authors' focus on only a selected aspect of sustainability is Goviandan's (2018) publication in which the authors provide a brief review of the literature on sustainable supply chain management and sustainable supply chains in the food industry.

In view of the above, the use of a taxonomic method that allows determining both the level of development and the structure of the characteristics of individual urban units in terms of sustainable consumption seems to make sense. In this context, consumption is treated as holistically as the available indicators within the previously mentioned five areas allow.

There are studies in the literature based on a suite of sustainable consumption indicators. However, they are often limited only to households or the consumer himself, assessing his behavior. An example is a study conducted in rural and urban areas in China as well as elsewhere. A system of indicators was developed to assess the sustainability of HFC (Cheng et al., 2023). This system consists of dimensions such as nutrition, environment, economy and socio-cultural culture, as well as a comprehensive index for evaluating the analysis.

2 METHODOLOGICAL ASSUMPTIONS

In the case of research on the level of development of a given territorial unit in the adopted aspect (sustainability or consumption) and the need to present rankings, Michalski's method is a frequent method. It is useful insofar as, in addition to identifying the level of development of units, it also

identifies units in terms of their similarity of feature structure to the model object, which seems to be valuable.

In order to achieve the set research goal, a taxonomic method called Michalski's method was used (Michalski, 2001). This method made it possible to study the similarities of the level and structure of the characteristics that describe the studied cities to the designated benchmark object, taking into account the dimensions of sustainable development. Taxonomic measures were determined for selected time moments, i.e. 2007, 2020, and then used in the comparative analysis of multi-feature objects for each year. The objects of the study are metropolitan cities in Poland. It is worth noting that indicators of sustainable development are considered as a feature.

Cities with a given level of sustainability may be characterized by a different structure of the analyzed phenomenon. Identifying the degree of similarity of the structure of the phenomenon for a given city with the ideal structure, provides information about the degree of sustainability of a given city. This provided a primer on the results of sustainable consumption for selected cities in the years analyzed.

A measure μ $(i; j)$ was used to identify the degree of similarity between metropolitan cities due to **the structure** of diagnostic features. This measure presents the similarity of the *i-th* city's feature structures with the benchmark object. The construction of the benchmark object consisted of determining the highest value for each feature in the studied set of cities.

At the same time, it should be emphasized that the highest value of the indicator in the studied group of cities, does not mean that this value is optimal, because the benchmark object applies only to the studied set of metropolitan cities.

In the process of constructing a measure to assess the similarity of the structures of diagnostic features in the *i-th* city and the benchmark object, vectors z_i and z_p were used . The measure of similarity of structures is given by the formula:

$$\mu(i; p) = \frac{z_i \times z_p}{|z_i|\,|z_p|},$$

where: z_i – *i-th* row of Z matrix (i-th object), z_p – *p-th* row of Z matrix (reference object), $z_i \circ z_p$ – dot product of vectors z_i, z_p, $|z_i|$ – length of z_i vector, $|z_p|$ – length of z_p vector.

For practical purposes, the measure $\mu(i; p)$ was normalised to eliminate taking values in the <–1,1> range. The normalised measure $\mu \times (i; p)$ s given by the formula:

$$\mu \times (i; p) = \frac{1 + \mu(i; p)}{2}.$$

The normalizes measure $\mu \times (i; p)$ takes values in the range <0,1> and means that the larger value of the similarity index takes, the more similar the objects are.

The higher the value of $\mu \times (i; p)$ indicator the more similar the metropolitan city was to the benchmark object i.e. it had a structure of diagnostic characteristics similar to the desire one.

As a second measure, a measure was introduced that represents the **level of values** of diagnostic characteristics describing the studied metropolitan cities. With this measure, it was possible to measure the distance between objects, taking into account the similarity of objects due to the variation in the level of values of diagnostic characteristics. The measure $d \times (i; p)$ is given by the formula:

$$d \times (i; p) = 1 - \frac{1}{2\sqrt{kn}}\, d(i; p),$$

where: k – number of features, n – number of cities.

$$d \times (i; p) = \sqrt{\sum_{j=1}^{k} (Z_{ji} - Z_{jp})^2} .$$

The construction of a measure of similarity of feature levels is based on the concept of distance between *i-th* and *p-th* objects. This distance is determined using the Euclidean metric. The parameter j determines the point from which the distance is measured. The measure $d \times (i; p)$ takes values in the range <0;1> and means that the closer the indicator value is to 1, the more similar the objects are to the reference object.

The difference between the level of values of diagnostic characteristics and their structure allows to identify units with the same level of development, but a different structure of diagnostic characteristics (city "Z" may have the same structure of characteristics as city "Y", for example, A: 5555, B: 2222, but a different level of characteristics).

The baseline set of potential sustainable development indicators consisted of 221 features and was based on the sustainable development indicators of the System of Local Government Analysis,[4] taking into account the three aspects of sustainable development: social, economic and environmental-spatial. In the case of sustainable consumption, on the other hand, the base set of potential indicators included 17 characteristics. During the process of selecting variables for the study, variables that were incomplete at selected time points, highly correlated with each other (>0.8) and those whose coefficient of variation was low (<10%) were eliminated. The final set of variables included: 19 characteristics describing the social dimension, 10 characteristics describing the economic dimension, 15 characteristics describing the environmental-spatial dimension, and 6 characteristics describing sustainable consumption (Appendix).

3 ANALYSIS AND RESULTS

3.1 Identification of feature structures of sustainable development aspects of metropolitan cities

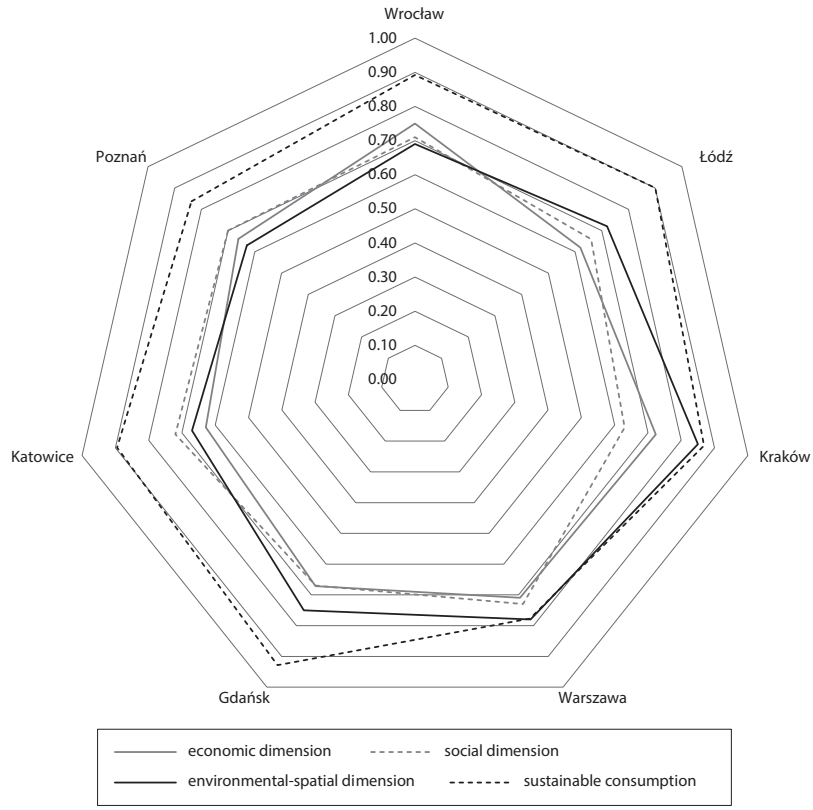
To determine the variation in the level of sustainable development of metropolitan cities, the resulting measures of development were analyzed. The studied cities were compared within the three dimensions of sustainable development as well as the level of sustainable consumption for two years: 2007 and 2020 (Figures 1 and 2). The analysis of the results shows that the levels of sustainable development obtained by the cities in each dimension, compared to the levels of sustainable consumption, differ from each other.

It should be noted that the similarity achieved by cities in the levels of sustainable consumption characteristics decreased in all cities. The exception is Gdansk, for which the similarity measure was unchanged. Wroclaw and Katowice were characterized by the largest changes because they decreased by 0.10 and 0.07, respectively (Table 1).

The biggest changes occurred in the economic dimension of sustainability, within which Krakow, Gdansk and Katowice achieved higher values of the similarity index, meaning that they came closer to the benchmark object. In the social dimension of sustainability, on the other hand, all cities except Poznań and Katowice moved closer to the benchmark in 2020 compared to 2007. In the case of the environmental dimension, an increase in the similarity of feature levels to the benchmark object (Wroclaw, Poznan, Gdansk, Katowice) was noted for most cities (Table 2).

[4] *<https://systemanaliz.pl>*.

Figure 1 Similarity of feature levels with the benchmark within the three dimensions of sustainability and sustainable consumption in 2007



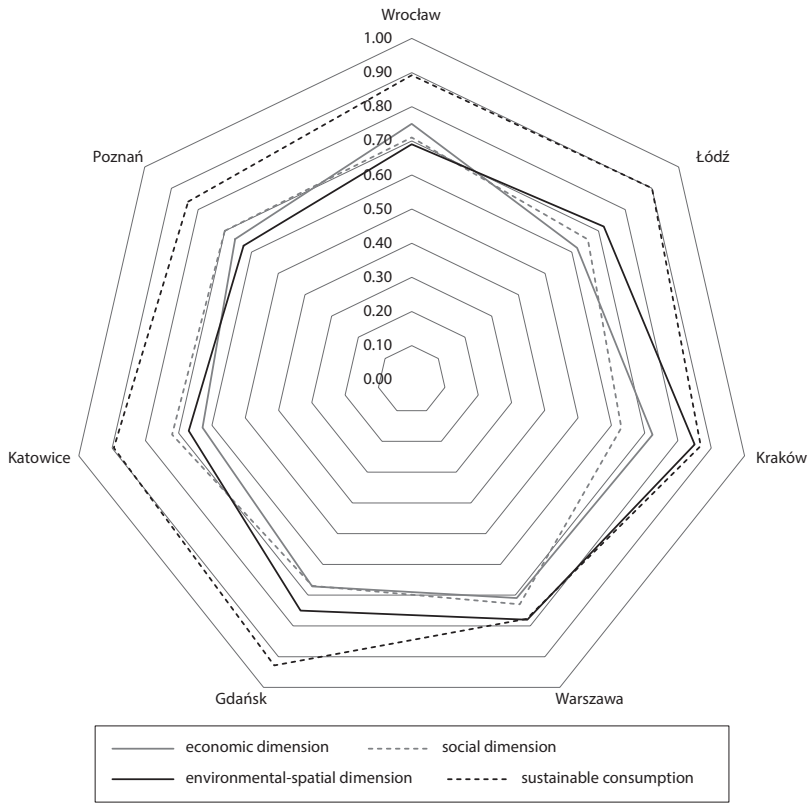
Source: Own study

Table 1 Level of similarity of feature levels to benchmark object in terms of consumption in 2007 and 2020

	2007	2020	Difference
Wrocław	0.89	0.79	0.10
Łódź	0.90	0.84	0.06
Kraków	0.87	0.83	0.05
Warszawa	0.78	0.75	0.03
Gdańsk	0.93	0.93	0
Katowice	0.89	0.82	0.07
Poznań	0.84	0.81	0.03

Source: Own study

Figure 2 Similarity of feature levels with the benchmark under the three dimensions of sustainability and sustainable consumption in 2020



Source: Own study

Table 2 Level of similarity of feature levels to the benchmark object in each dimension of sustainable development in 2007 and 2020

Economic dimension			Social dimension			Environmental dimension		
	2007	2020		2007	2020		2007	2020
Wrocław	0.75	0.72	Wrocław	0.71	0.73	Wrocław	0.69	0.70
Łódź	0.62	0.62	Łódź	0.66	0.68	Łódź	0.72	0.69
Kraków	0.72	0.74	Kraków	0.63	0.65	Kraków	0.85	0.79
Warszawa	0.71	0.67	Warszawa	0.73	0.74	Warszawa	0.78	0.77
Gdańsk	0.67	0.72	Gdańsk	0.67	0.68	Gdańsk	0.75	0.77
Katowice	0.63	0.62	Katowice	0.72	0.71	Katowice	0.67	0.69
Poznań	0.66	0.63	Poznań	0.70	0.63	Poznań	0.63	0.66

Source: Own study

3.2 Identification of feature structures of sustainable development of metropolitan cities in economic, social and environmental-spatial aspects

In the case of changes occurring within the structures of sustainable development features, there is a much higher rate of change than in the case of feature levels, so this issue is presented in more detail. The similarity of the feature structures of metropolitan cities to those of the benchmark object was also analyzed within the three dimensions of sustainable development with consumption. In the case of the value structure of sustainable consumption characteristics, the changes in the years under study are unfavorable. All cities moved away from the model object in this regard and achieved a worse structure of feature values. The largest changes were recorded for Wroclaw (0.56) and the smallest for Gdansk (0.03) (Table 3).

Table 3 Level of similarity of feature structure to model object in terms of consumption in 2007 and 2020

	2007	2020	Difference
Wrocław	0.84	0.28	0.56
Łódź	0.86	0.58	0.28
Kraków	0.85	0.49	0.35
Warszawa	0.65	0.36	0.29
Gdańsk	0.98	0.94	0.03
Katowice	0.80	0.44	0.36
Poznań	0.78	0.41	0.37

Source: Own study

In the case of the economic dimension, cities were characterized by varying directions of change. An unequivocal improvement in terms of similarity to the benchmark structure of features in the economic dimension took place in Łódź, Cracow, Katowice and Gdańsk (Figure 3). On the other hand, distancing from the benchmark during the examined time moments, characterized such metropolises as Wrocław, Warsaw and Poznań. The lowest values were characteristic for Poznań, and the highest for Cracow (Figure 3).

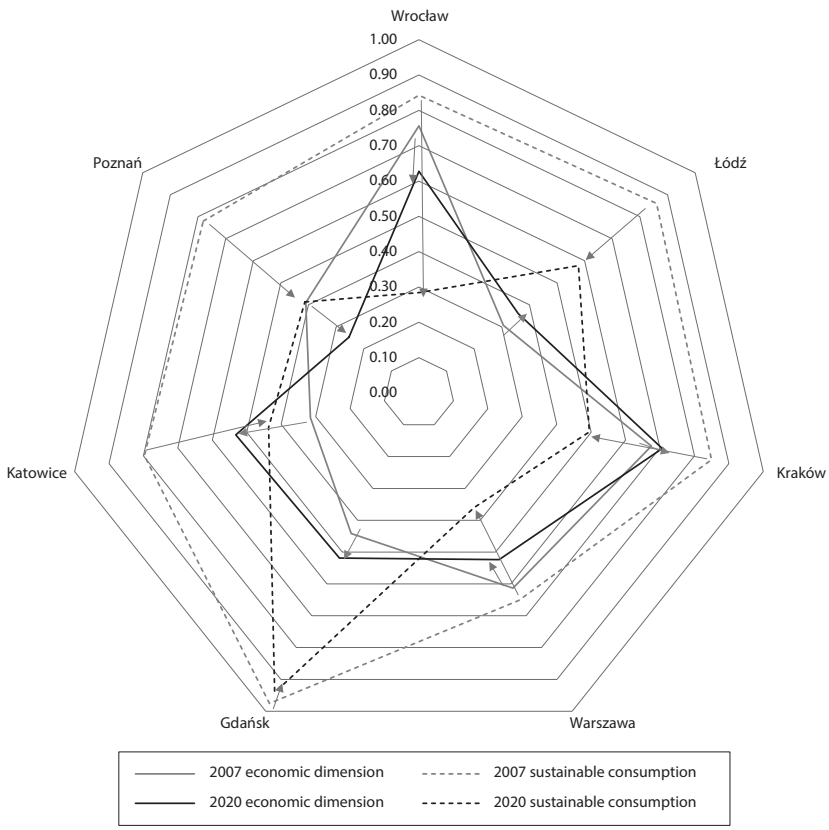
The achieved by cities structures of values of features in the economic dimension were compared with the structure of sustainable consumption. Among the studied metropolises there were those which approached the model object in the discussed scope, but at the same time moved away from the model in the case of sustainable consumption (Łódź, Kraków, Gdańsk, Katowice), as well as those which worsened the structure of feature values in both aspects (Poznań, Warsaw, Wrocław) (Figure 3).

Analyzing the dynamics of change occurring in the two issues under discussion, no clear direction of change emerges. The cities for which negative significant changes in consumption were noted were characterized by a slight deviation from the pattern in the economic dimension (Poznań, Warsaw, Wrocław). The second direction of change concerned Krakow, Lodz and Gdansk, for which improvements in the economic dimension were visible, while at the same time moving away from the pattern in the case of consumption. The only city for which a departure from the benchmark structure of feature values in consumption and a simultaneous significant improvement of this aspect in the economic dimension was noted was Katowice (Figure 3).

Changes in the structure of trait values in the economic dimension are not associated with deterioration or improvement in the structure of traits in sustainable consumption. The survey did not indicate the existence of a relationship in terms of the economic dimension and sustainable consumption.

Within the social dimension of sustainable development, the values achieved by the cities indicate that the most similar structure of features to the benchmark structure was recorded by Wrocław, reaching a value of (0.78) in 2020, while in 2007 this place was occupied by Warsaw (0.68) (Figure 4). In turn, Poznań in the last year under review recorded the lowest value among all metropolitan cities in the dimension in question (0.14). The analysis of changes in the structure of the characteristics indicates a dominant trend of improvement in the structures of the characteristics of individual cities. Only the aforementioned Poznań and Katowice show a trend of decreasing similarity of feature structures to that of the benchmark object.

Figure 3 Similarity of feature structures with the pattern within the economic dimension of sustainable development and sustainable consumption in 2007 and 2020



Source: Own study

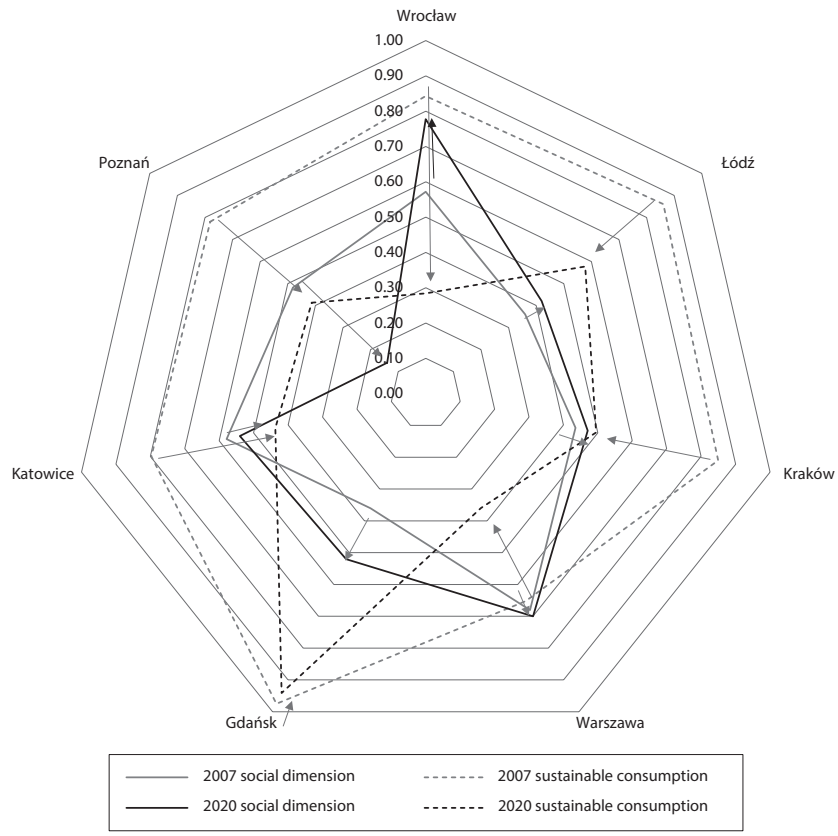
Comparing the obtained results for the social dimension of sustainability with the similarity values of the feature structure for sustainable consumption, two trends of change are evident. The first is characterized by the distance of the city from the benchmark object for both the social dimension and sustainable consumption (Poznań, Katowice), and the second by an improvement in sustainable consumption and a simultaneous deterioration in the social dimension (other cities) (Figure 4).

The reduction in consumption by the society and the realization of sustainable consumption is mostly reflected in the social development of this city and the feature structure in the social dimension represented by the city. An improvement in the structure of features in the social dimension is associated

with a deterioration in the structure of features in sustainable consumption. The exceptions are Poznań and Katowice for which this relationship was not observed (Figure 4).

Analyzing the dynamics of change, one can notice a significant deterioration in the structure of the value of the characteristics in the field of sustainable consumption (the exception is Gdansk, for which this change was small) and a much smaller dynamics of change in the social dimension in this regard (exception: Poznan, Wroclaw) (Figure 4).

Figure 4 Similarity of feature structures with the pattern within the social dimension of sustainable development and sustainable consumption in 2007 and 2020



Source: Own study

In terms of the environmental-spatial dimension, the city that had the most similar structure of features to that of the model object was Gdansk, and the least similar was Warsaw (Figure 5). Within the analyzed dimension, three directions of change are evident:

- cities that have moved away from the model structure of features (Katowice, Warszawa);
- cities that came close to the benchmark facility in the scope analyzed (Kraków, Łódź);
- cities that did not show major changes in terms of changing the similarity of feature value structures to the benchmark object (Poznań, Wrocław, Gdańsk).

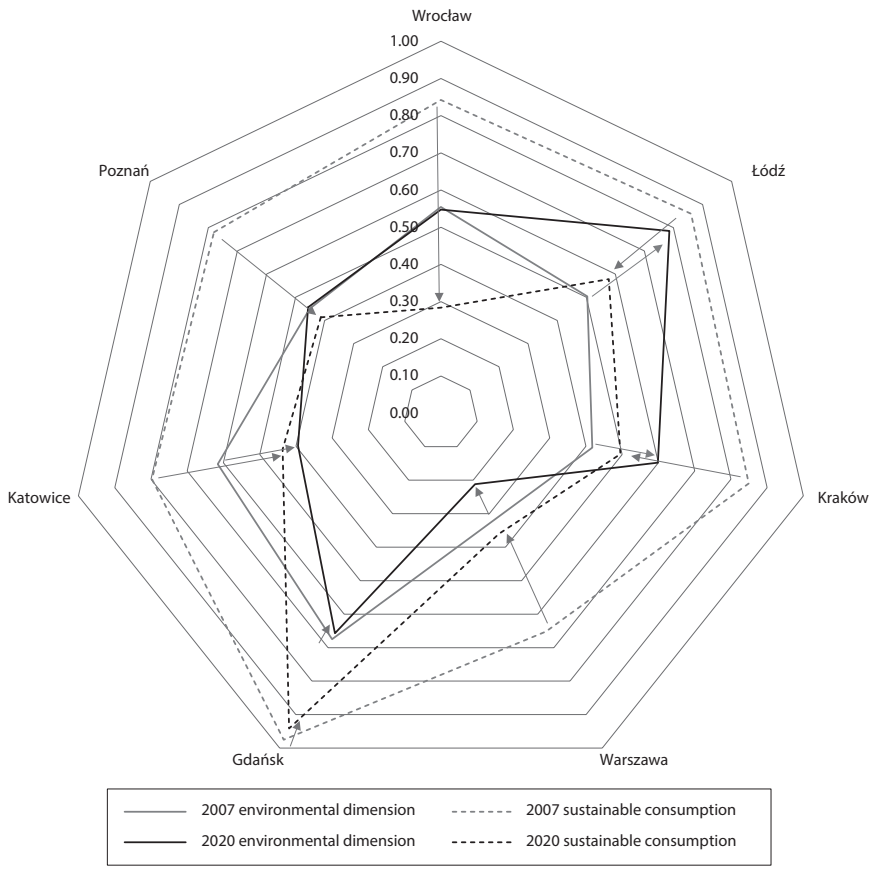
An analysis of the obtained results against sustainable consumption shows that almost all cities (with the exception of Lodz and Krakow) worsened the structure of features in the environmental and spatial

dimensions as well as sustainable consumption. Only Łódź and Kraków recorded an improvement in the dimension in question (Figure 5).

In order to better present the relationships occurring between the directions of change in a given dimension of sustainability and sustainable consumption, it was necessary to present these issues in separate figures (Figures 6a,b, 7a,b, 8a,b).

An analysis of the similarity of feature structures within a dimension to the feature structure of sustainable consumption reveals a significant similarity in the environmental-spatial dimension. In this case, the directions and dynamics of change in sustainable consumption as well as development within the mentioned dimension are very close to each other. Within the other dimensions of sustainable development, the similarity is no longer apparent. Changes in the value structure of consumption characteristics are correlated with changes in only the environmental-spatial dimension (Figure 8a,b).

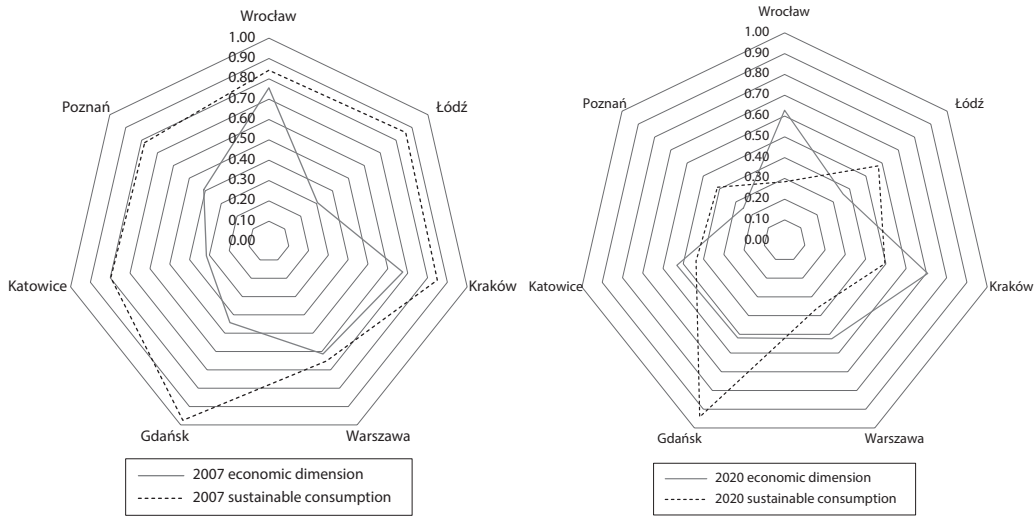
Figure 5 Similarity of feature structures with the pattern within the environmental-spatial dimension of sustainable development and sustainable consumption in 2007 and 2020



Source: Own study

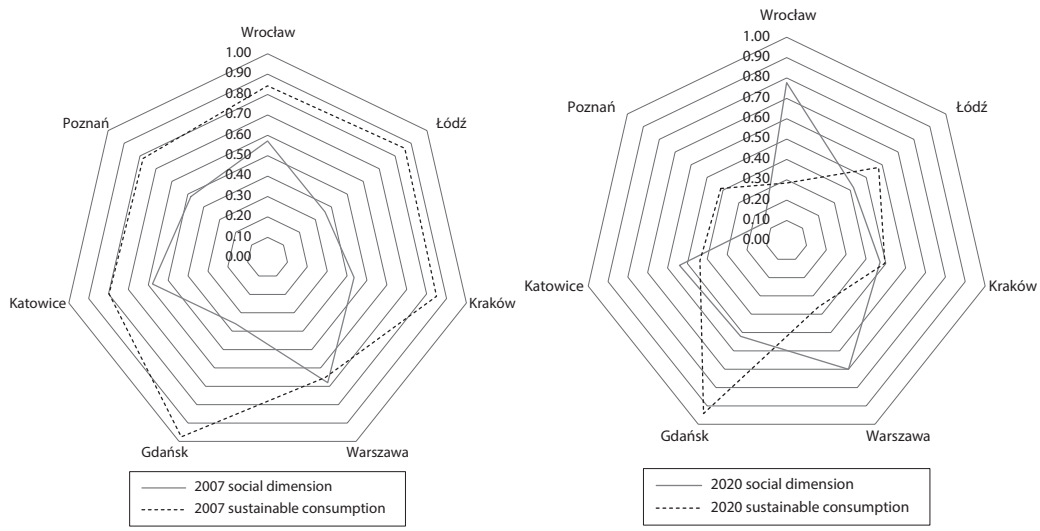
Comparing the years under study, it is evident that the structure of features is moving away from the benchmark object in consumption for all cities except Gdansk. This means that the community of metropolitan cities realizes the assumptions of sustainable consumption but to a lesser extent.

Figure 6 a,b Similarity of the features structure of features with the pattern within the economic dimension of sustainable development and sustainable consumption in 2007 (6a) and 2020 (6b)



Source: Own study

Figure 7 a,b Similarity of the features structure of features with the pattern within the social dimension of sustainable development and sustainable consumption in 2007 (7a) and 2020 (7b)



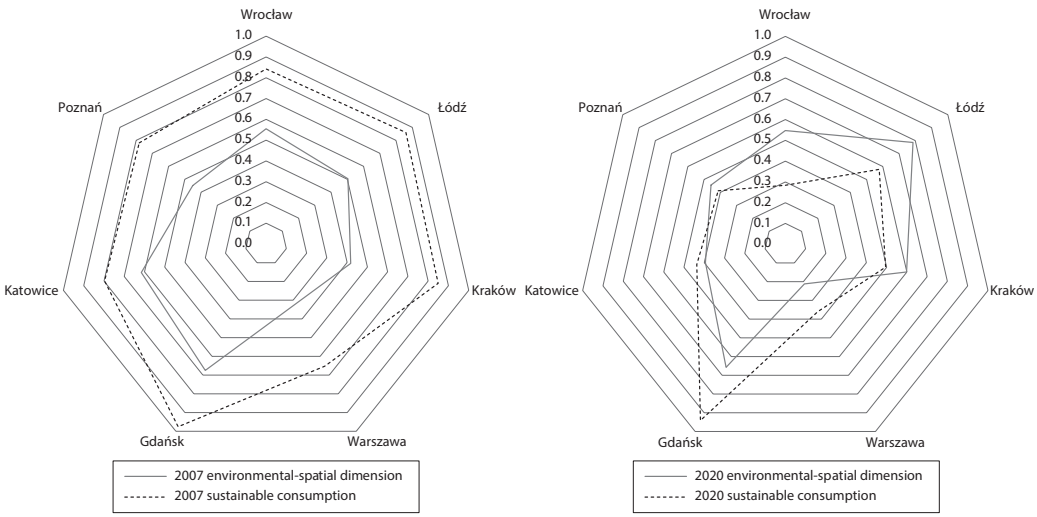
Source: Own study

At the same time, most cities record a departure from the benchmark feature structure in the environmental and spatial dimension (with the exception of Łódź, Kraków and Poznań).

The analysis of changes in the structure of feature values indicates differentiated ranges of values in each dimension of sustainable development. The highest values which testify to the greatest similarity of the trait value structure, metropolitan cities achieved in the environmental dimension.

It is important to note the development of cities within all three dimensions of sustainability and consumption. In this case, the city that in 2007 achieved the most similar feature structures in all dimensions was Poznań. In 2020, that city was already Gdansk. Looking through the prism of sustainable consumption, it is important to emphasize that Gdańsk deteriorated the structure of feature values to the least extent among the surveyed cities, as it only deteriorated by (–0.03). Poznań, on the other hand, in 2020 recorded significant differences between the similarity of feature value structures to the benchmark object between dimensions and a significant departure from the benchmark in terms of consumption (–0.37).

Figure 8 a,b Similarity of the features structure of features with the pattern within the environmental-spatial dimension of sustainable development and sustainable consumption in 2007 (8a) and 2020 (8b)



Source: Own study

DISCUSSION AND CONCLUSIONS

The analysis of the obtained results within the framework of similarity of the value levels of the characteristics of each dimension of sustainable development and sustainable consumption indicates small changes in the dynamics and directions of change. These changes are not correlated with each other, and it is not possible to clearly indicate the existence of a relationship between the levels of consumption and the levels of sustainability represented by the cities in the sustainability dimensions analyzed.

The level of similarity of feature levels to the benchmark object in terms of consumption worsened for all metropolitan cities except for Gdansk, for which the level was the same. On the other hand, in the case of dimensions of sustainable development, the most favorable changes occurred in the social dimension within which all cities except Katowice came closer to the model object in the analyzed scope. The departure from the model object within the level of feature values occurred to the greatest extent in the environmental-spatial dimension within which as many as three cities recorded lower values of the index (Łódź, Kraków, Warsaw).

Changes in the structure of feature values in the economic dimension are not related to deterioration or improvement of the structure of features in sustainable consumption. The survey did not indicate the existence of a relationship in terms of the economic dimension and sustainable consumption.

The deterioration of public consumption and the realization of sustainable consumption are mostly reflected in the social development of this city and the feature structure in the social dimension represented

by the city. An improvement in the structure of features in the social dimension is associated with a deterioration in the structure of features in sustainable consumption. The exceptions are Poznań and Katowice for which this relationship was not observed.

The dynamics and directions of changes in the value structure of consumption traits are correlated with changes in the environmental and spatial dimensions. This observation is also confirmed by other studies in the literature, which conclude that the volume of consumption is closely related to environmental impact (Alfredsson et al., 2018). Thus, there is a need to change the style of consumption in a way that ensures sustainability.

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APPENDIX

Table A1 Indicators of sustainalbe development of the city

	Social dimension
1	Total net migration per 1 000 population [in per mille]
2	Infant deaths per 1 000 live births
3	Natural increase per 1 000 population [in per milles]
4	Population density – number of population per km^2
5	Pharmacies per 1 000 population
6	Expenditure on health care per capita (PLN/person)
7	Expenditure on the lighting of streets, squares and roads per capita [PLN]
8	Total expenditure on dwelling economy per capita (PLN/person)
9	Property expenditure on dwelling economy per capita (PLN/person)
10	Expenditure on green areas in cities and gminas per capita [PLN]
11	Accommodation per 1 000 inhabitants
12	Nights spent (overnight stays) per 1 000 inhabitants
13	Collection of public libraries per 1 000 inhabitants
14	Public library users per 1 000 inhabitants
15	Councillors up to 29 years of age in relation to the total number of councillors [%]
16	Share of women in the council [%]
17	Number of economic entities per 1 000 population
18	Unemployed persons per 100 persons of working age
19	Unemployed women per 100 women of working age

Table A1 (continuation)

	Economic dimension
1	Gmina budget expenditure per capita (PLN/person)
2	Investment property expenditure compared to total budget expenditure [%]
3	Investment property expenditure per capita [PLN]
4	Employment rate – number of employed persons per 1 000 inhabitants
5	Accommodation per 1 000 inhabitants
6	Nights spent (overnight stays) per 1 000 inhabitants
7	Nights spent (overnight stays) by foreign tourists in tourist accommodation establishments per 10 thousand inhabitants
8	Expenditure on waste management per 1 gmina inhabitant
9	Expenditure on protection of air and climate per 1 gmina inhabitant
10	Expenditure on treatment of urban and rural areas per 1 gmina inhabitant
	Environmental-spatial dimension
1	Area of land under legal protection as % of gmina's area
2	Expenditure on green areas per capita [PLN]
3	Area of land under legal protection in ha per 1 000 inhabitants
4	Area of land under legal protection as a share of gmina's area
5	Area of landscape parks in the total gmina's area
6	Area of forests and forest land as % of gmina's area
7	Expenditure on treatment of gmina compared to total budget expenditure [%]
8	Waste generated during the year in thousand tonnes per capita (excluding municipal)
9	Municipal and industrial untreated wastewater (combined) in the total amount of produced wastewater
10	Untreated industrial wastewaster discharged directly into surface water or into the ground compared to total amount of wastewaster discharged by the industry
11	Water consumption per capita (m^3/year)
12	Total sulphur dioxide emission in t/year from plants of significant nuisance per km^2
13	Total carbon dioxide emission in t/year from plants of significant nuisance per km^2
14	Total nitrogen oxides emission in t/year from plants of significant nuisance per km^2
15	Total carbon oxide emission in t/year from plants of significant nuisance per km^2
16	Total emission of gaseous pollutants in t/year from plants of significant nuisance per km^2
	Sustainable consumption indicators
1	Consumption of electricity in households per capita
2	Average useful floor area of dwellings per capita
3	Number of passenger cars per 1 000 population
4	Sales of heat energy during the year to residential buildings (GJ)
5	Water sold from water supply system to households per capita
6	Total mass of municipal waste generated per capita (kg)

Source: System Analiz Samorządowych (Self-Government Analysis System) <*http://www.systemanaliz.pl*>

Evaluation of the Impact of the Covid-19 Pandemic on Consumer Spending in Turkey by Structural Break Analysis

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Abstract

The purpose of this study is to investigate and evaluate the impact of the global Covid-19 crisis on consumer spending tendencies in Turkey. The data of the study, which are weekly data, consists of the "Debit Card and Credit Card Expenditure" amounts of the Central Bank of the Republic of Turkey (CBRT) for the period 6/3/2015–5/8/2022. Changes in consumer expenditures during the Covid-19 pandemic process were examined with the help of structural break tests. The main contribution of this article subsists in an empirical study to examine structural breaks in Turkey using personal debit and credit card disaggregated total expenditure data during the Covid-19 period. According to the research findings; the change observed at the beginning of the Covid-19 period in card expenditures is less than the change observed at the end of the period. With the end of the pandemic, an upward breakout was observed in most of the expenditure items.[3]

Keywords	***DOI***	***JEL code***
Covid-19, pandemic, consumer, spending, structural break	*https://doi.org/10.54694/stat.2022.21*	*D12, P44*

INTRODUCTION

World history is full of epidemic events. It is for this reason that societies approach epidemics and diseases with fear. Events leading to diseases and epidemics are recurrent biological events and are completely unpreventable; what matters here is to learn from these epidemics. Thus, the main objective should

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be to be prepared (Donthu and Gustafsson, 2020; Kartal and Şentürk, 2020) and take precautions in case of a reoccurrence of the epidemic.

The novel coronavirus disease, which was first reported to have emerged in Wuhan, China, was first identified on January 7, 2020. Although the city of Wuhan was quarantined, the disease spread rapidly and was declared a pandemic by the World Health Organization on March 12, 2020. The Covid-19 pandemic is an event unprecedented in the last hundred years of human history. The whole world is feeling the effects of this epidemic. According to the Lancet Report (2020), the Covid-19 epidemic, unlike other epidemics, has affected the society both psychologically and physically. The uncertainty in this process has also significantly affected people's consumption behaviour and expenditures (Erdoğan, 2020).

Significant effects on many issues, from health to employment and income of individuals, were caused by the Covid-19 pandemic. In addition to long-term socio-economic effects on countries, it has both short-term macroeconomic and microeconomic impacts. Macroeconomic effects include a decrease in economic activities, an increase in inflation, and an increase in unemployment. Microeconomic effects include the decrease in consumption levels of consumers, job losses, and financial difficulties due to quarantines and restrictions (Cant, 2021). Moreover, all segments of society feel its effects on agricultural food supply chains, which mainly causes the rise in produce prices and an increase in prices in general. In this context, one of the most significant effects of Covid-19 is its effect on consumer behaviour and consumption expenditures.

There have also been significant changes in consumer spending and shopping behaviour since the emergence of Covid-19 in 2019. Overwhelmed by the recent threat of Covid-19, panicked shopping behaviour that led to the depletion of stocks and purchase limits in many food products have been instigated. According to some studies in the literature for the Covid-19 process and after (Chenarides et al., 2021; Jones, 2020; Tekin, 2020; He and Harris, 2020; IPSOS, 2020; Kotler, 2020),[4] it is predicted that some patterns of consumer behaviour will change and be irremediable. For example, Xie et al. (2020) revealed that in the future people's perception of Covid-19 will lead to an increase in organic food consumption and a decrease in game meat consumption. In a study conducted by Coibion et al. (2020), it has been revealed that consumption expenditures for travel and clothing have decreased due to the Covid-19 pandemic. It can therefore be said that the Covid-19 pandemic will significantly affect household consumption patterns (Cant, 2021).

According to James Rickards, author of The New Great Depression, "The pandemic and economic depression that started in 2020 is a turning point. Because our lives will never be the same again. It will take many years for all the effects of this to end, but when it is over, we will not be able to return to those old norms that we are used to" (Sözbilir, 2021). In this context, this study aims to reveal the effects of the Covid-19 outbreak on consumer spending.

In order to achieve this aim, structural breaks in the expenditure series in the weekly data obtained from the Central Bank of the Republic of Turkey (CBRT) were examined, and thus, the periods in which structural changes occurred were determined econometrically. Evaluations of the results were made by looking at the relations between the break dates and the statements about the pandemic previous to these dates. In the following section, previous studies on the subject are mentioned first. Then, the data set used was introduced and the econometric model was mentioned. After reviewing the findings, the conclusions and discussions were included in the last part.

1 LITERATURE REVIEW

After the World Health Organization (WHO) declared the virus a pandemic, many countries imposed travel restrictions, curfews, etc., to reduce the spread of the epidemic. As a result of these measures,

[4] <*www.mckinsey.com/tr/2021*>.

slowdowns have been observed in economic activities around the world (Ateş, 2021). The Covid-19 pandemic has caused both health and economic crises.

One of the most striking consequences of the pandemic is the sudden closure of businesses in some sectors and the resulting reduction in income for certain sectors. Such a development significantly affects the consumption behaviour of individuals. Except for the public service, which continues to provide minimum service due to the curfews in many countries, only the food and health sectors continued their activities (Chikhi, 2021). While the epidemic negatively affects some sectors (industry, domestic and foreign trade, airlines, logistics, tourism, and entertainment), it also affects some sectors (e-commerce, distance education, food, medical products, cleaning materials, mask making, platforms that provide movies and TV series, and communication) positively.

The pandemic has affected the lifestyle and shopping behaviour of consumers due to the curfew (Jribi et al., 2020; Perez-Rodrigo et al., 2020). Lehberger et al. (2021) stated that there was an increase of 126% and 137% in canned fruit and vegetable sales in Germany in March 2020, and the average sales of non-perishable products increased. In a study conducted in China, Wang et al. (2020) determined that after the outbreak of Covid-19, the food stocks of consumers extended from an average of 3.37 days to 7.37 days. Weersink et al. (2020), on the other hand, stated that market sales in Canada increased by 46% in March compared to 2019.

Jo et al. (2020) stated that the sales amount of virtual stores increased significantly during the pandemic process, the interest in technologies supporting health services increased, and there was a growth in technology sales related to online courses in the education sector. Despite these increases, it is stated that the global income of the travel and tourism industry had decreased by 17% in 2020 due to the closure of borders, and international tourist mobility had lost more than 1 billion (Algassim and Abuelhassan, 2021; Anderson et al., 2020).

The desire to "stock up", which was needed in times of war but was forgotten later, re-emerged with the Covid-19 pandemic period, and the purchasing patterns of consumers have changed as well as their purchasing priorities. As a result of some studies, it has been seen that the stocking behaviour of especially non-perishable food and cleaning products has increased in this period (Garbe et al., 2020; Kirk and Rifkin, 2020; Taylor, 2021). The demand for products with a long shelf life and medical products such as disinfectants, masks and gloves has increased, and orders have been placed online with the thought that not many people touch it. In this context, it can be predicted that the Covid-19 pandemic process will affect not only the actual period but also the consumer habits and consumption patterns afterwards (Hacıalioğlu and Sağlam, 2021). In this context, with the Covid-19 epidemic process, the excessive purchase of basic food products such as bread, pasta, the desire to stock up, and the rapid increase in demand for masks, medical supplies, colognes and toilet paper can be seen as a reflection of human survival mechanism on consumption behaviour (Iri, 2021).

On the other hand, the epidemic, increased health expenditures, decreased tax revenues and additional burdens to state budgets through direct income support to the public (Ateş, 2021). Sheth (2020) summarized the changes that occurred in the consumption behaviour of consumers during the pandemic period and classified and explained them as follows: Stocking, Improvisation, Supressed demand, Embracing digital technology, The store is coming home, Uncertainty of work and life boundary, Communication with friends and family, and Talent discovery. Consumers' stocking of products such as toilet paper, bread, water, meat, disinfection and cleaning products causes uncertainty in the product supply of businesses and difficulties arise in their management. For this reason, in addition to the product stocking of consumers, there is also the stocking of products by intermediaries and this causes price increases. Consumers find new ways/tools to consume despite restrictions. Due to this they learn how to improvise. In times of crisis and uncertainty, the general tendency of consumers is to delay the purchase and consumption of optional goods and services. In this respect, there is a suppressed demand. On the other hand, during

the pandemic period, consumers have adopted and used many new technologies and applications absolutely out of necessity. So much so that in this period, since consumers could not go to the market or shopping centres, these stores began to come to homes through jobs and education technology. However, this situation also reveals the uncertainty of the border between work and home. On the other hand, communication with distant friends and family has increased with the use of technology. At the same time, with the time spent at home and becoming more flexible during the pandemic period, consumers have had the opportunity to exhibit and develop their skills.

Studies on the subject are not only conceptual but also empirical studies. When the findings are evaluated as a whole, it was concluded that the Covid-19 epidemic greatly affected and will continue to affect the lifestyles and consumption behaviour of consumers (Wen et al., 2021; Akteri et al., 2021; Eger et al., 2021; Temizkan et al., 2021). In addition, it is stated that it is not possible for the world to get rid of the Covid-19 epidemic in the near future and people should continue the social isolation process (Cox et al., 2020; Bachas et al., 2020; Kissler et al., 2020; Sheth, 2020). These isolation conditions were created deliberately due to the consumer's effort to reduce the risk of disease and caused a social isolation. In this isolated environment, the consumer; preferred online stores, moved faster in the bazaar and market under anxiety and pressure, ordered his favourite food to his home, and planned the holiday he wanted to take under more isolated conditions. All these necessary changes have affected the routine purchasing habits of consumers. While this effect had a negative influence on some sectors (such as tourism, travel and transportation), it also had a positive effect on other sectors (such as technology and food manufacturers) (Howard, 2020; Ota et al., 2020; Tolun and Bulut, 2021; Hacıalioğlu and Sağlam, 2021). Apart from these, Ağan (2020), Koçak (2020), Kantur and Özcan (2021) examined the changes in card expenditures during the Covid-19 epidemic period in Turkey with different econometric techniques. However, the effects of the official decisions taken in these studies on expenditures were not considered. As long as the Covid-19 pandemic process continues, new studies are added to the subject and the subject continues to be investigated with different dimensions (economic, social, cultural).

As it can be understood from the literature review above, a comprehensive study covering the whole territory of Turkey and analysing the changes in the spending tendencies of consumers depending on the official decisions taken regarding the pandemic by using secondary data has not been conducted yet. This study was conducted by using the CBRT data to cover the whole of Turkey, and since it is the first in this regard, it will be an original study and it is understood that it will make an important contribution to the literature.

In unexpected situations, that is, during crisis periods, the demand for shopping is not stable and fluctuations can be very high. Identification of causes of these fluctuations is crucial for the following reasons: crisis management, changing the strategies and planning of the manufacturers in product groups, stock management, etc. Therefore, this study will provide useful outputs for scientists, producers, policymakers, and consumers working on this subject. Based on that, in this study, the structural break dates are revealed by the time series analysis of the weekly expenditures made between the selected dates using the CBRT data.

2 RESEARCH METHODOLOGY

2.1 Aim and objectives of the research

Consumption expenditures of consumers can be followed in different ways with macroeconomic data and official statistics. It is important to be able to analyse the effects of an epidemic such as Covid-19 quickly and accurately in order to take timely precautions. Based on that, in this study, "Debit Card and Credit Card Spending" statistics published weekly by the CBRT were used and analyses were made using the data for the period 6/3/2015–5/8/2022.

Structural breaking points in consumers' debit and credit card spending amounts and spending tendencies during the Covid-19 pandemic process, were found. Also, the decisions and measures taken

before the breaking dates were specified and the relationship between them was examined. Depending on the purpose of the study, the objectives are as follows:

- distribution between debit and credit card expenditures and spending items,
- to analyse the weekly changes in spending items during the pandemic and to reveal the relationship between structural break points and possible causes.

2.2 Data

The data of the study consists of weekly debit card and credit card expenditure amounts (thousand TL) for the period 6/3/2015–5/8/2022 and were obtained from the CBRT EDDS. Since the CBRT did not provide the data on daily basis, it was necessary to work with weekly data. In this context, "Debit Card and Credit Card Spending" statistics published by the CBRT on weekly basis and with a one-week delay were used. The main reason why the time range was chosen to reflect the pre-pandemic period is that the analyses to be made on the time series will be made with data in a wide range to clearly reflect the changes in the relevant period. In EDDS, card expenditures are presented both on total spending and various expenditure items. In this study, the effect of the pandemic on consumer spending was realized through consumption items. At the same time, the data are seasonally adjusted. Information on the items discussed and their explanations are given in Table A1 in the Annex.

2.3 Econometric methodology

The mean, trend or both components of a time series may change due to momentary shocks such as economic crises, policy changes, epidemics and natural disasters. Since the variables used in time series analysis may change over time, structural breaks may occur. The process of finding structural breaks or change points is based on quality control, and over time it has also been used in the fields of economics, finance, climatology and engineering (Aue and Horváth, 2013).

The Bai and Perron (BP) structural break test was used in the study. Bai and Perron (1998) established the theoretical structure for the determination of statistical distributions in case of structural break in a linear model estimated by the least squares method (Yıldırım, 2011).

The Bai Perron (BP) approach is not fundamentally a unit root test as it does not test any hypothesis regarding the stationarity of the series. The BP approach, which divides the relationship into regimes by finding significant structural breaks in the linear model with several different testing strategies, considers the following multiple linear regression model with m break (m + 1 regime):

$$y_t = x_t'\beta + z_t'\delta_j + u_t\,, \qquad t = T_{j-1} + 1, \cdots, T_j\,, \qquad j = 1, \cdots m + 1\,, \tag{1}$$

where: y_t dependent variable, x_t (p × 1) dimensional and z_t (q × 1) dimensional vector of arguments; β and δ_j ($j = 1, \cdots m + 1$) are the coefficients vector and u_t represents the error term. With $T_0 = 0$ and $T_{m+1} = T$, $T_1, \cdots, T_m$ represent unknown break times. The main purpose of the BP approach is to estimate the unknown regression coefficients and break dates together using the T-observed data set (Mert and Çağlar, 2019; Çil Yavuz, 2015). In the BP approach, the coefficients and break dates minimize the sum of squares of the model in Formula (1) and thus the regimes are an algorithm based on dynamic programming. Bai and Perron have developed different test strategies for structural break analysis:

- global L break test (*SupF test*),
- double maximum tests (UD_{max} and WD_{max}),
- sequential Bai-Perron test ($SupF(l|l+1)$test),
- break analysis based on information criteria.

The global L break test is a *supF* type test recommended for trendless series that analyze only level breaks and tests k breaks ($m = k$) despite the hypothesis that there is no structural break ($m = 0$).

Against the null hypothesis that there is no structural break ($m = 0$) in the double maximum tests, the alternative hypothesis with the maximum M structural breaks ($m \leq M$) is tested. In the sequential Bai-Perron test, on the other hand, the null hypothesis of no break at the beginning ($m = 0$) is tested, but the alternative hypothesis with 1 break is tested. If the null hypothesis is rejected, then the hypothesis of 1 break ($m = 1$) versus the null hypothesis of 2 breaks is tested. This is continued sequentially until the null hypothesis cannot be rejected. In the break based on the information criterion, it is aimed to find the number of breaks that minimize the value of the selected information criterion. Instead of the Akaike Information Criteria (AIC), mostly Bayesian Information Criteria (BIC), Schwarz (SIC) or modified Schwarz (LWZ) information criteria are taken into account (Mert and Çağlar, 2019). In this context, regimens were accepted as heterogeneous in the study, Sequential Bai-Perron test was preferred and heteroskedasticity autocorrelation consistent (HAC) correction was used. Quadratic spectral kernel function is used with First order autoregressive process (AR(1) approach). Andrews automatic bandwidth method was chosen and the error distributions were considered heterogeneous according to the regimes.

In this study, it was thought that it would be appropriate to use the BP method, which determines the structural break dates internally, in order to more clearly reveal the structural changes that occurred during the pandemic period. The BP method was chosen for three reasons. *First*, the method can handle multiple structural breaks simultaneously in a series. Second, the method assumes that potential structural break points are unknown and determines these dates internally. *Finally*, the BP method gives suitable results for small samples (Cró and Martins, 2017).

The BP multiple structural break test is widely used in different disciplines: The return and volatility of crypto assets (Telli and Chen, 2020), the structural changes in Wagner's Law (Kumar and Cao, 2020), the change in CO_2 emissions (Adedoyin et al., 2020) and determining the effects of population aging on consumption and savings (Boonyasana and Chinnakum, 2019). However, despite its widespread use in the analysis of time series, the BP method is not included in studies examining consumer behaviour. One of the studies in this area is Yang et al. (2019), they examined consumer demands for the use of different protein sources using the BP method.

In this study, the effect of the official decisions taken during the pandemic process, the statements made and the developments that took place, on consumption expenditures, and the relationship between them, were tried to be examined by taking into account the break dates obtained as a result of BP.

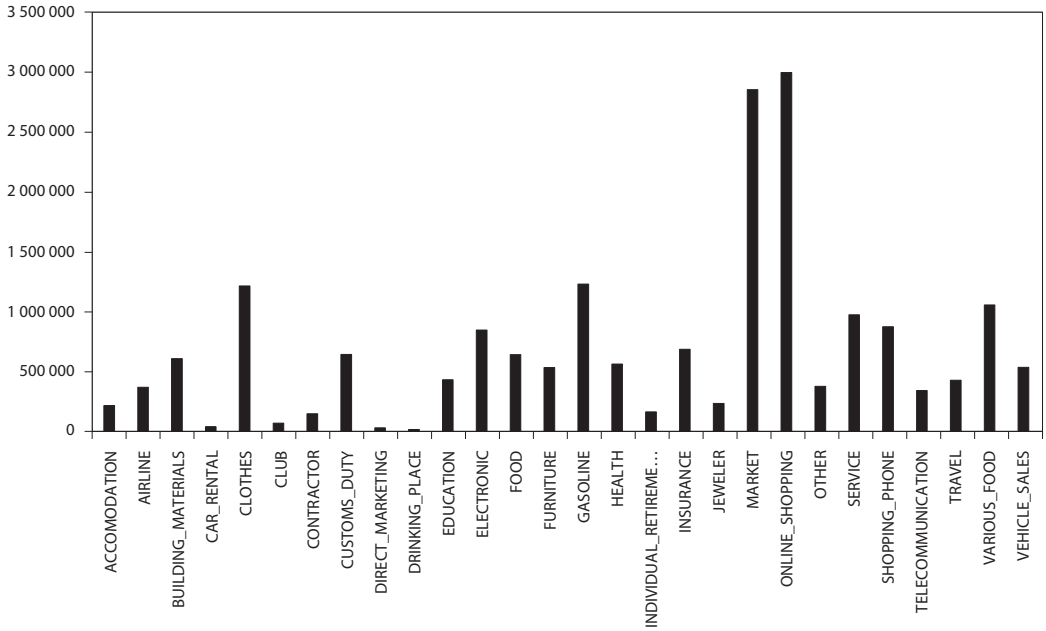
3 EMPIRICAL RESULTS

Descriptive statistics of bank and credit card expenditures received from the CBRT are given in Table A2 in the Annex. The coefficient of variation was calculated as an indicator of the volatility in expenditure amounts. Accordingly, it is seen that the biggest volatility in the related period is in "airline", "online shopping" and "accommodation" expenditures. The expenditure with the least volatility is the expenditures made in the "individual retirement" sector, followed by the "telecommunication" expenditures.

The median values of bank and credit card expenditure amounts are given in Figure 1. In the said period (6/3/2015–5/8/2022), it is seen that the highest amount of spending on average is in "online shopping" and "market" shopping.

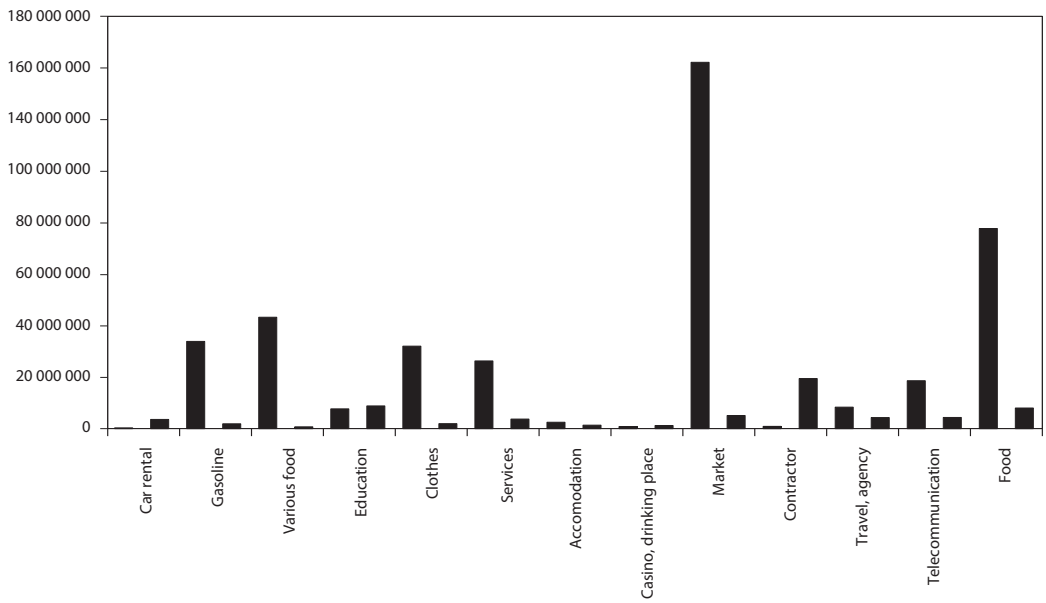
The dates of April 2019 and February 2021 were chosen to represent the onset of the pandemic and its relative relief in Turkey, and the general situation of card expenditures on these dates was examined. Accordingly, the total number of credit cards, which was 67 242 148 in April 2019, increased to 77 254 183 in February 2021. The total number of debit cards, which was 124 487 793, reached 141 270 606. The total number of transactions, which was 342 838 029 with credit cards and 181 336 010 with credit cards in April 2019, increased to 347 342 572 and 199 017 145 in February 2021, respectively. The sectoral distributions of the total number of bank and credit card transactions in April 2019 and February 2021 is given in Figure 2 and Figure 3.

Figure 1 Median values of expenditure amounts



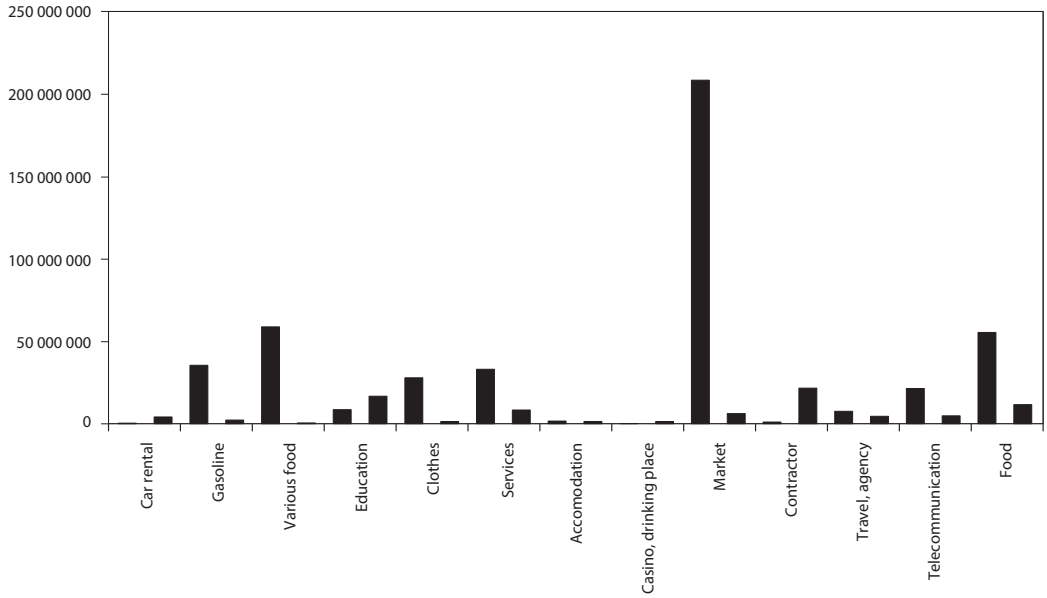
Source: The Central Bank of the Republic of Türkiye (CBRT)

Figure 2 Sectoral distribution of total number of debit and credit card transactions as of April 2019



Source: The Central Bank of the Republic of Türkiye (CBRT)

Figure 3 Sectoral distribution of total number of debit and credit card transactions as of February 2021



Source: The Central Bank of the Republic of Türkiye (CBRT)

The sectoral distribution of the total number of debit and credit card transactions as of April 2019 (Figure 2) and the sectoral distribution of the total number of debit and credit card transactions as of February 2021 (Figure 3) are given. When these two figures are compared, while the number of transactions increases (expenses) in food, electrical/electronic goods, computers, markets and shopping centres, the number of transactions and thus the expenditures decreased in the travel agencies/ transportation, building materials, hardware, ironmongery, airlines, clothing and accessories, furniture and decoration groups.

Whether there is a structural break in bank and credit card expenditures for the period 6/3/2015–5/8/2022 and, if any, the data covering these dates have been analysed with the help of BP analysis and the break dates obtained are shown in Table 1. All analyses were made in E-views 12 program. The highest breaks observed are "individual retirement", "building material", "contractor", "drinking place", "health", "market", "online shopping", "service", "shopping phone", "travel", "various food" and "vehicle sales" expenditures. Expenditure item with a single break is an "accommodation".

Considering the breaking dates in all expenditures as a result of the BP analysis, Figure 4 was created to see how many expenditure types were observed during these dates. According to the figures, the highest break was observed in the week of July 23, 2021, while a structural break occurred in a total of 14 expenditure items, as can be seen from Table 1.

Therewithal, the week of July 16, 2021 is in the second place with 11 intervals. From Figure 4, it is seen that after the pandemic announcement, the breaks increased in March and April 2020 and intensified as of May 2020. In July 2021, which coincides with the end of the restrictions, it is seen that the breaks reached the highest level.

The graphs showing the break dates and direction changes obtained as a result of the structural break analyses made with BP for bank and credit card expenditures are given in Figures 5(a–c) in the online

version. One of the most striking results in the charts is that all three downside breaks coincided with the period when the pandemic was declared in Turkey. "drinking place", "tax" and "travel" are expenditures where downward breaks are observed.

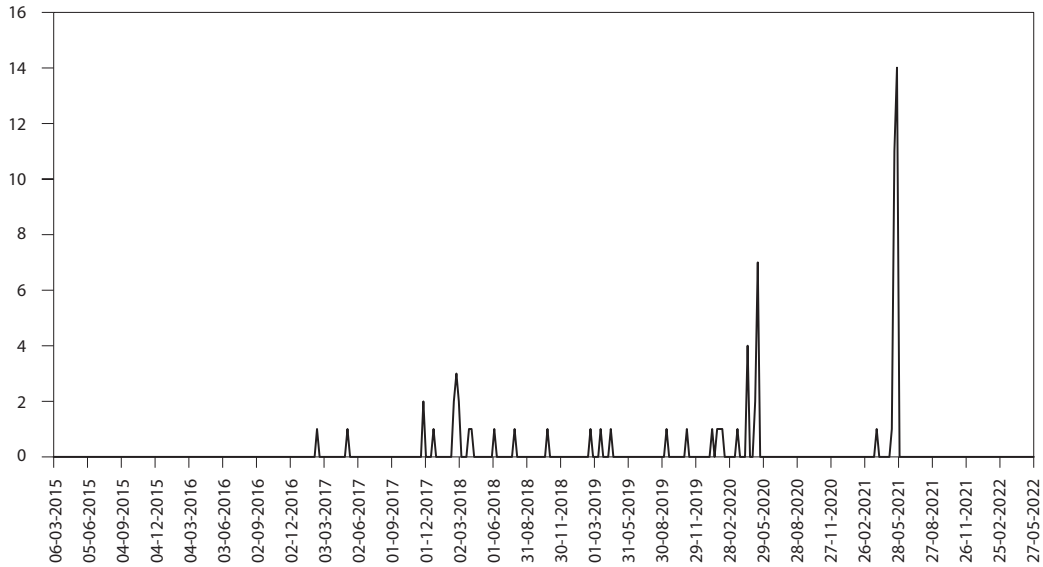
Another striking result regarding the period under consideration; In the period of July 2021, when the pandemic ended in Turkey, upward breaks were observed in all expenditure items except "tax". A total of 25 breaks were observed during the weeks of 16 and 23 July 2021, all of which were upside breaks. The breaks in these dates show that there has been a serious increase in the expenditures of "club", "airline", "drinking place", "service", "online shopping" and "market" with the removal of restrictions.

Table 1 Structural break dates and directions of breakage in spending amounts

Series	Break times and direction			
ACCOMMODATION	23/7/2021↑			
AIRLINE	23/3/2018↑	23/7/2021↑		
BUILDING_MATERIALS	22/12/2017↑	5/6/2020↑	16/7/2021↑	
CAR_RENTAL	3/7/2020↑	23/7/2021↑		
CLOTHES	23/3/2018↑	16/7/2021↑		
CLUB	24/5/2019↑	16/7/2021↑		
CONTRACTOR	22/12/2017↑	5/6/2020↑	16/7/2021↑	
DIRECT_MARKETING	20/12/2019↑	23/7/2021↑		
DRINKING_PLACE	30/11/2018↑	20/3/2020↑	23/7/2021↑	
EDUCATION	31/8/2018↑	9/7/2021↑		
ELECTRONIC	8/5/2020↑	16/7/2021↑		
FOOD	23/3/2018↑	23/7/2021↑		
FURNITURE	5/6/2020↑	16/7/2021↑		
GASOLINE	23/7/2021↑			
HEALTH	30/3/2018↑	26/6/2020↑	16/7/2021↑	
INDIVIDUAL_RETIREMENTS	3/3/2017↑	26/4/2019↑	3/7/2020↑	23/7/2021↑
INSURANCE	25/10/2019↑	16/7/2021↑		
JEWELER	29/3/2019↑	16/7/2021↑		
MARKET	4/5/2018↑	13/3/2020↑	23/7/2021↑	
ONLINE_SHOPPING	6/7/2018↑	3/7/2020↑	23/7/2021↑	
OTHER	3/7/2020↑	23/7/2021↑		
SERVICE	27/4/2018↑	3/7/2020↑	23/7/2021↑	
SHOPPING_PHONE	16/3/2018↑	26/6/2020↑	16/7/2021↑	
TAX	26/5/2017↑	27/3/2020↑		
TELECOMMUNICATION	3/7/2020↑	23/7/2021↑		
TRAVEL	19/1/2018↑	28/2/2020↑	28/5/2021↑	
VARIOUS_FOOD	30/3/2018↑	3/7/2020↑	23/7/2021↑	
VEHICLE_SALES	16/3/2018↑	5/6/2020↑	16/7/2021↑	

Source: E-Views Program

Figure 4 Number of breaks in terms of break dates



Source: E-Views Program

Figure 5(a) Breaks and regimens found with sequential BP

Note: See the online version of *Statistika: Statistics and Economy Journal* No. 1/2023: <*https://doi.org/10.54694/stat.2022.21*>.
Source: E-Views program

Figure 5(b) Breaks and regimens found with sequential BP

Note: See the online version of *Statistika: Statistics and Economy Journal* No. 1/2023: <*https://doi.org/10.54694/stat.2022.21*>.
Source: E-Views program

Figure 5(c) Breaks and regimens found with sequential BP

Note: See the online version of *Statistika: Statistics and Economy Journal* No. 1/2023: <*https://doi.org/10.54694/stat.2022.21*>.
Source: E-Views program

DISCUSSION AND CONCLUSION

There is no country, industry, business or consumer that has not been affected by the Covid-19 pandemic. The negative effects of the pandemic are seen especially in the service sector, and it has a wide range of effects, such as the loss of customers in the food and beverage businesses (restaurant, cafeteria, etc.) operating in the service sector, the cancellation or postponement of reservations in transportation enterprises, the closure of touristic businesses and hotels (Morris and Karmin, 2020). According to the findings of the study, it was observed that the epidemic caused deterioration in the expenditures and expenditure items of consumers in Turkey.

In this part of the study, it is discussed whether there is a relationship between the breaking points (dates) determined by the analyses made in the previous section and the statements released by the officials of official institutions and organizations regarding the Covid-19 outbreak in Turkey and it is evaluated with the results of studies on Covid-19.

The data used in the research covers the dates 6/3/2015–5/8/2022, and it is seen that the most intense breakout occurred on 16 and 23 July 2021 (Figure 4). Considering that the first coronavirus case in Turkey was announced on March 11, 2020, and with the announcement of the restrictions right after, it is seen that there is a negative break in some expenditure items. It is actually a highly expected result that the first reaction against the pandemic is in "travel" expenditures. The fact that consumers reduce their travel and holiday expenses with the epidemic is related to the seriousness of the epidemic and the closing of borders both inside and outside the country.

According to the new restrictions announced on March 15, 2020, it has been decided to temporarily close bars and nightclubs. The effect of this decision showed itself in the week of March 20, 2020, and a downward break was observed in "drinking place" expenditures. According to a new decision announced on March 22, 2020, all enforcement and bankruptcy proceedings have been postponed, except for enforcement proceedings regarding alimony receivables. The effect of this news caused the "goverment/ tax payments" expenditures to break down in the week of March 27, 2020.

Again, on 5/6/2020 and 3/7/2020, it is seen that there are positive breaks in 11 expenditure items. Depending on the decisions taken in the second phase of the normalization process announced on June 1, 2020, a positive break in the expenditures of "car rental", "service", "telecommunication", "vehicle sales", "contractor", "building materials" and "furniture" appears to be.

After the start of the pandemic process in Turkey, it is seen that there is a fluctuation in the expenditures of consumers (Figure 4). Jung et al. (2020) analysed the effect of the epidemic on consumer spending by analysing the expenditures made by bank and credit card, and according to their findings, they revealed that the epidemic caused a significant deterioration in consumer spending.

Despite the apparent decrease in "travel" and "drinking place" expenditures during the period between the beginning and the end of the pandemic, the increase in expenditures in other items is one of the remarkable points of this study. Binder (2020) investigated the opinions of consumers in the USA on the interest rate cut of the US Federal Reserve (FED) and the decisions they made due to the fear of coronavirus. According to the findings of the study, it was revealed that 40% of consumers purchased food or supplies due to coronavirus concerns, and 28% canceled their travel plans. Again, Coibion et al. (2020) examined how various restrictions and bans brought about by Covid-19 affect consumers' household spending and macroeconomic expectations at the local level. About 50% of the participants stated that they lost their income and wealth due to the corona virus, and that their total consumption expenditures decreased, especially in travel and clothing. Güder et al. (2021), concluded that the use of public transportation decreased, the consumers would not participate in social activities for 6 months after the epidemic ended, they canceled their holiday plans, and they would not prefer crowded holiday areas for 12 months even if the epidemic ended. Sayyida et al. (2021) stated that the increase in online retail sales in the second quarter of 2020 was due to unusual purchasing behavior as consumers fear market restrictions due to the global Covid-19 pandemic.

The first case in Turkey was announced on March 11, 2020. With the statement made on March 12, the education was suspended, and it was decided to play sports competitions without spectators. One day after these decisions, the borders with some of the EU member states were closed. After these explanations, as can be seen in Table 1, structural breaks were detected in various expenditure items in March. As of the end of May and the beginning of June, the restrictions were partially relaxed and domestic travel restrictions were lifted. After these statements, it was observed that upside breaks intensified this time.

With the removal of the restrictions as of June 2021, despite a few breaks seen at the beginning of the pandemic, it has been observed that the expenditures have increased markedly in all items. This is an important result of the study. The reaction of consumers to the restrictions and their reactions to the end of the restrictions differ significantly. While the restrictions do not change the card expenditures, card expenditures suddenly increased with the return to normal life. Jones (2020) states that consumers' lives

will be divided into two groups as before and after the epidemic, and there will be significant differences between the two lifestyles. Due to the rapid spread of the virus, consumers who are afraid of the crowd may not prefer crowded places such as entertainment places, restaurants, shopping malls, gyms, even after the virus is under control. Even socializations can be home-based or in smaller groups. According to He and Harris (2020), although the short-term impact of the Covid-19 pandemic process is hardly felt in the initial period due to globally widespread quarantine and social distancing measures, long-term economic, social, political, and cultural effects, negative effects on ideas, beliefs, values, habits, and behavior will be seen once the pandemic process ends. In addition to the fact that the pandemic process causes significant changes in consumer priorities, behavior and spending, governments and businesses around the world should take measures to mitigate the effects of the pandemic by acting with proactive foresight (İri, 2021).

We hope that the study will contribute to further studies on the Covid-19 outbreak, and will provide information, discussion and guidance for future studies on this subject. Restrictions brought by governments and the impact of the Covid-19 pandemic may differ geographically, even within the country. In the future, new studies can be conducted by considering this situation. In addition, this research can be renewed by expanding the range of use of the data, so that the fluctuations and their causes can be analysed in more detail.

Of course, when interpreting the findings of the analysis, it should also be considered that consumers may have changed their payment methods due to anxiety about infectious diseases. Some of the increases in card spending may be due to the change in payment method rather than the spending behavior itself. For this reason, it will be important in this respect to conduct a similar study on card expenditures after the pandemic.

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ANNNEX

Table A1 Time series and explanations used in the study

Series name	Description
Accommodation	Accommodation (thousand TL)
Airlines	Airlines (thousand TL)
Building material	Building materials, hardware, ironmongery (thousand TL)
Car rental	Car rental (thousand TL)
Clothes	Clothing and accessories (thousand TL)
Club	Club/Association/Social services (thousand TL)
Contractor	Contractor works (thousand TL)
Direct marketing	Direct marketing (thousand TL)
Accommodation	Accommodation (thousand TL)
Airlines	Airlines (thousand TL)
Building material	Building materials, hardware, ironmongery (thousand TL)
Car rental	Car rental (thousand TL)
Clothes	Clothing and accessories (thousand TL)
Club	Club/Association/Social services (thousand TL)
Education	Education/Stationery/Office supplies (thousand TL)
Electronic	Electrical-electronic goods, computer (thousand TL)
Food	Food (thousand TL) level public/Tax payments (thousand TL)
Furniture	Furniture and decoration (thousand TL)
Gasoline	Gasoline and fuel stations (thousand TL)
Health	Health/Health products/Cosmetics (thousand TL)
Individual retirement	Private pension (thousand TL)
Insurance	Insurance (thousand TL)
Jeweler	Jewelers (thousand TL)
Market	Markets and shopping centers (thousand TL)
Online shopping	Online shopping (thousand TL)
Other	Other (thousand TL)
Service	Service sectors (thousand TL)
Shopping phone	Shopping by letter/Telephone (thousand TL)
Tax	Government/Tax payments (thousand TL)
Telecommunication	Telecommunications (thousand TL)
Travel	Travel agencies/Transportation (thousand TL)
Various food	Various food (thousand TL)
Vehicle sales	Car rental-sales/Service/Spare parts (thousand TL)

Source: The Central Bank of the Republic of Türkiye (CBRT)

Table A2 Descriptive statistics

Series	Mean	Median	Maximum	Minimum	Std. dev.	Skewness	Kurtosis	Coefficient of variation
ACCOMMODATION	310 769.8	214 785	2 220 211	15 580	293 964.4	3.531901	18.64831	0.972586
AIRLINES	551 819.7	368 254	3 186 371	16 311	582 789.9	2.744017	10.63689	1.027679
BUILDING_ MATERIALS	856 134.2	605 614.5	3 574 739	154 461	646 348.2	2.17292	7.523153	0.868885
CAR_RENTAL	54 223.23	39 399	330 729	12 925	45 947.76	3.096167	14.97574	0.920533
CLOTHES	1 531 768	1 212 417	6 941 531	369 195	981 448	2.267506	8.887688	0.800455
CLUB	90 088.72	68 274.5	945 334	25 525	70 809.14	6.158084	62.65455	0.886563
CONTRACTOR	21 6219.9	146 766.5	1 195 177	27 687	194 717.1	2.224439	8.155135	0.948974
DIRECT_MARKETING	36 333.46	28 647	197 816	9 012	21 231.69	3.37133	19.78543	0.764432
DRINKING_PLACE	24 963.6	16 472.5	133 859	1 570	22 530.16	2.045217	7.789499	0.950011
EDUCATION	539 851.4	430 350.5	2 636 855	162 178	316 543.3	2.069303	9.153874	0.765737
ELECTRONIC	1 378 169	843 934	5 212 958	415 971	1 048 743	1.708193	5.166776	0.872335
FOOD	882 780.4	640 061.5	4 273 117	173 814	754 140.5	2.315686	8.398694	0.924272
FURNITURE	676 528.1	532 659.5	2 341 070	233 879	384 697.8	2.045349	7.153598	0.754079
GASOLINE	1 558 966	1 229 087	7 738 934	584 730	1 101 152	3.141083	13.3469	0.840437
HEALTH	743 061.9	561 514.5	2 713 556	167 283	484 197.4	1.790253	5.952248	0.807233
INDIV_RETIR.	175 574	162 154.5	422 233	60 434	65 922.29	1.116574	4.38847	0.612754
INSURANCE	818 291.3	684 116	3 268 279	206 301	452 529.7	2.644097	11.68336	0.743652
JEWELER	311 015.4	233 170.5	1 439 853	55 808	215 466.8	2.443047	9.551932	0.832337
MARKET	3 919 659	2 848 942	15 517 616	1 509 559	2 635 114	2.03785	7.111298	0.819928
ONLINE_SHOPPING	4 637 090	2 991 777	23 937 765	747 114	4 417 965	1.964739	6.840043	0.976087
OTHER	656 044.7	375 033	3 164 249	138 030	604 598	2.012884	6.666738	0.95999
SERVICE	1 190 579	971 763	4 656 018	262 198	831 173	1.944176	6.736165	0.835539
SHOPPING_PHONE	1 115 899	872 463	3 952 855	370 193	702 798.4	2.236942	7.876491	0.793602
TAX	597 947.6	640 839	2 137 042	6 885	429 733.5	0.101211	2.313533	0.84775
TELECOMMUNICATION	414 281.9	340 237.5	1 097 469	166 142	167 497.3	1.472947	4.311699	0.635852
TRAVEL	508 877.7	426 679.5	2 226 818	94 173	342 215.1	2.57343	11.52179	0.820055
VARIOUS_FOOD	1 377 339	1 053 180	5 396 607	458 180	938 811	1.988575	6.833861	0.825598
VEHICLE_SALES	722 516.1	534 517	3 007 960	136 277	496 698	2.088806	7.501149	0.82913

Source: The Central Bank of the Republic of Türkiye (CBRT)

Evaluation of the Socioeconomic Impact of Income Inequality in Morocco Using a CGE Model

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Abstract

The main objective of this paper is to assess the impact of a change in household income inequality on macroeconomic variables of a developing country, in this case Morocco. To this end, we run a static CGE model calibrated to the 2016 Moroccan SAM. Among the main results, we find that a 1% increase in household income inequality leads to a decrease of (–1.60%) in GDP at market prices, which implies a loss of (–1.93%) in primary sector value added (agriculture and fishing) which remains a key sector in this economy. Furthermore, we find that a fiscal and budgetary policy that targets reducing inequality can also improve social and economic outcomes.[3]

Keywords	*DOI*	*JEL code*
Income inequality, socioeconomic impact, public policy, North Africa, computable general equilibrium model	*https://doi.org/10.54694/stat.2022.31*	*C68, D63, E62, H31*

INTRODUCTION

Across all human societies and ideologies, there has long been a significant debate about the nature of the relationship between economic development and social inequality (Piketty, 2021). Various exploratory studies on economic inequality, particularly in terms of income, assert a worldwide and extremely rapid increase since the 1980s. Henceforth, this phenomenon is perceived as global and unavoidable (Alvaredo, 2018; Lakner and Milanovic, 2015). Many authors, including Nobel Prize laureates in economics, express their concerns about the extent of this phenomenon (Deaton, 2015; Stiglitz, 2012, 2015; Krugman, 2008; Banerjee and Duflo, 2003; Sen, 1992). Therefore, if economic inequality is not effectively addressed, it is likely to lead to all sorts of political and social catastrophes. In fact, the Sustainable Development Goals

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[3] This study was presented during the 25th Annual Conference on Global Economic Analysis organized by Global Trade Analysis Project (GTAP) in collaboration with the Economic Commission for Africa (UNECA), Raouf and Chtouki (2022), Retrieved from: <*https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=6518*>.

(SDGs), which outline the optimal way to address the challenges facing the world, consider the reduction of inequality as a central feature to achieve the expected progress.

Although the phenomenon is global, its socio-economic impact and the strategies used to deal with it cannot be generalized to all countries. The primary objective of this study, at least in part, is to assess the potential impact of an increase in income inequality on a national economy, particularly a developing economy such as Morocco. Using a static computable general equilibrium (CGE) model calibrated for the Moroccan economy, this study aims to simulate the shock of the variation of the level of inequality between income households on socioeconomic variables. This shock is applied by differentiating the direct taxation of the income of each category of representative household (namely, rural poor households, urban poor households, rural rich households, and urban rich households).

Additionally, our approach is to use the headcount data for each of the representative household agents to calculate the level of income inequality that emerges via the Gini method. Based on the level of income redistribution that results from the simulated shock, the variation in the level of income inequality is accompanied by a variation in multiple economic (production, consumption demand, firm performance, return on capital, trade openness, etc.) and social (living standards of poor and rural households, social transfers, access to education and health, etc.) variables that illustrate the impact of this inequality.

1 THEORETICAL BACKGROUND OF INCOME INEQUALITY IMPACT

Social and economic inequality is a global, complex, and highly varied phenomenon. Given its significance and complexity, we restrict our attention to dealing with income inequality. This refers to the flow of resources available to feed one's consumption and savings (Hicks, 1948). The growth of income inequality generates a form of division that reinforces the gap between certain social classes, some refer to it as the great divide (Deaton, 2015). This social structure puts low-income individuals or young people who are unable to access the labour market far behind the highest social classes (Serfati, 2015; Alvaredo, 2018). Some epidemiologists consider that the less equal a society is, the better it has the capacity to produce in terms of citizenship and strengthening social factors (Wilkinson and Pickett, 2009).

The socioeconomic impact of income inequality is supported by many theoretical studies (Mdingi and Ho, 2021; Hombres et al., 2012). Therefore, to enhance the relevance of our approach, we will limit it to the inputs related to the modelling approach. Thus, this theoretical review discusses two components: (i) Conceptualization of the impact channels of income inequality on the macroeconomic equilibrium with reference to Walras' general equilibrium theory; (ii) Presentation of the key variables of the model that illustrate the extent of this socioeconomic impact.

1.1 Inclusion of income inequality concept into general equilibrium analysis

According to Walras' general equilibrium theory (1874) of the late 19th century, the economy in its global perception is represented by a circulation of monetary flows that results from the interactions of the market between at least three actors:[4] Household, firm, and government. Under this illustration, the supply of factors of production (mainly labour and capital) by households generates a regular flow of income to finance their consumption expenditures. At the same time, the final consumption of households translates into sales, which in turn generate income for the general economic structure (sales for firms).

In a system that is as intertwined as it is interactive, we imagine that an increase in household income inequalities could affect final consumption demand and thus threaten the maintenance of the fluidity of this monetary circulation. As a result, our approach to analyzing the impact of income inequality consists of following the propagation of the impact of an additional income gap between households

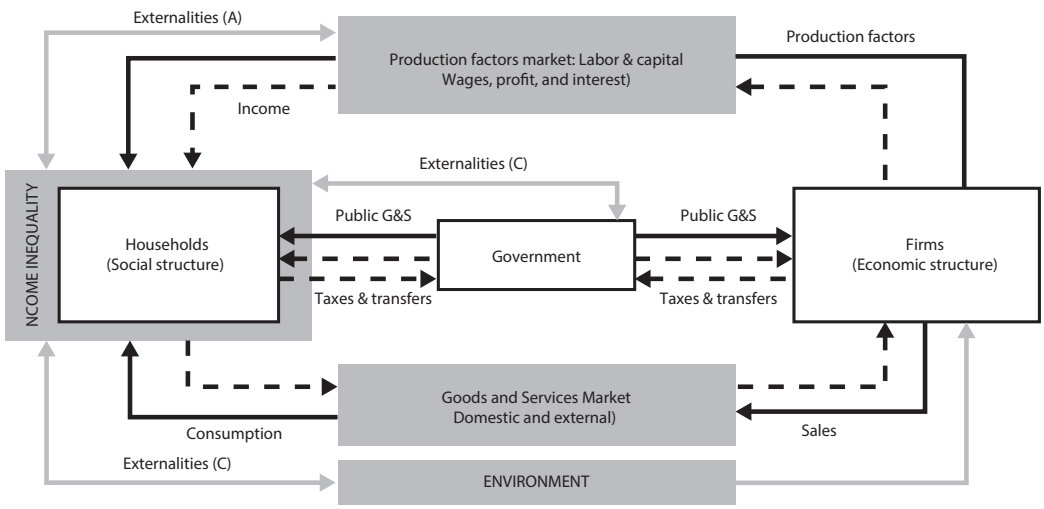
[4] On one side, households, which are supposed to own the production factors. Second, firms, which rent factors from households for use in the production of goods subsequently purchased by households and other firms (intermediate consumption). The third actor is the government, which provides public goods that are consumed by households and firms.

on its economic environment as shown in Figure 1. We distinguish three types of externalities that affects this equilibrium:

Externalities (A): These refer to the mutuality of effects between the level of income inequalities, the labour markets, and the capital market. The first connection to be highlighted concerns the returns to factors of production in proportion to households. On that note, Piketty (2013) confirms through his thesis on the forces of income divergence that capital incomes rise much more than labour incomes. This is reminiscent of Kalecki's (1954) thinking on the inevitable gap between workers and capitalists.

The second connection relates to the impact of inequality on employment and capital. It is often discussed in studies that address the impact of inequality on growth. Some argue that unequal income growth can lead to an increase in national savings, as theorized by Kaldor (1957) in his thesis on the virtuous cycle. Others draw on Kuznets' work to confirm the positive impact that inequality can have on long-term growth (Forbes, 2000; Barro, 2000). On the contrary, several other studies reject this optimistic view (Banerjee and Duflo, 2003; Benhabib, 2003; Alesina and Rodrik, 1994; Persson and Tabellini, 1991; Bourguignon, 2015). Also, other studies testify to a qualitative impact of inequalities on the factors of production: deterioration in the market supply of jobs, instability of financial markets, a trap in access to the financial market for the poor and intermediate social class, etc.

Figure 1 Household income inequality in the circulatory flow of the economy



Source: Own construction (adapted from Mankiw, 2014)

Externalities (B): This concerns the impact of inequalities on the economic, social, and societal environment. Many different studies aim to establish a link between inequalities and the determinants of their socioeconomic impact (Ostry et al., 2014; Alesina and Rodrik, 1994; Galor and Zeira, 1993). The major finding of this review is that there is a negative causal relationship in both directions. Thus, an unequal environment is unfavorable to economic development in the long term for multiple reasons, mainly: recession of social cohesion, political instability (risk of riots), emergence of a sense of injustice (leading to increased crime, breakdown of the political system, lack of general confidence and others). This reinforces the idea that inequalities are evolutionary, multiform and above all cumulative (Piketty, 2013).

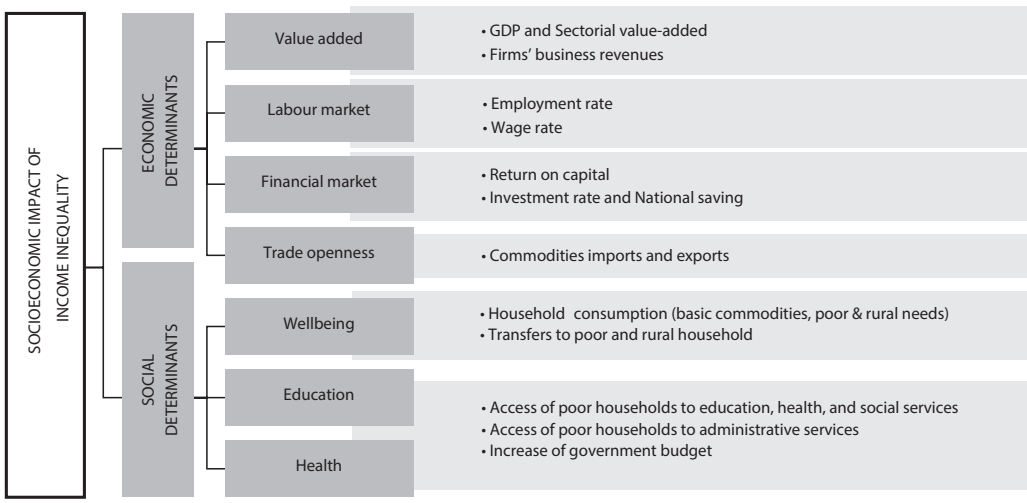
Externalities (C): It relates to the impact of inequalities on public policies. We support the principle that the social impact of income inequality – relating to education and mental and physical health - exerts a heavy burden on public funds by increasing the need for investment and current expenditure on social policies. As for the societal impact, although difficult to measure, we believe that its factors have effects that are undeniable: between the depreciation of trust, popular disengagement from political processes and the rise of corruption and criminality to the societal implications of gender inequality.

1.2 Determinant of the socioeconomic impact of income inequality

Since the 2007 crisis erupted, several researchers have become extremely concerned on whether these inequalities are an economic obstacle (Ostry et al., 2014; Bourguignon, 2015) or stimulus (Barro, 2000; Kuznets, 1955). Piketty (2013) reveals that, unlike the traditional view based on Kuznets (1955), developed economies do not systematically evolve towards more egalitarian societies. These facts have given rise to an intense and multidisciplinary debate to define the determinants of the impact of inequalities, mainly on macroeconomic standards and the foundations of social and environmental cohesion (Stiglitz, 2015; Nissanke and Thorbecke, 2006; Banerjee and Duflo, 2003; Alesina and Rodrik, 1994).

According to the scientific community, the study of the impacts of income disparities will be structured in two parts: (i) Economic impact, which concerns economic determinants such as growth (Kuznets, 1955), employment (Card and DiNardo, 2002; Acemoglu, 1999), financial stability (Brei et al., 2018; Beck et al., 2007), and trade openness (Daumal, 2013); (ii) Social impact, which includes social variables, namely: wellbeing (Berg and Veenhoven, 2010; Alessina et al., 2004), education (Acemoglu and Pischke, 2001), and health (Leigh et al., 2009). Therefore, our approach consists of studying the shift in some variables, shown in Figure 2, to illustrate the nature of their impacts.

Figure 2 Description of the impact variables of income inequality in the CGEM



Source: Own construction

2 METHODOLOGY

In the methodology section, we will focus on the description of our CGE model, and the social accounting matrix (SAM) used to assess the Moroccan economy. Built on the above mentioned Walrasien theory,

the computable general equilibrium model (CGEM) is a system of simultaneous equations that makes it possible to define the equilibrium between the resources and uses of the different markets, in terms of factors, products, branches of activity and the different agents. The relationships between the different variables, in volume or in value, are described at the individual level (by agent) using Behavioral functions, equilibrium relationships or accounting identities. The latter, as its name suggests, is based on the theory of general equilibrium presented earlier.

The following model is a static and real CGEM inspired by the standard model produced by the PEP organization, namely the "$PEP_{1-1\ model}$". As to the accounting component, the model structures its data supply via the Social Accounting Matrix (SAM). This matrix reproduces the overall flows of the Moroccan economy so that the income of each agent must be equal to all his or her expenditures. Also, the output of each branch of activity must be equal to the sum of the output sold on the local market and the exports of the branch (Raouf et al., 2021). The SAM is the result of extensive adaptation and disaggregation to meet the needs of this research. It is calibrated on data from the table of resource and employment for the year 2016. Thus, the main accounts of this matrix are distributed as follows:

- 19 branches of economic activity that can be consolidated into three sectors: Primary sector related to "agriculture", secondary sector related to "industries and manufacturing" and a tertiary sector for private and public services,
- 2 factors of production: labour and capital,
- 9 agents, including 4 households (poor urban household, poor rural household, rich urban household, and rich rural household),
- 3 additional accounts associated with taxes (indirect taxation "TI", direct taxation "TD" and customs import taxation "TM").

The selected model is composed of 96 blocks of equations and 1 674 singular equations for a total of 1 674 variables, of which 1 466 are free or endogenous. To allow the resolution of the model, the 208 variables presented in Table A2 in the Annex C are fixed and made exogenous including the parameters whose values are obtained by assignment or by the calibration of the model.[5] After the resolution, the general equilibrium verification variable "*Leon*" is equal close to a zero value (3.781 E-9). This is the minimum value we could obtain, given the parameters of the model. It seems marginal, very close to zero. At the end of this step, the basic solution, without shock, is found and all the model parameters are calibrated.

3 DATA DESCRIPTION AND MODELLING STRATEGY

3.1 Household income inequality at base year of the CGE model

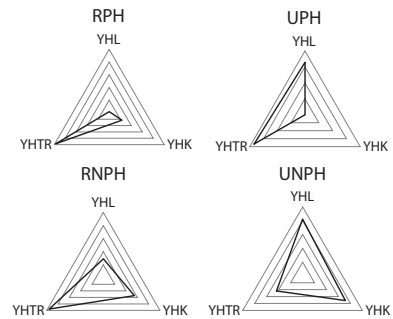
As mentioned earlier, national household income is divided into four representative household categories. Each of these categories includes a headcount in line with the HCP survey data (HCP, 2016). Thus, this structure does not follow a quartile split (25% for each category) but rather according to poverty rate and place of residence (HCP, 2019). As shown in Table 1, the overall household income is divided into three income categories: labour household income (YHL) with a share of 39.48%, capital household income (YHK) with a share of 33.92% and transfer household income (YHTR) with a share of 26.61%. The household with the lowest income is RPH[6] with a share of the national household income estimated at 2%. The richest household in the distribution, the UNPH household, has a share over 68% of the total household income. For capital income, we note that UPH has no capital.

In terms of domestic demand, household consumption is distributed just as unequally as the income distribution, especially for urbain household. This results from the fact that it includes the two household agents with the lowest and highest consumption shares. As for savings, the relationship is less unequal.

[5] Please refer to the Annex for more details on the variables fixed to solve the CGE model.
[6] For further details on the designation of each household agent, please refer to the Annex A.

Table 1 Household income structure at the base year equilibrium

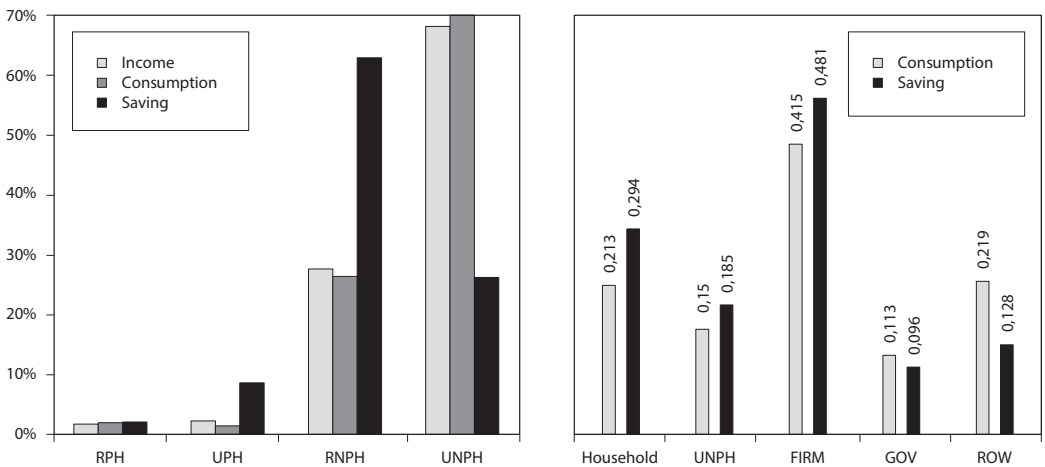
	YHL	YHK	YHTR	YH
RPH	0.10%	1.15%	4.85%	1.72%
UPH	3.29%	0%	3.68%	2.28%
RNPH	14.45%	27.38%	47.82%	27.71%
UNPH	82.15%	71.47%	43.65%	68.28%
TOTAL	**39.48%**	**33.92%**	**26.61%**	



Source: Model outputs estimated according to HCP database (2019)

In the case of the non-household agents, the income of public and private administrations is almost similar, but their consumption behaviour is not: the intermediate consumption of firms is four times greater than that of the public sector and almost twice as great as the total external demand for products intended for export.

Figure 3 Share of consumption and savings by agents at the base year



Source: Model outputs estimated according to HCP database (2019)

Moreover, the consumption and savings of the FIRM agent represent about twice the consumption of households and more than three times the consumption of the government. Thus, the contribution of household consumption and savings, particularly the UNPH agent which represents approximately two thirds of the total, is considerable in the Moroccan economy. By studying household data in the SAM 2016, we note that savings (HS) and transfer income are among the least unequal household aggregates compared to consumption and other forms of household income.

3.2 Procedure for simulating the impact of inequalities in the CGE model

The procedure for incorporating the study of income inequality between parameterized households into our modelling is based on two overarching approaches.

3.2.1. Income inequality measuring approach

The measurement of income inequality on the CGEM is carried out via the Gini index (1921). In addition to the cumulative income share data ($\mathbf{Y_k}$), we use the headcount data ($\mathbf{X_k}$) that aggregates each of the representative households modelled.

$$I_{Gini} = \left| 1 - \sum_{k=0}^{n-1} (X_{k+1} - X_k)(Y_{k+1} - Y_k) \right|.$$

It is possible to measure the level of inequality, not only for income structures, but also for consumption and savings, as illustrated in the Annex. In our model, the Gini index of household income inequality (YH) in the basic equilibrium is estimated at 39.34%. This is consistent with the level of income inequality in the model's base year of 2016 (HCP, 2019).

3.2.2. CGEM simulation strategy

First, to stimulate the income inequality in CGEM, our approach consists of incorporating a mobilizing shock to household income gaps via two policies:

(i) Tax policy: This consists of establishing an overtaxation of household incomes via a direct tax (DT). As shown later in the simulation plan, this overtaxation targets a variation of 25% on urban household incomes and 15% on rural household incomes.

(ii) Mixed policy: This policy is composed of a fiscal and tax policy. The fiscal component uses the same measures as the first policy, while the second consists of a 20% increase in public current expenditure. The interest is to reduce the effect of the increase in government revenue generated by the direct tax on household income.

Regarding the policies explained previously, the simulation strategy is formulated to set up different scenarios where changes in income inequality impact the macroeconomic aggregates of the model. Our simulation strategy is summarized in three parts:

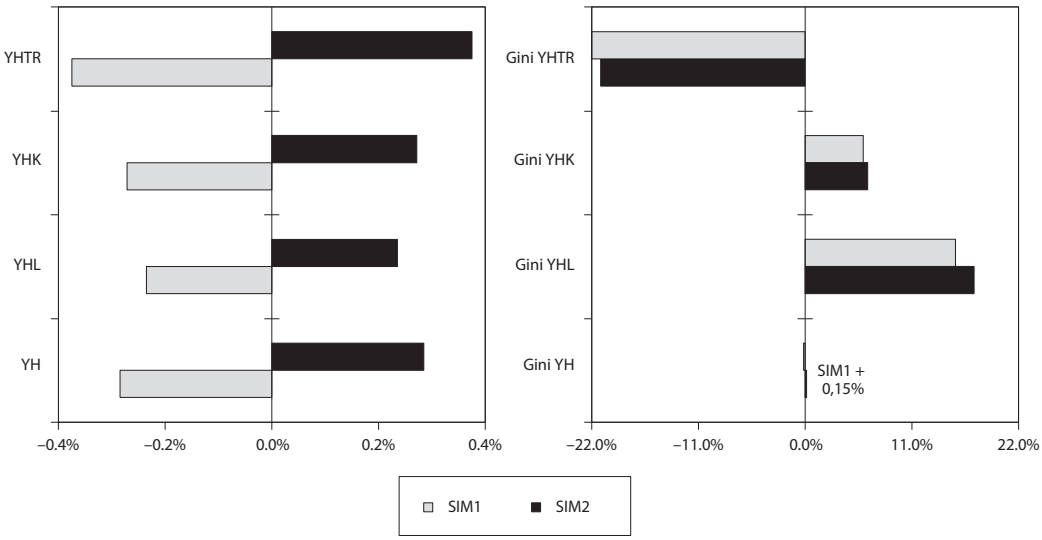
- **Simulation of the increase in inequality:** The impact of overtaxing the non-poor against a reduction in the direct tax on the poor is simulated in SIM1, SIM3 and SIM5. Although these policies aim at reducing the income gap between poor (UPH and RPH) and non-poor (UNPH and RNPH) households through taxation, the results show a relative increase in inequality in the sense of Gini, especially in SIM1 (increase in inequality of +0.15%).
- **Simulation of the reduction of inequalities:** The impact of overtaxing the poor against a reduction of the direct tax on the non-poor is simulated in SIM2, SIM4 and SIM6, which, in parallel with the other simulations, lead to a decrease in household income inequalities, especially in SIM2 (variation of –0.15% in the Gini sense).
- **Impact of public spending: "SIM0":** This simulation is designed to assess the impact of a one-time increase in public spending on the Moroccan economy. This simulation is used only as a differential to the variations generated by the last four simulations, namely SIM3, SIM4, SIM5 and SIM6.

4 MAIN RESULTS OF THE CGEM SIMULATIONS

4.1 Effects of the simulated shocks on income redistribution

To provide a better understanding on the extent of the impact of the simulated shocks on inequality, our approach distinguishes these simulations into two groups: the impact of fiscal policy and the impact of mixed policy. Thus, the first group includes only SIM1 and SIM2. According to the results, we specify that the impact of SIM1 leads to results that are perfectly inverse to those of SIM2. In fact, reducing income inequality through SIM2 leads to an increase in income, mainly in transfer income. This increase is more beneficial to non-poor households, hence the increase in their shares of YHTR of (+0.2%) for UPH and (+0.1%) for RPH.

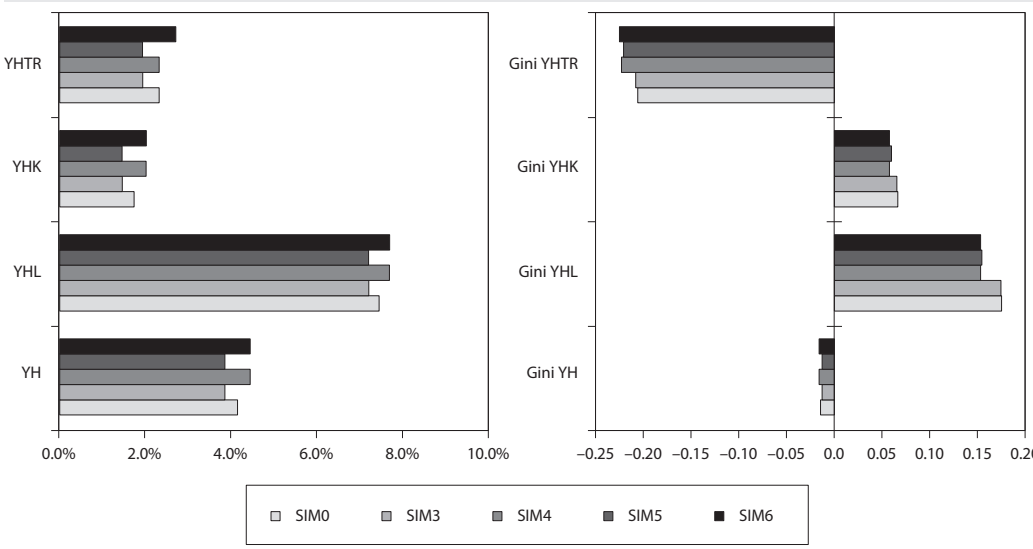
Figure 4 Impact of fiscal policy on household income



Source: Model outputs estimated according to HCP database (2019)

The second group includes SIM3, SIM4, SIM5, and SIM6. We also add SIM0 to establish a baseline value for their changes. In contrast to the first group, inequality results of this second group are more pronounced in terms of the reduction in inequality, with a reduction that varies between (–1.62%) and (–1.30%). Assuming that the change in income inequality index for SIM0 is (–1.46%), we consider only those simulations that have decreased beyond this point, namely SIM4 and SIM6. Considering

Figure 5 Impact of the mixed policy on household income



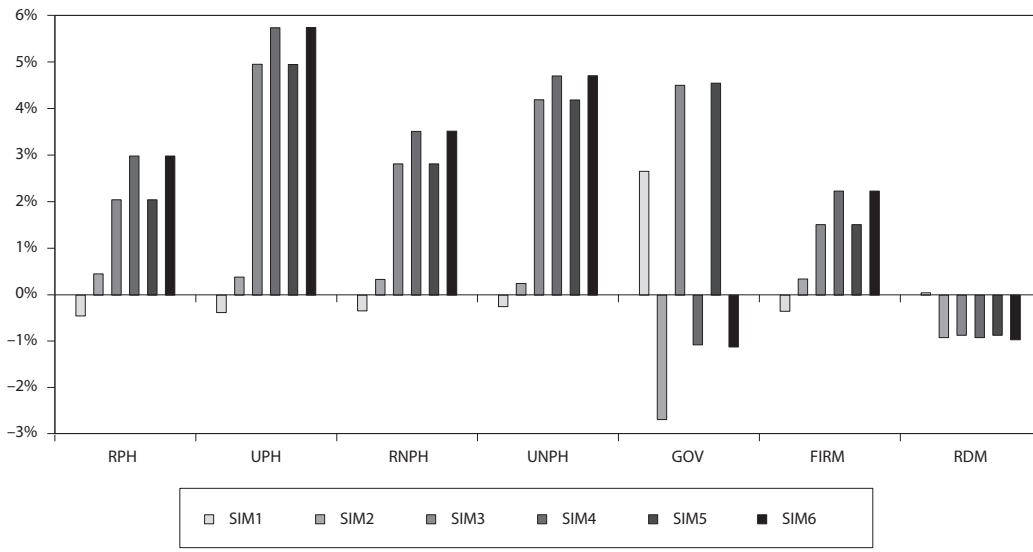
Source: Model outputs estimated according to HCP database (2019)

these assumptions, we note that fiscal restructuring in favor of poor households limits the positive effects generated by this expansionary fiscal policy, mostly in terms of limiting the equalizing effect of the increase in public spending.

Other than household income, these inequalities have a negative impact on the economic structure. Indeed, SIM1 causes a decrease in business revenues of (–0.35%). Instead, SIM4 and SIM6 cause an increase in firms' income at a similar rate of (+2.27%). Meanwhile, inequality has a stimulating effect on the public and external revenues. For the public agent, we relate this effect to the increase in tax revenue generated by the overtaxation of households. For the external agent, we find that the reduction in domestic firm's revenue is beneficial for the rest of the world. This is more strongly demonstrated by SIM4 and SIM6 results, where the decrease in the income of the "rest of the world" agent reflects a gain from the exchange, as it coincides with an increase in firm's revenue.

Given all results on the impact on revenue, the most economically beneficial policies are SIM4 and SIM6. However, we strongly recommend the policy simulated by SIM6. Although both confirm a positive correlation between inequality reduction and household income enhancement, SIM6 is technically and socially more adequate. As a matter of fact, SIM6 policy raises the incomes of the poorest without applying any tax pressure on household incomes. We find that an income tax cut of 25% for urban poor households and 15% for rural poor households allows them to increase their UPH income by (+5.844%) and their RPH income by (+3.036%) respectively, with a Gini index that decreases from 39.4% to 38.7%.

Figure 6 Results of the simulations of the impact on the income of economic agents



Source: Model outputs estimated according to HCP database (2019)

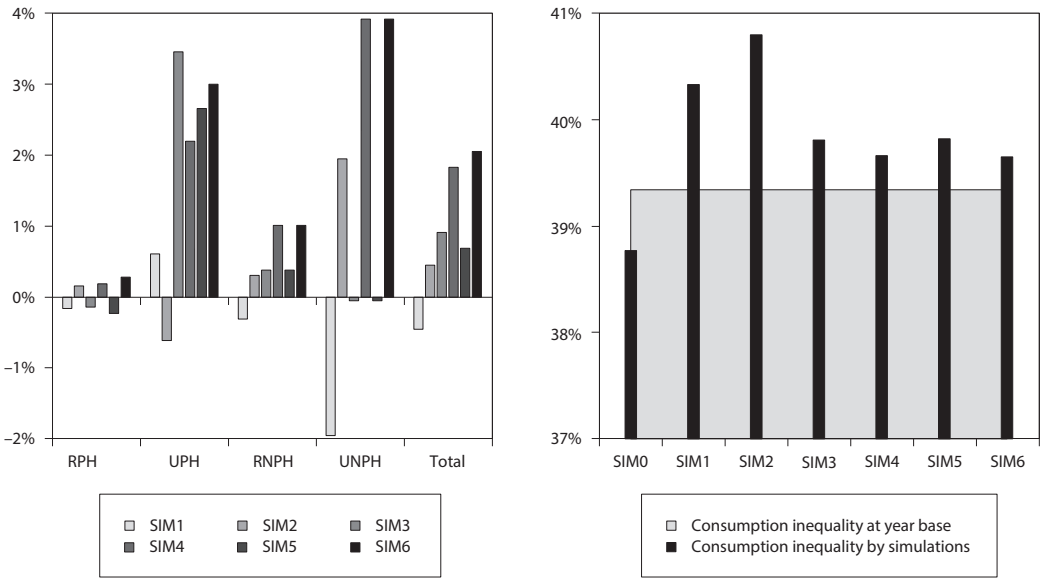
4.2 Impact on the behaviour of different households

Our results demonstrate that inequality has an impact on the individual households' behaviour, which are illustrated in the following three main components: consumption, savings, and transfers between agents.

4.2.1 Impact on household consumption

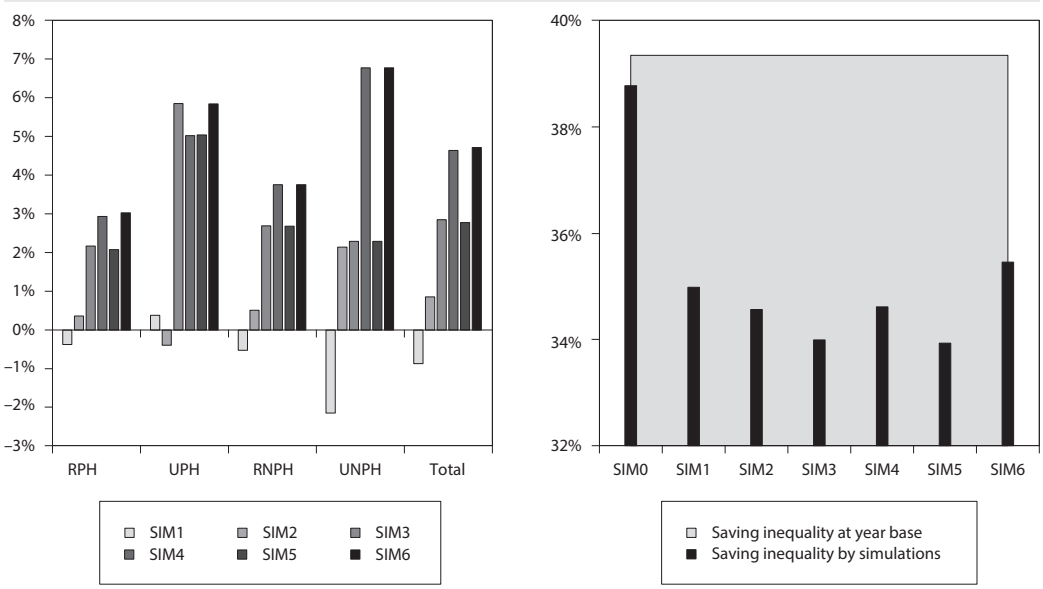
Income inequality increases consumption inequality and reduces the overall level of household consumption. As the results of the simulations show, the level of consumption inequality increases

Figure 7 Results of simulations of the impact on household consumption



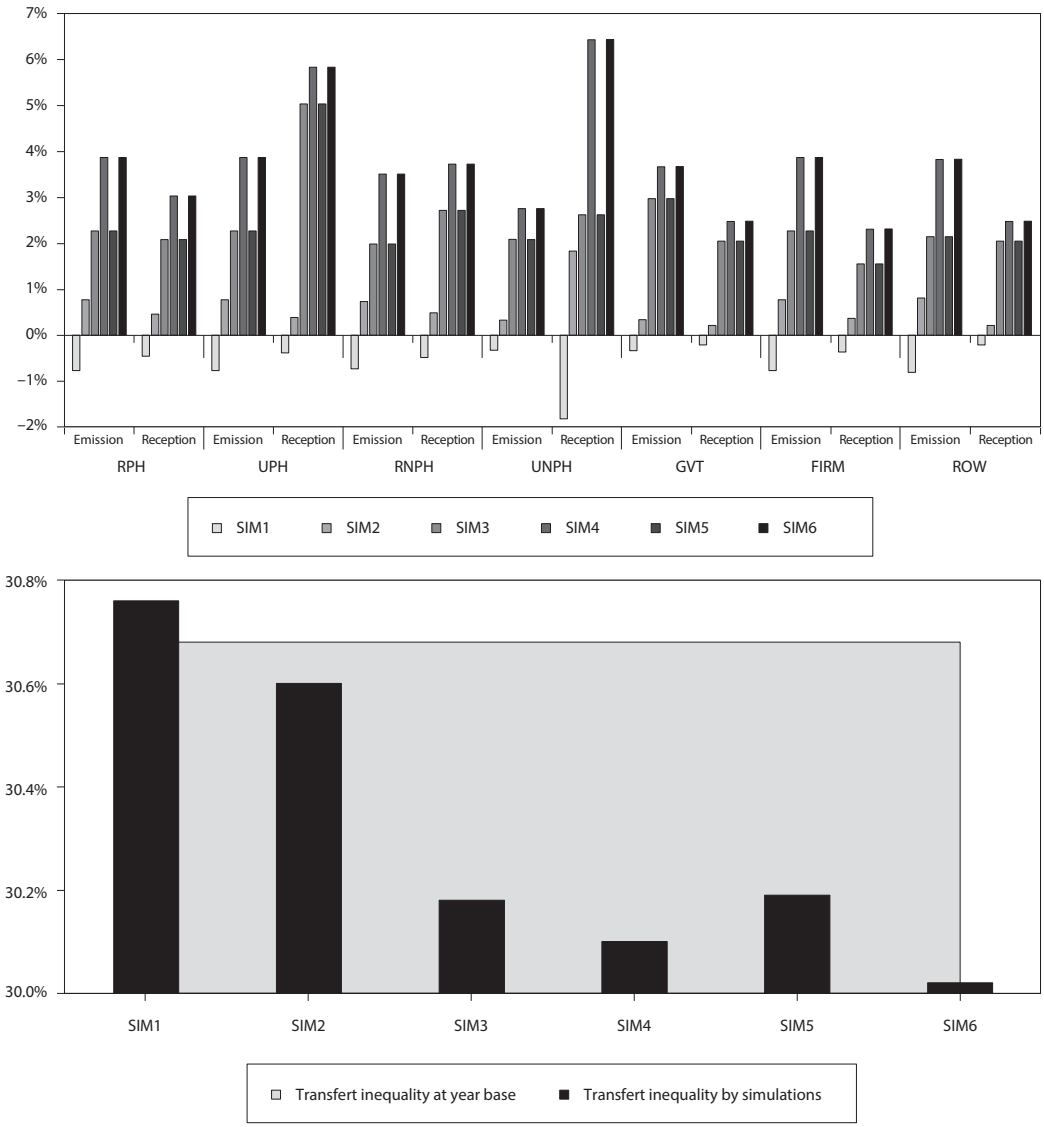
Source: Model outputs estimated according to HCP database (2019)

Figure 8 Results of impact simulations on household savings



Source: Model outputs estimated according to HCP database (2019)

Figure 9 Impact of the simulations on transfers between agents



Source: Model outputs estimated according to HCP database (2019)

in response to all shocks simulated, except for SIM0. In fact, any variation in income affects inequalities in household consumption demand. However, according to SIM2, the reduction in inequality increases the level of final household consumption, in particular that of the UNPH agent by (+1.96%), which represents 15% of overall consumption. Conversely, the UPH household increases its consumption expenditure in SIM1.

4.2.2 Impact on household savings

According to SIM1 results, income inequality increases savings' inequality and reduces national household savings. Noteworthy is that UPH increased both its savings and its consumption expenditure. When

a fiscal policy is added to SIM1's fiscal policy, in this case SIM3, UPH further increases its consumption and savings. We find that UPH's consumption and saving behaviour is particularly highly sensitive to increases in income. As for his rural counterpart, it is only savings that are sensitive to these shocks, in particular the mixed policy.

4.2.3 Impact on the mutuality of household transfers

The structure of income shows that transfers represent a total of 27% of household income. In fact, they are the least unequal, having a Gini index of 30.6%. The increase in inequality leads to a reduction in the mutuality of transfers between the different agents in the model, even reducing transfers from abroad, according to SIM1. In terms of household transactions, poor households' transfers to the government decreased by (–0.77%). This rate is near the decline in transfers issued by RNPH (–0.73%). In the case of the upper household UNPH, the issuance of transfers decreased only by (–0.33%). Similarly, UNPH is the only agent whose decrease in transfer receipt exceeds its issuance. However, its impact remains minor, given that UNPH's income represents only 17% of its total income.

The variation in the level of transfer inequalities per simulation is almost the same for all the shocks except for the fiscal policy simulated at SIM0 (inequalities increase by almost 8% compared to the baseline level). However, it is important to keep in mind that the redistribution hierarchy of transfer income is different from that of total income, where the higher income share is held mainly by rural households. To this end, the increase in inequality implies more transfers to RPH and RNPH. Therefore, the increase in income in SIM4 and SIM6 for urban income relatively reduces transfer inequalities. Our findings confirm that the redistribution of transfer income has a regulatory function on the level of inequality in Morocco. Similarly, a fiscal stimulus policy will strengthen transfers to the rural environment, while favoring the RNPH agent. As for the non-household agents, the most significant decrease in emissions is linked to the external agent ROW. Technically, the increase in inequality reduces external transfers and, thus, increases income for this external agent.

4.3 Impact on the components of market equilibrium

Once the impact of income inequality on household behaviour has been highlighted, this section focuses on the impact on the various components of market equilibrium by presenting the results of the impact on the demand for factors of production, aggregate supply, and prices.

4.3.1 Impact on aggregate demand

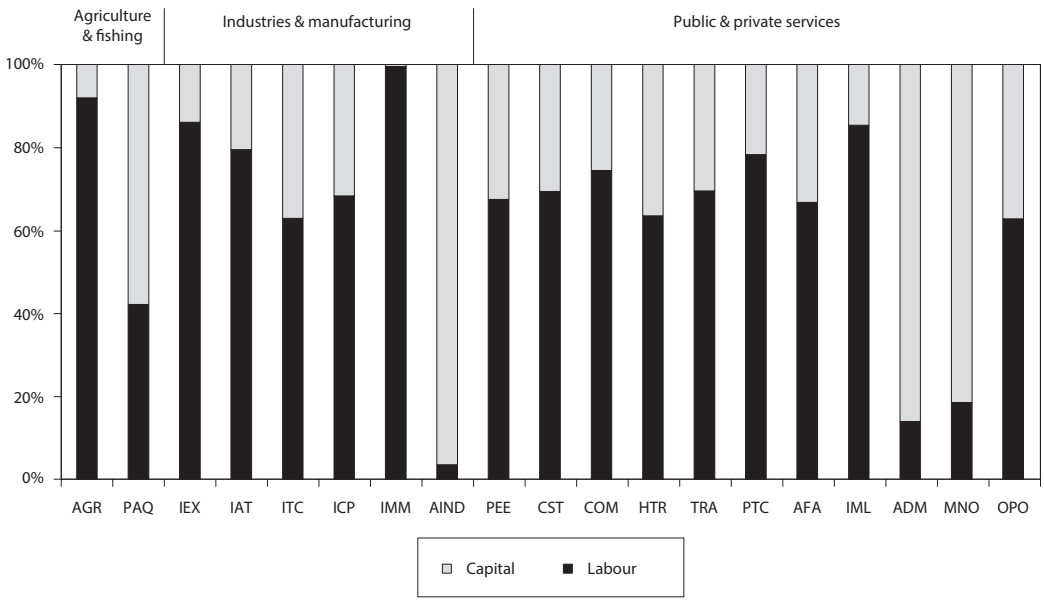
The presentation of the impact on aggregate demand concerns the exposition of impact results of the factors of production and commodities.

Impact on the demand for factors of production

The structure of demand for factors of production by branch is calibrated so that most branches are capital-dependent, except for fishing (PAQ), public services (ADM), social services (MNO), and other industries (AIND). By sector, we note that an increase in income inequality following SIM1 reduces the demand for factors of production in the primary sector of agriculture and the tertiary sector of services.

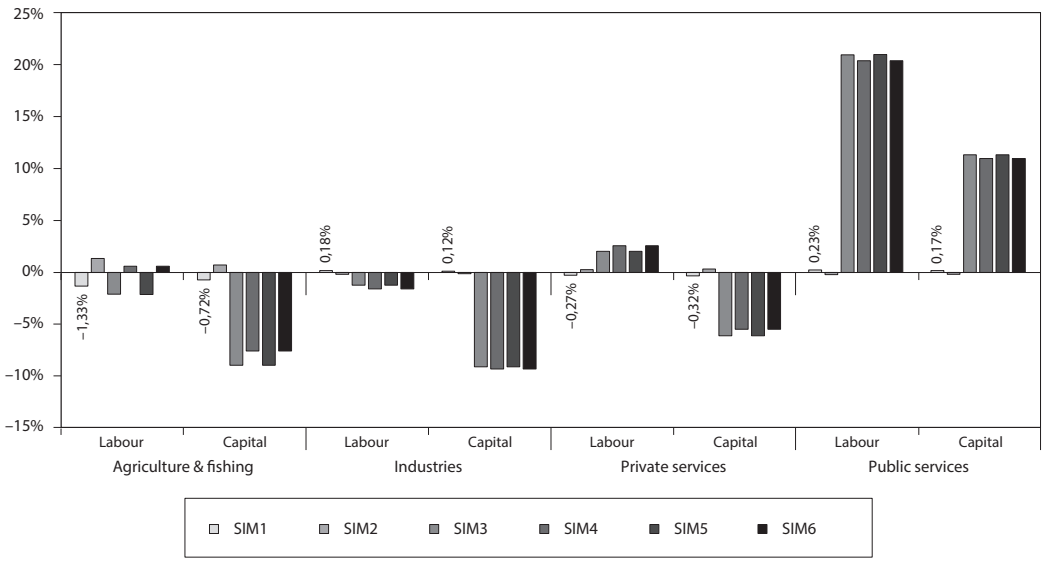
In contrast, it has a stimulating effect on the secondary sector of industry and manufacturing. The most impactful effect is associated with agriculture with a decrease in labour demand of (–0.66%) and a decrease in capital demand of (–0.72%). This effect is reflected in a risk of increased unemployment and the weakening of return on capital. We also find that introducing a fiscal policy has a negative effect on the demand for capital in all private sectors. Regarding employability, the mixed policy shock has a mixed effect depending on the sector of activity: negative effect for the secondary industrial sector, positive for the service sector and mixed for the primary sector of agricultural and fishing.

Figure 10 Distribution of factors of production by branch



Source: Model outputs estimated according to HCP database (2019)

Figure 11 Impact on the demand for factors of production by sector

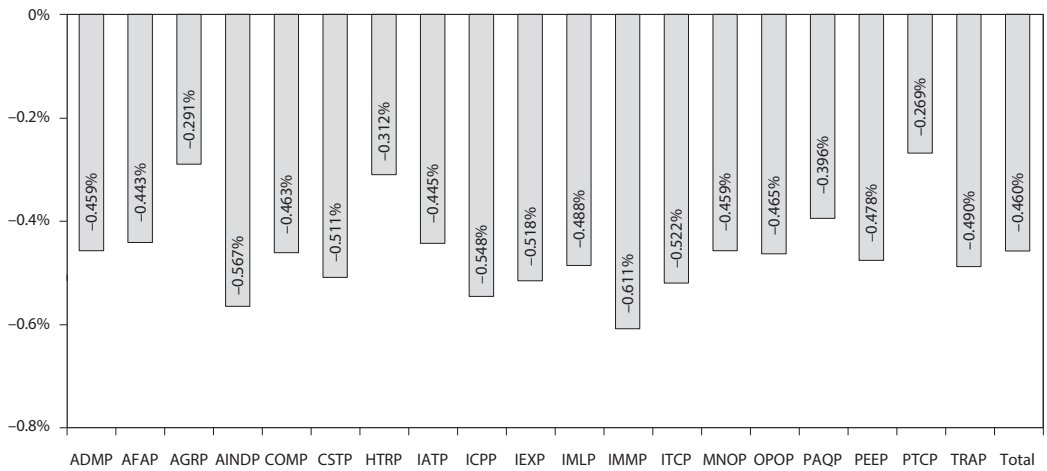


Source: Model outputs estimated according to HCP database (2019)

Impact on demand on the goods and services market

Demand on goods and services market is negatively impacted by the growth of income inequality in SIM1. For the mixed policy simulations that result in a relative reduction in inequality (SIM3 and SIM5), the commodities where consumption has declined are those belonging to the primary sector of agriculture and fishing (AGRP and PAQP) as well as education, health, and other social services (MNOP). Since these scenarios aim to simulate an eventual increase in income inequality during a period of sustained public policy stimulus, we consider that this increase in inequality has a reducing effect on the demand for these products that are fundamental to household social progress.

Figure 12 Impact of the simulations on consumption by branch in SIM1[7]



Source: Model outputs estimated according to HCP database (2019)

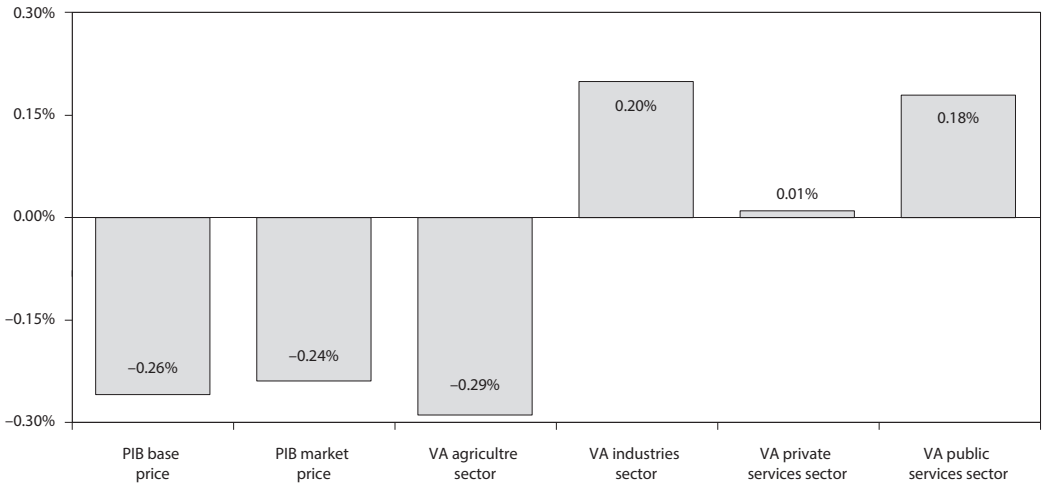
4.3.2 Impact on aggregate supply: production and value added

To assess the impact on production, we study the variation in GDP. We distinguish two forms of measurement: (1) GDP at market prices, which represents the sum of value added (VA) plus taxes net of subsidies on products. (2) GDP at basic prices excludes taxes on products and includes subsidies. Subsequently, we present the changes in wealth produced at the level of each of the economic sectors through the sum of the VA relative to the branches of activity that belong to them.

Without an increase in public spending, the simulation of an increase in inequality in the short term (SIM1) generates a decrease of (–0.24%) in GDP at market prices and (–0.26%) in GDP at basic prices. At the level of value added, we note a divergence in the sensitivity of each sector to this shock: a decrease in the primary sector of (–0.29%), a growth in industries of 0.2% and a quasi-stagnation in services (+0.01%). Indeed, this increase in inequalities simulated in SIM1 is accompanied by an increase in inequalities in labour income (YHL) of (+17.4%) and capital income (YHK) of (+6.45%) in the Gini sense. These results show that a rise in wage inequality causes a reduction in national GDP. This reduction is associated with the decline in primary sector output. Despite the increase in the VA of the industrial branches and public services, this loss of value added in the primary sector, composed of agriculture and fishing, causes not only a decrease in the income of all categories of households, but also in the private funds of firms illustrated by the FIRM agent, which loses (–0.32%) of its income.

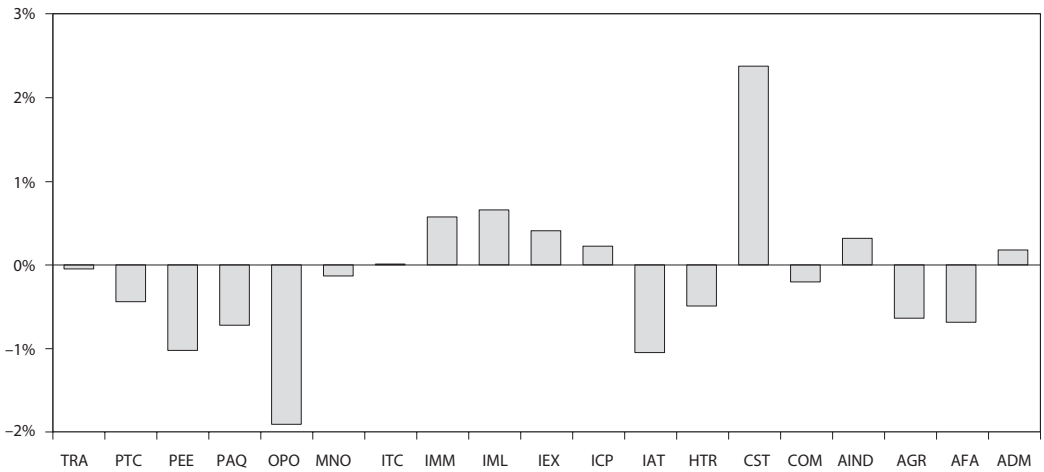
[12] In Figures 12 to 14, we will display only SIM1 results. Further detailed results are available in the Annex C.

Figure 13 Impact on national and sectoral production in SIM1



Source: Model outputs estimated according to HCP database (2019)

Figure 14 Impact of the simulations on value added by industry in SIM1



Source: Model outputs estimated according to HCP database (2019)

Through increased government intervention through current spending, output growth is higher. Indeed, the results of the last four simulations show both an increase in economic performance accompanied by an increase in household and business income, with more reduction in the overall income inequality. SIM6 and SIM4 produce the highest variation in output with a rate of (+4.07%) for GDP at basic prices, a rate of (+3.54%) for GDP at market prices, also an increase of (+5.28%) in primary value added. Under these same simulations, the two sectors, secondary and tertiary excluding the public sector, recorded a counter-performance estimated at an average of more than 3.5 points for industry and a quasi-stagnation for services.

The main variation generated by the shock of SIM1 is the increase in the value added of the "Construction and Public Works" branch (+2.38%). This result is explained in part by the reduction in prices associated with production costs compared to sales prices (with an index of 0.754). This index means that the cost of production has fallen by more than a quarter of the selling price, which leads to an increase in the value added in this sector. In addition to this industry, we note that activities that experienced deflation

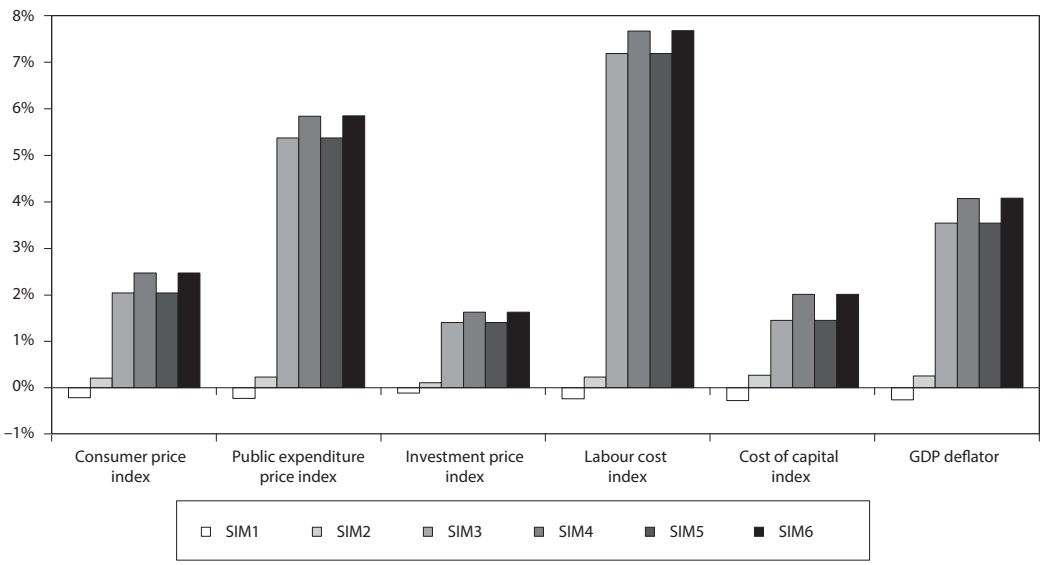
in production prices, as well as sales prices, also recorded an increase in value due to SIM1, with (+0.32%) of other industries (AIND) and (+0.66%) of mechanical, metallurgical, and electrical industries (MMI). SIM1 generates a generalized deflation on all branches, whether on sales prices or production costs, especially for production in the secondary industrial and tertiary services sectors. This explains the increase in industrial value added and the stagnation in the service sector.

On SIM1, the branches that recorded a decline in their value added are firstly other non-financial services (OPO), with a negative variation of (–1.91%), then food and tobacco (IAT) by (–1.05%), electricity and water (PEE) by (–1.03%), marine fishing and aquaculture (PAQ) by (–0.73%), hotels and restaurants (HTR) by (–0.49%), etc. When comparing sales prices to production costs, these industries show a sales price/production cost variation index greater than 1, with the variation in sales prices remaining higher than that of costs. This has the effect of minimizing the profits generated by these activities, explaining therefore the reduction in their contribution to total value added. Through these results, we can see that the performance of industries which production is intended for the larger demand, such as food and household services, declines as income inequality increases. Although, this same unequal environment is favorable to industries in need of strong investment, such as construction or capital goods maintenance. This is reinforced by the 2.35% increase in GFCF in SIM1.

4.3.3 Impact on price indices

With a rate of around 2%, inflation in Morocco is rather rampant. However, our analysis also includes a component that aims to measure the impact that the simulations may have on price stability. However, we believe that the inflationary effects can only be measured at a static level (in the very short term),

Figure 15 Impact of the simulations on the main price indices



Source: Model outputs estimated according to HCP database (2019)

particularly in the context of a standard CGE model. Although, to assess the impact on prices, we will limit ourselves to the prices associated with the factors of production, labour, and capital, as well as the price indices, namely: The GDP deflator, the consumer price index, the investment price index, and the public expenditure price index.

The results of the simulations show that the tax-only policies (SIM1 and SIM2) have variations that do not exceed the 0.28%, where the values of the two simulations are perfectly opposite. Unlike SIM2, SIM1 shows a generalized decline in all indices, with a decline of (–0.213%) in the consumer price index. Although the employment cost of capital index is at its lowest point (down –0.272%), the smallest change is in the investment price index, at a rate of (–0.11%). Relating these results to those of income, we can see that an increase in income inequality by public policy (mainly fiscal) of 1% results in a fall in the CPI of 1.41%. This fall in consumer prices is accompanied by a deflation of GDP of 1.70%.

As our model represents a free economy, the risk of inflation is highly anticipated, especially through an increase in government current expenditure. Indeed, the last four simulations cause more inflation in the studied price indices, where the most significant impact is that of the labour index (reflecting wages) and that of public expenditure prices. The smallest variation is in the price index of investment and the cost of using capital. However, a specific feature emerges for each index in these simulations: Simulations SIM4 and SIM6 generate more inflation than SIM3 and SIM5, principally in the use of capital where the difference between these two groups of simulations is more intense.

5 ANALYSIS AND DISCUSSION

To summarize the results of the model, we provide an illustration of the socio-economic impact of income inequality using an extrapolation approach of an increase in inequality of 1% in the Gini index (Annex D). As shown in annex, we retain the three simulations outcomes, namely SIM1, SIM3 and SIM6. So, we note that an additional 1% in inequality limits not only the growth potential of poor households but also that of the richest. Encouraging these better-off households to lower their consumption and saving behaviour by more than 10%. An unequal environment is likely to disengage them from participating in the consumption and savings process.

Although it has a reducing effect on inflation, this decline in consumption affects the internal and external commodity markets. In addition to the negative effects on exports (–22.93%), we note that it has a negative impact on firms' private resources, where an increase of 1% leads to a decrease of (–2.23%). This has the effect of reducing the demand for production factors, mainly labour. As long as industrial emergence is not accompanied by an absorption of unemployment, this favorable economic impact on the industrial secondary sector is accompanied by a negative social impact relating to underemployment. Also, it is important to point out that any leveraging effect associated with investment and the budget surplus is not necessarily linked to inequalities, but rather to the fiscal policy used to chock the model.

On the social impact of a 1% increase in income inequality, we detect a decline of more than 2.5% in the income of poor households as well as rural households, since this reduction is associated with a decline of more than 5% in transfers destined to these households. In addition, we notice other factors of this reduction in income that are associated with the reduction in the demand for labour by (–3.13%) and the wage rate by (–1.57%). We also note a considerable decrease in household access to basic commodities (food, education, health and public). However, poor households show a small increase in their ability to access these products. This minor increase is due to the increase in consumption by poor urban households.

Regarding the theoretical implications that justify the results obtained from the model, Table 2 represents an interpretation of the set of economic and social impact determinants in relation to the theoretical contributions rooted in the economic literature.

Table 2 Analysis of the socio-economic impact of income inequality

	Impact determinants		Effect	Analyze & discussions
Economic impact	Production & economic growth	GDP	Negative	Increasing inequality affects demand in markets of goods and services which in turn affects the profitability of firms and the returns on investment for the richest and encourages rent-seeking (Rodrik, 1999; Nissanke and Thorbecke, 2006) resulting in sluggish growth and an inability to absorb unemployment and increase household incomes. Inequality imposes a cost on the economy (Stiglitz, 2015).
		Primary sector value added (agriculture & fishing)	Negative	As with industrial food production and financial services, the unequal environment appears to be incompatible with agricultural and fisheries production, where their value-added falls by an average of 0.6 points for every 1% increase in inequality. This is related to the decline in consumption of the basket of basic household products to the detriment of equipment and investment products, especially by non-poor urban households.
		Secondary value added (industries)	Positive	Income inequality increases the added value of the branches where the activity is based on industrial investment for two reasons: (i) the selling prices of these branches decrease more than the investment costs, generating economies of scale; (ii) the demand for industrial products increases as a substitute for products of a consumable nature, such as industrial foodstuffs, agricultural and fishing products, etc.
		Tertiary value added (services)	Mix	Inequality has, on average, little impact on the service sector. However, the construction and real estate branches, which are support services for the realization of durable physical assets, see their demand increase considerably with the rise in inequality. On the other hand, rising inequality affects the performance of the financial sectors by (–1.3%) in terms of average value added.
		Firms' income	Negative	Declining returns on capital and profits on sales lead to lower returns for companies.
	Labour market	Employment rate	Negative	The relationship between inequality and employment is marked by reciprocity. On the one hand, the rise in unemployment causes a growth in inequality (Tregenna, 2011). This growth in inequality impacts the demand for labour inputs, which leads to underemployment (Acemoglu, 1999).
		Wage rate	Negative	The decline in job demand results in a lower wage rate. This decline in wages is of little benefit to firms (because of their declining revenues).
	Financial market	Return on capital	Negative	The decline in demand for capital is relatively less extreme than that of labour. Consequently, this decline is associated with the decline in economic activity, especially financial.
		Investment rate	Positive	Inequalities have a positive effect on investment (Barro, 2000). However, the excessive rise in physical investment expenditures is accompanied by a limitation in human capital investment (Nissanke and Thorbecke, 2006). This weakens the share of income going to the middle class and reduces demand in the market of commodities.
		National savings/GDP	Negative	Contrary to Kaldor assumption (1957), rising inequality lowers national savings because of the generalized decline in resources in the economy.
	Trade liberalization	Exportation	Negative	For some (Colluch et al., 2001; Krugman, 2007; Daumal, 2013), trade openness is positively correlated with a decline in inequality, as a redistributive factor. In the case of an increase in income disparities, the factors of production are weakened, even weakening production for export, and reducing external trade.
		Importation	Negative	
Social impact	Well-being (happiness)	Household consumption/GDP	Negative (Extreme)	More inequality presents itself as a decrease in household income, with a deeper rhythm at the low-income level. In this respect, this decrease in resources causes a decrease in consumption, leading to a feeling of unease among individuals belonging to this household (Alesina et al., 2004; Dynan and Ravina, 2007).
		Access to the food product	Negative	Decrease in the consumption of basic household products leads to a feeling of intense unhappiness that affects the well-being.
		Accessibility of poor households to commodities	Positive (weak)	Despite the general decline in household consumption, the small increase in consumption by poor households is due to consumer price deflation, especially in urbain region. This causes a slight increase in demand through the price effect.

Table 2 (continuation)

	Impact determinants		Effect	Analyze & discussions
Social impact	Well-being (happiness)	Transfers to the poor and rural household	Negative	Theoretically, households that receive additional income tend to invest more in their children's education (Akee et al., 2010). The 5-point drop in transfers following a 1-point increase in inequality has an atrocious effect on households that is not limited to education.
	Education and health	Access of poor household to Social Services	Negative	Economic impact generated by increases of income inequality limits access to social services, affecting human capital (Perotti, 1996; Aghion et al., 1999) which weighs on government spending and economic growth.
		Access of poor household to administrative services	Negative	The more egalitarian the society, the more public policies are oriented towards investment in human capital and social services (Perotti, 1994). This improves the quality and compatibility of public services for households.
		Government budget	Positive	In theory, an increase in the state budget means a possible increase in the budget for social policies, especially when an increase in inequality forces a correction of the redistribution function (Meltzer and Richard, 1981). However, it is important that the increase in inequality is not the origin of this increase in public funds, but rather an effect produced by the overtaxation of rich households. In this respect, the budget surplus only has a social effect when a stimulus policy is implemented.

Source: Own construction

CONCLUSION

Even though the world is richer than it used to be, this enrichment is far from being beneficial to everyone (WID, 2018). As much as inequality continues to expand around the world (Lakner and Milanovic, 2016), it is not necessarily an issue in and of itself. What matters is whether they have a right to exist, or to put it another way, do not have a detrimental impact on economic and social stability (Piketty, 2021).

Our research aims to address the question of income inequality and its impact on social and economic structures. Therefore, we used a CGE model while disaggregating the households into four agents distinguished not only by their earnings but also by their place of residence (urban and rural). The choice of integrating this distinction comes down to the territorial nature of income inequalities in Morocco: Deficiency of social factors related to rural households (e.g., 93.3% of rural households have no family member with medical coverage, compared to 66.1% of urban households), the decline in their living standards (71% of rural households live in precarious or unhealthy housing) and increased vulnerability to economic shocks (during the confinement imposed by the Covid-19 crisis, the poverty and vulnerability rates in rural areas reached 57% and 64.4%, respectively, compared to 12.7% and 21.5% in urban regions).

In short, the modeling results show that household income inequality is a significant obstacle to Moroccan growth in the short run. This disproves the optimistic claims about the positive correlation between inequality and growth made since the work of Kuznets (Forbes, 2000; Barro, 2000). Indeed, the increase in income inequality leads to a less efficient equilibrium in terms of production, consumption, and savings, and to a greater lack of accessibility to social and public services for poor households. We note that the integration of an additional tax exoneration for poor households with a budgetary expansion policy, as shown in SIM6, helps to alleviate the adverse effects of income inequality. However, this fiscal and tax policy generates significant inflation, which is mainly reflected in the consumer price index. In this regard, we note that a policy approach to reduce inequality must include a monetary policy to control inflation.

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ANNEX A DESIGNATION OF SECTORS, BRANCHES AND PRODUCTS ON THE MODEL

Sector	Code	Branche	Product	Designation
Primary sector (Agriculture & fishing)	A00	AGR	AGRP	Agriculture, forestry, and related services
	B05	PAQ	PAQP	Fishing, aquaculture
Secondary sector (Industries & manufacturing)	C00	IEX	IEXP	Extraction industry
	D01	IAT	IATP	Food and tobacco industries
	D02	ITC	ITCP	Textile and leather industries
	D03	ICP	ICPP	Chemical and Para-chemical industries
	D04	IMM	IMMP	Mechanical, metallurgical, and electrical industries
	D05	AIND	AINDP	Other industries
Tertiary sector (Services)	E00	PEE	PEEP	Electricity and water
	F45	CST	CSTP	Construction and public works
	G00	COM	COMP	Commerce
	H55	HTR	HTRP	Hotels and restaurants
	I01	TRA	TRAP	Transport
	I02	PTC	PTCP	Post and telecommunications
	J00	AFA	AFAP	Financial and insurance activities
	K00	IML	IMLP	Real estate, renting and business services
	L75	ADM	ADMP	General public administration
	MN0	MNO	MNOP	Education, health and social work
	OP0	OPO	OPOP	Other non-financial services
	UFO	TRO		Territorial correction

Source: Model outputs estimated according to HCP database (2019)

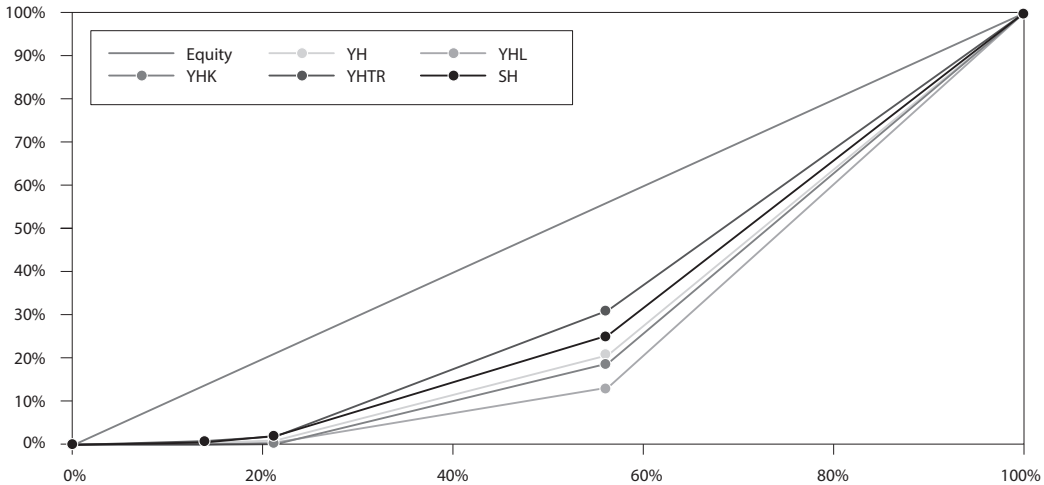
ANNEX B SOCIAL STRUCTURE AND HOUSEHOLD BEHAVIOR

Table A1 Main indicators on economic agents in basic equilibrium

	Designation	Income	Consumption	Saving	Population
RPH	Rural Poor household	14 065.27	11 704.49679	2 077.78	14%
UPH	Urbain Poor household	18 616.47	8 428.878059	8 751.19	8%
RNPH	Rural Non-Poor household	226 421.71	15 5502.6003	26 650.03	35%
UNPH	Urbain Non-Poor household	557 864.53	413 015.0249	63 919.27	44%
FIRM	Economic structure (Firms)	302 378.73	1 143 361.042	165 908.7673	
GOV	Government	313 755.82	311 669.8678	33 113.98684	
ROW	Rest of the world	491 003.3	713 932.192	44 186	

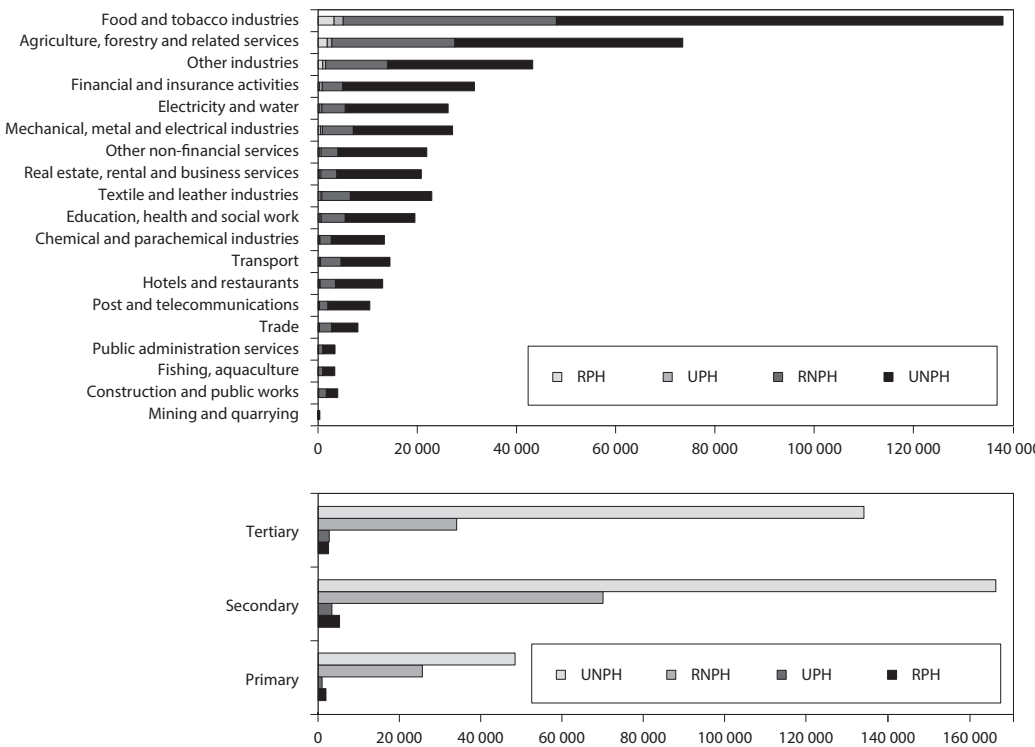
Source: Model outputs estimated according to HCP database (2019)

Figure A1 Lorenz of income inequality, consumption, and savings



Source: Model outputs estimated according to HCP database (2019)

Figure A2 Basic equilibrium consumption by product and sector



Source: Model outputs estimated according to HCP database (2019)

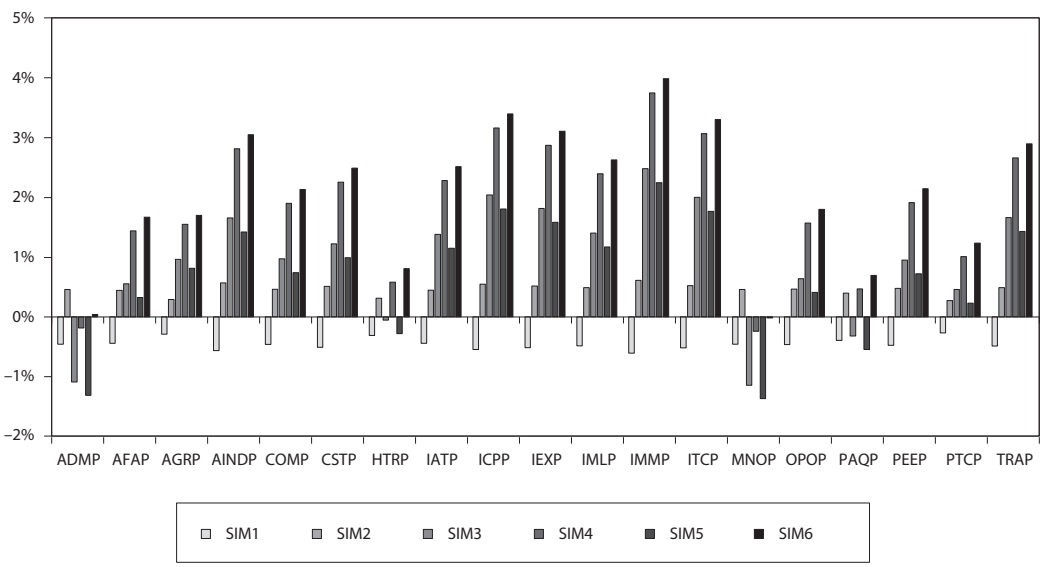
ANNEX C MORE DETAILS ABOUT CGE MODEL RESOLUTION

Table A2 Fixation of the exogenous variables necessary to solve the CGE model

Variable	Designation	Dimension
e	Exchange rates	1
CAB	Current account balance	1
$C_{i,h}^{MIN}$	Minimum household consumption, in each product	$19 \times 4 = 76$
G_i	Public expenditure	19
LS_l	Labour supply	1
KS_k	Capital supply	1
PWM_i	International price of imports, for each product	15
PWX_i	International export price, for each product	15
$VSTK_i$	Stock variation of product i	7
The variables of savings, transfers, direct and indirect taxation are fixed at their base year values, after allocation or calibration		$4 \times 4 = 16$ $1 \times 2 = 2$ $4 \times 2 = 8$ $19 \times 1 = 19$ 15 $19 \times 1 = 19$
Total		**208**

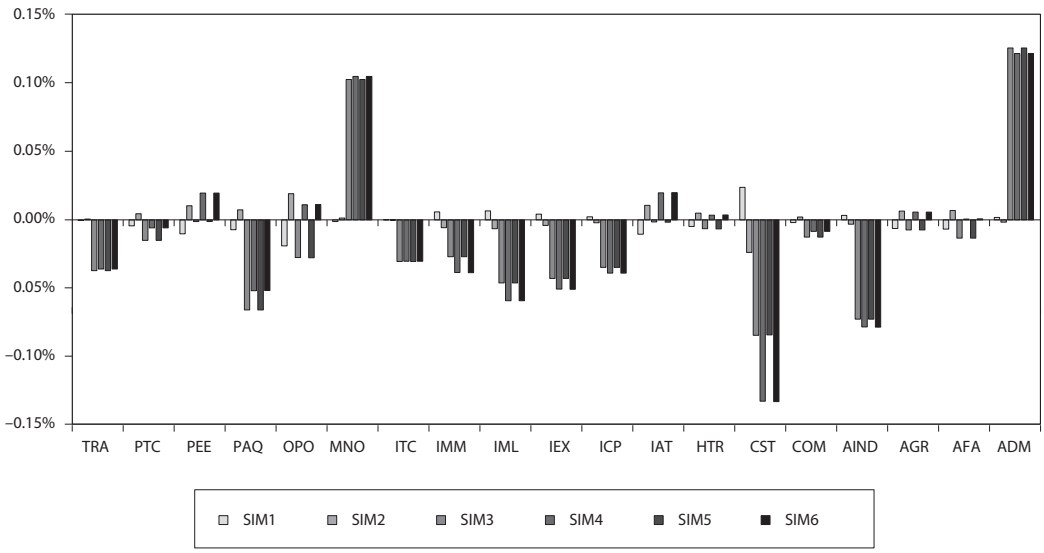
Source: Model outputs estimated according to HCP database (2019)

Figure A3 Variation of consumption by branch in each simulation



Source: Model outputs estimated according to HCP database (2019)

Figure A4 Impact of the simulations on value added by industry



Source: Model outputs estimated according to HCP database (2019)

ANNEX D RESULTS OF THE EFFECT OF A RISE ON 1% ON MODEL VARIABLES

Table A3 Impact of inequalities on household living standards

	Impact of +1% of income inequality by fiscal policy (SIM1)	Impact of +1% of income inequality by mix policy (SIM3)	Impact of +1% income inequality within optimal policy (SIM6)
Impact on household income (YH)	–1.89%	2.97%	2.74%
RPH	–3.03%	1.60%	1.87%
UPH	–2.54%	3.88%	3.61%
RNPH	–2.29%	2.21%	2.21%
UNPH	–1.69%	3.28%	2.96%
Impact on consumption income (YH)	–3.07%	0.71%	1.29%
RPH	–1.07%	-0.11%	0.18%
UPH	4.12%	2.71%	1.88%
RNPH	–2.09%	0.30%	0.63%
UNPH	–13.22%	-0.04%	2.46%
Impact on saving income (YH)	–0.80%	0.56%	0.62%
RPH	–2.47%	1.67%	1.87%
UPH	2.53%	4.50%	3.61%
RNPH	–3.40%	2.07%	2.32%
UNPH	–14.27%	1.77%	4.18%

Source: Model outputs estimated according to HCP database (2019)

Table A4 Economic impact of 1% of income inequality in CGEM

	Impact of +1% of income inequality by fiscal policy (SIM1)	Impact of +1% of income inequality by mix policy (SIM3)	Impact of +1% income inequality within optimal policy (SIM6)
National and sectoral production			
GDP at basic prices	–1.73%	2.72%	2.51%
GDP at market prices	–1.60%	2.35%	2.19%
Value added by sector			
Primary (agriculture and fisheries)	–1.93%	3.62%	3.26%
Secondary (industry)	1.33%	–2.76%	–2.46%
Tertiary (services)	0.07%	–0.03%	–0.04%
including public services (ADM)	1.20%	9.69%	7.53%
Consumption & investment			
Household final consumption/GDP	–9.37%	–0.45%	1.40%
Consumer price index	–1.42%	1.58%	1.53%
National household savings/GDP	–4.18%	–0.15%	0.70%
Investment rate (GFCF/GDP)	17.33%	–7.50%	–9.24%
Investment price index	–0.74%	1.09%	1.01%
Capital demand	–0.02%	–0.06%	–0.04%
of which non-public	–0.02%	–0.06%	–0.05%
Rate of return on capital	–1.81%	1.12%	1.25%
Public and private institutions			
Government budget (YG)	18.03%	3.53%	-0.70%
Price index of public expenditure	–1.53%	4.15%	3.62%
Government transfers to households	–1.42%	1.58%	1.53%
Revenue from taxes on products and imports	–0.35%	–0.41%	–0.27%
of which indirect taxes on consumption	–0.10%	–0.48%	–0.37%
Private funds of enterprises (YFIRM)	–2.35%	1.19%	1.40%
Corporate tax revenue	–1.81%	1.12%	1.25%
Trade openness			
Exports of goods and services	–22.93%	–5.02%	–4.30%
Imports of goods and services	–6.00%	–3.12%	–2.79%

Source: Model outputs estimated according to HCP database (2019)

Table A5 Social impact of 1% of income inequality in CGEM

	Impact of +1% of income inequality by fiscal policy (SIM1)	Impact of +1% of income inequality by mix policy (SIM3)	Impact of +1% income inequality within optimal policy (SIM6)
Standard of living of poor households			
Income of poor households	–2.79%	2.74%	2.74%
Consumption of poor households	1.52%	1.30%	1.03%
Savings of poor households	0.03%	3.09%	2.74%
Transfers to poor households	–5.13%	1.75%	2.39%
Standard of living of rural households			
Rural household income	–2.66%	1.91%	2.04%
Rural household consumption	–1.58%	0.09%	0.41%
Savings of rural households	–2.94%	1.87%	2.10%
Transfer to rural households	–5.01%	1.64%	2.28%
Access to the labour market			
Need for recruitment (demand for labour)	–3.13%	0.13%	0.70%
of which non-public	–3.13%	–0.33%	0.33%
Labour compensation rate (wages)	–1.57%	5.55%	4.76%
Market access for goods and services			
Access to agricultural and industrial food products	–2.52%	0.52%	1.01%
of which poor households	0.57%	0.39%	0.31%
Access to education, health, and social services	–3.07%	–0.88%	–0.01%
of which poor households	0.54%	–0.29%	–0.22%
Access to government services	–3.07%	–0.84%	0.02%
of which poor households	0.54%	–0.27%	–0,20%

Source: Model outputs estimated according to HCP database (2019)

Development of Balance of Payments Concept and Theoretical Approach to Its Equilibrium (with the Emphasis on the Current Account)

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Abstract

The paper tries to find an answer to how to perceive the term *balance of payments (dis)equilibrium*. The text follows the individual editions of the IMF Balance of Payments Manual and concurrent opinions on balance of payments (dis)equilibrium from the point of view of both the IMF and economists outside the IMF. Despite the difficulty and complexity of balance of payments analysis, there was a considerable demand among the economic and lay communities for a "single figure" covering balance of payments (dis)equilibrium. Eventually, the current account balance was selected as the "single figure." The simplest way to perceive the current account balance equilibrium is as a tendency to return to its zero value. However, some more complex approaches allow considering a long-term non-zero balance of the current account as a state of equilibrium.[2]

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International Monetary Fund, balance of payments, balance of payments equilibrium	*https://doi.org/10.54694/stat.2022.26*	*B27, F32, F33*

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INTRODUCTION

Although balance of payments issues and theory have been evolving for several centuries,[3] most publications regard the development since the establishment of the International Monetary Fund (IMF) as crucial. The IMF has been pivotal in international standardization of balance of payments reporting and has reflected the state of the art of the issues.

Almost since its beginnings, the IMF has published the Balance of Payments Manuals.[4] The IMF has published six editions of the Balance of Payments Manual to date. The Manuals defined the contents of individual balances, both component and cumulative, and the overall structure of the balance of payments.

The objective of the paper is to make a brief introduction to the development of the balance of payments concept (with an emphasis on the current account) and structure as presented in the Balance of Payments Manuals published by the International Monetary Fund and, most importantly, to convey the evolution of opinions regarding the issues and perceptions of balance of payments (dis)equilibrium.

The paper contents is as follows. Section 1 presents the development of and fundamental changes in the structure of balance of payments since the IMF was established. Section 2 introduces the reader to the evolution of the concept of balance of payments equilibrium from the point of view of both the IMF and (theoretically focused) economists. For the sake of clarity, economists' opinions are divided into those primarily focused on a statistical view of balance of payments, and those offering a more theoretical concept for the analysis of (dis)equilibrium of the balance of payments. Section 2 also describes the gradual shift towards the current account as the "main" part of the balance of payments, which experts and the general public have used to date. A summary of the paper follows.

1 DEVELOPMENT OF STRUCTURE OF AND FUNDAMENTAL CHANGES IN PERCEPTION OF BALANCE OF PAYMENTS SINCE IMF ESTABLISHMENT

There have been numerous significant as well as small changes in balance of payments structure and opinions on it and its analysis. These processes are explained in the Balance of Payments Manuals (IMF, 1948, 1950, 1961, 1977, 1993, 2009).[5] The first four editions of the Manual (IMF, 1948, 1950, 1961, 1977) gradually specified the coverage of individual transactions (first edition), the terminology and concept of balance of payments (second edition), balance of payments methodology (third edition), and specification of coverage of financial transactions in the context of the 1970s changes (fourth edition). The fifth and sixth editions of the Manual (IMF, 1993 and 2009) discussed three other broad spheres. The first was aspects relating to the stock statistics of net foreign assets and their interconnection with the flow statistics of balance of payments. The other topic of the Manuals was the discussion of financing current account deficit and issues related to current account surplus. The third sphere concerned the connections between balance of payments and net international investment position of countries with national accounts.

This paper will present only fundamental changes in the structure and perception of (not only) balance of payments issues from the IMF perspective.

The first edition of the Manual (IMF, 1948) brought a template for tables intended to complete data on international transactions. Balance of payments consisted of two basic parts: *Current Transactions*

[3] Those interested in the history and theoretical development of balance of payments before World War II are recommended to read Chipman (1984) and Gomes (1990).

[4] The title is only a general one, not the actual title of each of the Manual editions.

[5] Also see Table A1 for development of balance of payments basic structure according to the individual Manual editions. See preparations for the seventh edition of the Manual: Update of the sixth edition of the Balance of Payments and International Investment Position Manual (BPM6) (imf.org). A new edition of the Manual should be published in March 2025.

and *Movement of Capital and Monetary Gold*, broken down into *Private, Excluding Banking Institutions, and Official and Banking Institutions*.[6]

The second issue (IMF, 1950) presented the balance of payments concept in more detail. Structurally, the *Current Transactions* section was split into two: *Total Goods and Services* and *Donations*, while the next section, *Movement of Capital and Monetary Gold*, remained virtually without major changes.

The third edition (IMF, 1961) further specified reporting of balance of payments data to the IMF and defined principles for balance of payments compilations for countries own use. The balance of payments now had three main components: (a) *Goods and Services*, (b) *Transfer Payments*, and (c) *Movements of Capital and Monetary Gold*.

The fourth edition (IMF, 1977) reflected the events of the 1970s (end of the Bretton Woods monetary system) and abandoned the clear preference for presenting the *overall balance* as the most suitable presentation of balance of payments. At the same time, the IMF noted that the presentation of the individual cumulative balances was normative rather than positive. Therefore, the user ought to be informed about the contents of the cumulative balances. The balance of payments consisted of three main parts: *Current Account* with two sub-components: *Goods*, *Services, and Income* and *Unrequited Transfers, Capital Account* with two main components: *Capital*, *Excluding Reserves*, and *Reserves*.[7]

The fifth edition of the Manual (IMF, 1993) emphasized connections between balance of payments and national accounts and between the balance and macroeconomic analysis (particularly the savings-investment relation).[8] At the same time, it views the economy not as a whole but as individual sectors and units. The fifth edition included a section on the stock statistics of *net foreign assets* (synonym: *net international investment position*). Besides the current account deficit, financing, and correction, it also discussed the current account surplus. There were fundamental changes in terms of balance of payments structure. Within the *Current Account*, the *Income* item was removed from the *Services*.[9] A new balance of payments account, known as the Capital Account, was introduced. The formerly used term Capital Account (IMF, 1977) was now replaced with *Financial Account*. Thus, the balance of payments structure consisted of two main parts: *Current Account* and *Capital and Financial Account*. The Current Account was subdivided into three parts: *Goods and Services*, *Income*, and *Current Transfers*.

The full name of the sixth edition of the Manual, *Balance of Payments and International Investment Position Manual*, indicates the emphasis that the IMF (2009) put on both the flow and stock statistics. There was also a tighter connection between national accounts and balance of payments, reflected, *inter alia*, in the terminology of current account items: the income (balance) was renamed *Primary Income*, and the current transfer (balance) became *Secondary Income*. Besides, *Capital Account* was excluded from the Capital and Financial Account section (see IMF, 1993) and classified "after" the current account in the vertical presentation of balance of payments (see below). Balance of payments *Financial Account* items no longer had a credit and debit side; instead, they use the terms *Net acquisition of financial assets* and *Net incurrence of liabilities*. These changes brought about a different logic of accounting and the "sign convention" for transactions recorded in the balance of payments. The stock statistics of net foreign assets duplicates the basic structure and logic of the financial account of the balance of payments. The balance of payments thus consists of three main parts: *Current Account* (which is divided into three segments: goods and services, primary income, secondary income), *Capital Account*, and *Financial Account*.

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[6] The item Errors and Omissions is an integral component of balance of payments, but is omitted in this paper for the sake of clarity.

[7] This refers to change in foreign-currency reserves as part of the balance of payments, which is a flow statistics.

[8] This is also reflected in the balance of payments analysis in IMF (1993), where the Fund emphasized the savings-investment relation. The balance of payments analysis in terms of savings and investment also dominated the journal papers.

[9] IMF (1961) justified previous inclusion of the investment revenue balance in Services by their *de facto* being use of production factors in the production of goods analogously to goods or services being inputs for a production process.

Summing up this evolution, it doesn't appear easy to determine what different authors in the history of the theory and practical analysis of balance of payments have included under the terms *net exports* (of goods and services), *current account*, etc., and whether they even followed a balance of payments concept according to a specific manual. Besides purely "statistical problems" when comparing countries, there arises the question of defining balance of payments equilibrium. The following section deals with this issue from the perspective of both theory and the IMF.

2 BALANCE OF PAYMENTS EQUILIBRIUM CONCEPT

The IMF and significant 20th and 21st century economists have discussed the concept of balance of payments equilibrium. The views of the IMF and (theoretically focused) economists have overlapped. It is therefore difficult to distinguish the "causality of thought." The distinction is more for better structuring of the text than for a precise differentiation of the origin of thoughts.

Economists' opinions on the balance of payments are further distinguished in this part of the text into more statistical concepts of balance of payments and its (dis)equilibriums and in the last sub-chapter into a looser (not so strict) concept of the (dis)equilibrium of the balance of payments within the framework of various theoretical concepts. The division of this chapter into opinions on balance of payments equilibrium held by the IMF and by economists "outside" the IMF, therefore, has to be taken with a grain of salt.

2.1 Balance of payments equilibrium definition by the IMF

Suppose all the balance of payments items are placed vertically, each with a credit and a debit side. In that case, the balance of each item is calculated as the difference between the credit and the debit side, resulting in a so-called component ("single") balance. A cumulative balance is obtained by summing selected component balances. Due to the double-entry recording of items entering the balance of payments, the credit side of all the component balances has to be equal to the debit side.[10] Therefore, it is terminologically incorrect to speak of "balance of payments surplus/deficit" where the debit side is less/more than the credit side. Therefore, a horizontal line divides the balance of payments items "above the line" from those "below the line" in the vertical form of balance of payments. In terms of an initial encounter with the problem, balance of payments equilibrium can be described as a situation where the sum of the selected component balance above the horizontal line equals zero. Failing that, when the sum of items above the line differs from zero, we speak of disequilibrium.

Items above the line are autonomous, and those below the lines are accommodating (induced, compensatory). Autonomous items occur independently of a situation in balance of payments development. Induced items are ones that compensate for any disequilibrium in autonomous items.

Two questions arise: (1) What (cumulative) balance can be considered the best to show (dis)equilibrium of balance of payments? (2) What induced items in the balance of payments establish equilibrium?

The first three editions of the Balance of Payments Manual (IMF, 1948, 1950, and 1961) considered the *overall balance* to be the appropriate cumulative balance encompassing the items above the line. Generally speaking, the overall balance captured current transaction items (goods, services, etc., i.e., the current account under modern terminology in very simplified terms) and movements of private long-term and short-term capital. In the first edition of the Manual (IMF, 1948), the items below the line comprised long-term and short-term capital of governmental and banking institutions and monetary gold. The first edition already recognized the problem of which items to consider suitable for inclusion below the line as compensatory ones. In the second edition (IMF, 1950), the main items below the line remained the same. Still, the suitability of including certain transactions among compensatory items

[10] This does not apply to the current sixth edition of the Manual (IMF, 2009), see further in the text.

became even more acute (e.g., governmental securities and loans, gold movements, etc.). The third edition of the Manual (IMF, 1961) did not, in author´s opinion, bring a clearer insight into the issue.[11]

The fourth edition of the Manual (IMF, 1977) abandoned the preference for the overall balance as the indicator of balance of payments (dis)equilibrium and invited to use various cumulative balances when analysing balance of payments.[12] Given the disintegration of the Bretton Woods monetary system in 1971, the Smithsonian Agreement in the same year, and the gradual expansion of a more flexible exchange rate regime, the overall balance partly lost its information value.

IMF (1977) suggested using the three following cumulative balances when analysing balance of payments:

a. *Current account* (current balance) comprises balances of goods, services, income, and unrequited transfers. Analyses frequently excluded governmental unrequited transfers from the current account and put them under governmental capital movements. According to IMF (1977), current account items have little volatility and do not change much in the short term (unlike some items under capital movements).
b. *Overall balance* – the balance comprises all the items except reserve assets and near substitutes for reserve assets, if any. This again gives rise to the problem of which items to consider near substitutes for reserve assets that might "finance" the disequilibrium. Due to the changes in international monetary relations associated with the end of the Bretton Woods monetary system, the overall balance was no longer of much information value for countries with flexible exchange rates. However, it is a fact that the (pure) floating exchange rate regime was not very widespread in the 1970s, so the overall balance still had information value, particularly in countries using more rigid exchange rate regimes. Due to the disunity and unclarity as to which items to include below and above the line, IMF (1977) recommends against using the overall balance.
c. *Basic balance* – the balance comprises current account items and long-term capital movements.[13] It is a compromise between the current account and the overall balance. Thus, items below the line include volatile international capital items. However, IMF (1977) does not make it absolutely clear which items to label as volatile and which not.

More than the basic and overall balance, the fifth edition of the Manual (IMF, 1993) highlights an analysis of current account (savings-investment relation), financial and capital accounts. However, it mentions total balance (IMF, 1993, p. 161). It can be deduced that IMF (1993) includes transactions with reserve assets below the line as part of the overall balance concept.

The sixth, and so far last, edition of the Manual (IMF, 2009) is again grounded in the national account concept and its connection to the balance of payments items. The text highlights the savings-investment relation as a balance of payments analysis framework. Due to the strong relationship with national accounting, the departure from the use of the term "credit" and "debit" side in the financial account

[11] In the early days of the Manual publication, there were discussions between the IMF and, e.g., Machlup (1950) concerning which items to put below and which above the line. Short-term capital was the most debatable item. For example, IMF (1961) split the governmental sector into central and local ones. Local government (Art. 338) may behave similarly to the private sector, which should be reflected in analyses. Monetary institutions were divided into central and others. Central monetary institutions included, e.g., the central bank; the others included private commercial banks (Art. 342) with potentially different behaviours and motives for transactions. Unclarities for analysis arose from other parts of the third edition (such as Art. 343).

[12] At the same time, it notes that cumulation of selected component balances is normative rather than positive.

[13] This leads to the question how to categorize international capital movements and what "types" of capital to put above and below the line. Can foreign direct investment be put above the line, and portfolio and other investments below the line? Or should the property form of capital (foreign direct investment and the part of portfolio investments covering property securities) be put above the line, and the debt form of capital (the part of portfolio investments covering debt securities and other investments) below the line? Alternatively, should long-term capital be written above and short-term capital below the line? Change in foreign-currency reserves always comes below the line.

(see the previous chapter of the text) and the inclusion of reserve assets in the financial account, it is no longer possible to deduce from this Manual which items are below the line and which they are above the line. So, it is no longer the case that items above the line finance items below the line and vice versa. Such an analysis is, therefore, purely in the hands of the user of balance of payments and does not follow directly from the sixth edition of the Manual.

2.2 Theoretical approaches to determining balance of payments equilibrium – a statistical view

To define balance of payments equilibrium, it was necessary first to clarify the actual balance of payments concept. There have been several concepts of, or views on, balance of payments. They can generally be divided into ex-ante and ex-post approaches (Kindleberger, 1969; Stern, 1973). Both approaches see balance of payments equilibrium in the form of a zero balance of the items below the line (generally short-term capital, gold, and reserves). In addition, the ex-ante approach requires compliance with the requirement to maintain equilibrium under certain conditions (Stern, 1973). The ex-ante approaches include the balance of payments concepts of Nurkse (1945), and the two approaches of Machlup (1950) and Meade (1951). The ex-post approaches include one defined in Machlup (1950) and Kindleberger (1969, 1978).

Nurkse (1945) defined an equilibrium exchange rate (a fixed regime, i.e., its changes are exogenous) as one that is also consistent with the notion of balance of payments equilibrium and the state of the economy at full employment. However, he asked three questions, the first of which was also discussed by the IMF. (1) Balance of payments is always in equilibrium from the accounting point of view; i.e., certain items have to be "removed" from balance of payments to assess balance of payments (dis) equilibrium. This leads to the question of which items to remove, i.e., which ones will be below the line. (2) What period is consistent with the term "balance of payments is in equilibrium"? (3) What policies (e.g., additional restrictions in international trade or payments) must not be applied to attain balance of payments equilibrium?

Nurkse (1945) answers the first question by saying that short-term capital items and gold should be removed from the balance of payments and put below the line.[14] The second question follows a temporal view. Balance of payments equilibrium should be viewed not from the perspective of a single period but from one of several years to encompass the entire economic cycle, e.g., five or ten years. In answering the third question, pre-existing policies (barriers in international trade and payments) are considered, and there must not be additional restrictions on international trade and payments.

Machlup (1950) presents three balance of payments concepts (market balance, programme balance, and accounting balance), and his notion of equilibrium develops from there. Market and programme balance can be regarded as an ex-ante approach. *Market balance* covers the expected demand for and supply of foreign currency. The demand side does not consider any newly established restrictions (tariffs, quotas, etc.), and the supply side only considers "market motives," i.e., excludes operations with foreign-currency reserves and other items of a compensatory nature. Balance of payments equilibrium occurs when supply intersects demand. *Programme balance* is an overview of resources and use of foreign currency (expected or planned) in the coming years based on the country's requirements, e.g., to a certain degree of consumption and investment activity. Generally speaking, therefore, these foreign means are to be used to achieve specific (even politically defined) goals. If the resources and use of foreign currency are equal, the balance of payments is in equilibrium.

Besides achieving an internal equilibrium, Meade (1951) considered separating autonomous and compensatory balance items crucial for analysing balance of payments equilibrium. The amount

[14] This notation, with the items below the line being short-term capital and gold and those above the line current transactions and long-term capital movements, became known as basic balance in the 1950s (Kindleberger, 1969).

of compensatory items can be understood as the degree of balance of payments disequilibrium. However, Meade (1951) had difficulty distinguishing between the autonomous and compensatory balance of payments items. The approach of Meade (1951) is suitable for theoretical reflections but not very good for analyses and comparisons.[15]

Ex-post approaches to balance of payments are the aforementioned Machlup (1950) and Kindleberger (1969). Machlup (1950) introduced the so-called *accounting balance*. It covers transactions that occurred in the past period(s) between residents and non-residents and is recorded in the balance by double-entry record (one on the credit side, another on the debit side). Thus, this accounting balance is always in equilibrium. The equilibrium occurs if the sum of balances of selected (autonomous) items above the line equals zero. Machlup (1950) describes the IMF's efforts to define items that should be below the line (compensatory items). Machlup's notion of balance of payments from this "accounting" perspective is the closest to the concept in use today.

Kindleberger (1969) discourages using a single method of determining and presenting balance of payments (dis)equilibrium[16] and requires a detailed analysis of balance components, but is also aware of the fact that the public demands a "single figure" on (dis)equilibrium. Kindleberger (1969, 1978) focuses on the definition of selected (usually) cumulative balances and thus divides balance of payments into items above and below the line. Again, an equilibrium is a state where the sum of balances of items above the line equals zero.

He regards net export as the least interesting; it was of some information value in the mercantilist period but not in the second half of the 20th century. Items above the line are net exports, and below the line are changes in reserves (gold, foreign currency reserves, etc.).

In the case of current account balance, items above the line refer to the sum of trade balance, balance of services, and balance of transfers, and items below the line are (movements in) long-term capital, short-term capital, and change in reserves. According to Kindleberger (1969), this equilibrium concept is the most common among entities and is indeed the "single figure."

Basic balance, used by Nurkse (1945), includes among items above the line trade balance, balance of services, and movements in long-term capital. Short-term capital movements and change in reserves are below the line. However, it is not necessary that the sum of balances of items above the line equal zero in every instant (Kindleberger, 1978). Kindleberger (1969) does not see the reason for putting short-term capital movements among compensatory items in its volatility. Still, the original intention for that placement consisted of transfer issues, a debated topic in the interwar period. At present, the interconnection and advancement of financial markets often mean that even long-term capital movements are not "supported" by real flows; thus, their movements simply shift liquidity, and basic balance loses its information value.

Kindleberger (1969, 1978) offers various other forms of splitting balance of payments items above and below the line. They generally differ in how they break the short-term capital movement item into two parts, placing one among autonomous items (above the line) and the other among compensating items (below the line). His papers subsequently discuss (un)suitability of such division, including the concept used in the Manual's first edition (IMF, 1948).

It follows from the text of Subsection 2.2 that, as a matter of fact, any balance of payments item could be either autonomous or compensatory. Thus, compensatory items could even include goods if their international movement resulted from an effort to restore balance of payments equilibrium (Bakule, 1976). On the unclarity as to which items to regard as autonomous and induced, see Machlup (1950),

[15] Machlup (1958) points out occasional inconsistency in the definition of equilibrium by Meade (1951). Meade also defined balance of payments equilibrium without having the achieved internal equilibrium (full employment) or judgements.

[16] That is, which items should be below and above the line.

Meade (1951), and Bakule (1976). When forming the balance of payments vertically (ordering items below one another),[17] it cannot be even used the logic that autonomous items (whatever they include) are placed above the line, and compensatory items are written below the line. The Keynesian concept of the balance of payments considers autonomous items to be those above the line (for example, export and import of goods and services). On the contrary, the monetary concept of the balance of payments understands as autonomous items those that are below the line (for example, international capital flows), see Frenkel (1976) and Johnson (1976).[18]

2.3 Approaches to the analysis of the balance of payments and its equilibrium from the point of view of economic theory

The previous part of the text mostly dealt with the purely statistical concept of balance of payments (dis)equilibrium and did not take into account the wider spectrum of factors that influence the balance of payments and are influenced by the balance of payments. Various approaches to the analysis of the balance of payments and its dis(equilibrium) from the point of view of economic theory are devoted to these factors.

Hume (1752) already dealt with the analysis of the balance of payments and based his approach on the quantitative theory of money. This approach came from a price equalization mechanism based on the international movement of gold (not, therefore, a change in exchange rates), which established a balance of payment (more precisely trade balance) equilibrium.

The gradual abandonment of the fixed exchange rate system within the framework of the gold standard forced economists to include in their considerations the effect of exchange rate changes. Therefore, the theory of import and export elasticity associated with the Marshall-Lerner condition (Lerner, 1944; Marshall, 1923) comes to the fore. At the turn of the 1940s and 1950s, the theory of absorption arose (Alexander, 1952). Absorption theory deals with the effects of devaluation (depreciation) of the domestic currency on domestic income and domestic demand (i.e., absorption). It responds to the limitations of the previous theory, which does not discuss these effects. The negatives of the absorption theory include, above all, the narrow concept of the relationship between the domestic economy and the foreign economy only through the net export, i.e. it ignores the movements of the international movement of capital.

These deficiencies are responded to by the monetarist concept of the balance of payments theory, which perceives the disequilibrium of the balance of payments as a reflection of the imbalance in the domestic money market. Equilibrium must then be established with the help of the international movement of capital, see Frenkel (1976) and Johnson (1976). The approaches mentioned so far perceive the balance of payments as flow statistics and neglect the stock view of external (dis)equilibrium.

An intertemporal approach to the current account has been evolving since the 1980s. This approach has pointed out the importance of connecting the flow statistics of balance of payments with the stock statistics of net foreign assets via primary income balance (Obstfeld and Rogoff, 1994). Due to the growing movement of international capital, net foreign assets have become the subject of deeper analyses thanks to, e.g., the concept of sustainability of net foreign assets (Lee et al., 2008; Brůna, 2013) and the effect of revaluation of net foreign asset items (Gourinchas and Rey, 2005; Clarida and Magyari, 2016).

The most important activity in the (theoretical) analysis of current account equilibrium is currently pursued by the IMF (not only within its Manual), which has published the External Balance Assessment

[17] This notation was customary until the fifth edition of the manual (IMF, 1993).

[18] The issue is still relevant today due to, among other things, the existence of the so-called sudden stop or capital flight (suspension of capital import or capital outflow), which for many developing economies is rather exogenous in nature (Eichengreen and Gupta, 2016; Forbes and Warnock, 2011). If a sudden stop or capital flight occurs, then above-the-line items (e.g., international trade) usually have to be adjusted. See, for example, international capital movements at the Fed's (hind) ending of quantitative easing in 2013 (Chari, Stedman and Lundblad, 2017).

Report (EBA) annually since 2012, based on the methodology of Phillips et al. (2013). Based on selected fundamental factors, these IMF reports calculate a (normatively determined) equilibrium current account balance for significant economies of the world; the basic theoretical framework comprises (a) national accounting identity, understanding the current account as the difference between the rates of savings and investments (and considering their determinants as independent variables), as well as (b) the relationship within balance of payments, where the sum of the current account and the financial account equals the change in reserve assets (based on IMF, 1993). IMF (2012) defines current account disequilibrium more generally and says that excessive current account balance surplus or deficit does not comply with the fundamentals and appropriate policies of the economy. In the context of the methodology of IMF (2012), it would therefore be a mistake to apply an a priori strict view of an external equilibrium connected with a zero current account balance (whether in each period or as an average over several periods), since a non-zero current account balance need not always mean an external disequilibrium[19] (Blanchard and Milesi-Ferretti, 2009).

CONCLUSION

Simultaneously with the establishment of a balance of payments structure described in the successive editions of the IMF Manual, the development in this area has been concerned primarily with the notion of balance of payments (dis)equilibrium from the point of view of the IMF and of (theoretically focused) economists. The discussion has led to a gradual shift in attention to the current account balance as an indicator of balance of payments (dis)equilibrium. The balance of payments (dis)equilibrium assessment has gradually abandoned additional requirements, typically associated with a equilibrium exchange rate or full employment (Machlup, 1958). In determining the period for which the balance is to be in equilibrium (zero balance), the opinion has been that it need not be in equilibrium in every instant but that it should be in equilibrium within a specific time frame (e.g., one economic cycle). More recent approaches, influenced by the intertemporal approach to the current account, no longer regard the zero state of this cumulative balance as equilibrium, even over more extended time frames.

Monitoring balance of payments equilibrium on a "narrower basis," e.g., through net exports, would mean focusing only on international flows of goods and services, which is nowadays insufficient due to the increasing importance of primary and secondary income. On the other hand, by including certain items describing movements of international capital, the paper would fall in with the notion of equilibrium at the level of basic balance. That would, however, give rise to the question of which "types" of capital to include above the line and below the line.

Currently, the dominant part of the professional public tends towards the current account balance as a suitable indicator of balance of payments (dis)equilibrium. The value of this balance should be “near” zero in the long term. Moreover, abstracting from the capital account and the effect of revaluation of net foreign asset items, the zero value of the current account balance does not worsen the stock statistics of net foreign assets.

[19] The European Union applies a so-called *Macroeconomic Imbalance Procedure – MIP*. The 14 criteria for assessing the macroeconomic imbalance of an EU member state include its current account and net international investment position. The three-year moving average of an EU member state's current account balance has to be between –4% and +6% of the GDP. The net foreign assets must not be below –35% of the GDP. These rules are discussed, e.g., by Coutinho, Turrini and Zeugner (2018).

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ANNEX

Table A1 Development of the balance of payments basic structure according to individual editions of the IMF Manual

IMF (1948): BPM 1	**IMF (1950): BPM 2**	**IMF (1961): BPM 3**
Current transactions	Current transactions	Goods and services, and transfer payments
Merchandise	Goods and services	Goods and services
Non-monetary gold movement (net)	Merchandise	Merchandise
Foreign travel	Non-monetary gold movement (net)	Nonmonetary gold
Transportation	Foreign travel	Freight and insurance on international shipments
Insurance	Transportation	Other transportation
Investment income	Insurance	Travel
Government, not included elsewhere	Investment income	Investment income
Miscellaneous	Government, not included elsewhere	Government, not included elsewhere
Donations	Miscellaneous	Other services
Errors and omissions	Donations	Transfer payments
Movement of capital and monetary gold	Errors and omissions	Private
Private (excluding banking institutions)	Movement of capital and monetary gold	Central government
Long-term capital	Private (excluding banking institutions)	Movements of capital and monetary gold
Short-term capital	Long-term capital	Private long-term capital (excluding monetary institutions)
Offical and banking institutions	Short-term capital	Private short-term capital (excluding monetary institutions)
Long-term capital	Offical and banking institutions	Local governments (excluding monetary institutions)
Short-term capital	Long-term capital	Central government (excluding monetary institutions)
Monetary gold	Short-term capital	Central monetary institutions
	Monetary gold	Other monetary institutions

Table A1 (continuation)

IMF (1977): BPM 4	IMF (1993): BPM 5	IMF (2009): BPM 6
Current account	Current account	Current account
Goods, services, and income	Goods and services	Goods and services
Merchandise	Goods	Goods
Shipment	Services	Services
Other transportation	Income	Primary income
Travel	Compensation of employees	Compensation of employees
Investment income	Investment income	Investment income
Other goods, services, and income	Current transfers	Other primary income
Unrequited transfers	General government	Secondary income
Capital account, excluding reserves	Other sectors	General government
Direct investment	Capital and Financial account	Financial corporations, nonfinancial corporations, households, NPISHs
Portfolio investment	Capital account	Adjustment for changes in pension entitlements
Other capital	Capital transfers	Capital account
Reserves	Acquisition/disposal of nonproduced, nonfinancial assets	Gross acquisitions/disposals of nonproduced, nonfinancial assets
Monetary gold	Financial account	Capital transfer
Special drawing rights	Direct investment	Financial account
Reserve position in the Fund	Portfolio investment	Direct investment
Foreign exchange assets	Other investment	Portfolio investment
Other claims	Reseve assets	Financial derivatives (other than reserves) and employee stock options
Use of Fund credit		Other investment
		Reserve assets

Note: BPM = Balance of Payments Manual.
Source: IMF (1948, 1950, 1961, 1977, 1993, 2009)

How Digital Banking Affects Greenhouse Gas Emissions in Turkey? An Empirical Investigation

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Abstract

This paper investigates the impact of digital banking on greenhouse gas emissions in a case of developing economy, Turkey. Digital banking means more technological innovations in banking transactions. If banking transactions can be made in digital rather than physical environments, environmental effects are expected. We assume the environmental effect is positive, so the examination of this relationship is quite important. Technological innovations mean an increase in cost of digital banking transactions in the short run but in the long run this cost-increased effect is expected to turn opposite by an increase of active users in digital banking. We analyse the long-run relationship for the period between 2011/1 and 2019/4 by employing the Autoregressive Distributed Lag (ARDL) model. The results show that the increase in digital banking transactions have a positive and statistically significant effect on greenhouse gas emissions in Turkey. The findings reveal the positive trend in increasing transactions in digital banking in Turkey.

Keywords	***DOI***	***JEL code***
Digital banking, greenhouse gas emissions, Turkey, environmental Kuznets curve	*https://doi.org/10.54694/stat.2022.37*	*G21, O16, Q01, Q55*

INTRODUCTION

Recently, one of the most effective growth engines in any economy has been financialization level. Financialization means a well-organized financial system in an economy. Financial systems are the centre of economic growth and development process. Insomuch that finance has started to be regarded the main building block both in developed and developing countries (Öztürk and Acaravcı, 2013).

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Financialization has developed and spread all over the world for about 30–40 years. Digitalization has become one of the most important factors within the process of evolution and dissemination of financial systems. The digitalization in finance, which is known as 'digital finance', means the digitalization of the entire financial industry. Zhong (2022) stated that the McKinsey Report introduces digital finance as financial services, which is delivered with mobile phones, the internet, or cards. The digital finance is also described in other ways. Ozili (2018) pointed out that digital finance could be used as a reliable digital system of payment by means of mobile phones, personal computers, the internet, etc. Furthermore, there is a report that introduces the digital finance as a mode in which digital technology is applied allowing payment, investment, and providing other financial services (Huang and Huang, 2018).

The development of financial system has increased the energy demand all around the world. Digitization of financial systems mean enormous energy consumption. Therefore, digitization has become an important mechanism, which may have a serious damaging effect on the environment all over the world. On the one hand, the development in the financial system may lead to adverse environmental consequences. On the other hand, an increase in population and its effect on the increase on energy demand may also remarkably damage environment. An increase of population is naturally followed by increase of production capacities of individual countries with an adequate increase of consumption. This circulation has led to the robust growth of fossil fuels consumption and thus to the recent acceleration of environmental degradation. As a result of the population increase, the use of financial transactions has increased, and financial institutions have taken advantage of the technological innovations to make financial transactions easier and more accessible. Thus, basically, population expansion and the continuous increase in energy demand has increased the environmental degradation (Zhao et al., 2021).

Turkey is a densely populated country among countries using new technologies in their financial systems. Following the 2000s, an amazing economic growth in Turkey has put pressure on ecosystem and Turkey has made efforts to decouple its growth from environmental issues (World Bank, 2022). According to this report, like for all countries, the financial sector's readiness to react to environmental factors is a core priority for Turkey. While environmentalists' efforts continue in socio-economic life, the goal of banks to provide faster, more standard, and better quality service to their customers has become more evident over time. For this reason, it has been observed that banks have brought digital service channels to the fore. Focusing on digitalization, besides increasing customer satisfaction, banks can increase their profitability by reducing unit service production cost. Thus, it appears that banks have increased their profitability rates by focusing on the use of technology in recent years (Özen and Vurur, 2021).

Increasing the scope and diversity of digital services by banks depends on new technological investments. The new investments bring new additional fixed costs for banks and raise energy consumption. These increases contribute constantly to environmental pollution. In this case, it is necessary to examine the effects of the new process in banks on carbon emissions in two dimensions. How the digital finance increases environmental pollution? (i) It should be emphasized that technological investments in the financial world will increase the energy use, as in other industries, and this will lead to an increase in carbon emissions. How the digital finance reduces environmental pollution? According to Zhao et al. (2021), there is an internal rationale for the offsetting effect of digital finance on carbon emissions. (ii) Digital finance supports the technological process. Thus, it promotes economic growth and reduces environmental pollution. When the technological development reaches a sufficient level, a good environment and economic growth re-emerge. Thanks to high technology, inefficient use of resources is reduced, and this reduces environmental pollution. (iii) Digital finance supports industrial restructuring. Funds provided by digital finance enhance the transformation of high energy-using industries into low-carbon and high-profit industries. (iv) Digital finance encourages consumers to participate in environmental behaviour in daily life.

It can be said that the two-way effect can be explained more appropriately by the Environmental Kuznets Curve (EKC) (Kuznets, 1955). This paper determined that there was an inverted-U-shaped relationship

between these two variables. Then, Grossman and Krueger (1991) claimed that a similar relationship was valid between economic growth and environmental pollution. They found that as per capita income in a country increase, environmental pollution increases as well, but declines after a certain level of development. In parallel with the approaches of Kuznets (1955), and Grossman and Krueger (1991), it can be said that it is possible to examine the effects of changes in digital finance transactions on environmental pollution. Accordingly, although investments made for digital banking channels increase carbon emissions in the short term, while a reducing effect on carbon emissions should be expected in the long term. So, how digital banking affects the greenhouse gas emissions both in the short- and long-term in a developing country such as Turkey? Should banks continue to invest in technology? These questions are the main objectives of this paper. This paper seeks to provide empirical evidence about the digitalization effect of banks and greenhouse gas emissions in the case of Turkish economy during 2011/1 and 2019/4 by using Autoregressive Distributed Lag Model (ARDL) methodology. The data has not been calculated for after this period. The remainder of the paper is organized as follows: the next section discusses the related empirical literature. The second section introduces model, methodology and data. The third section shows the empirical results. Finally, the last section covers the findings of the estimated model.

1 LITERATURE SURVEY

This paper analysed the relationship between digital banking and environmental degradation by the lens of Environmental Kuznets Curve (EKC). The basic assumption in the analyse is that when technological innovation is included in the banking transactions, the cost of banking transactions rises to a certain level, in the long run this cost-increased effect will reverse with the high level of use of banking transactions. In the literature, many empirical studies have investigated the nexus of environmental degradation and some macroeconomic variables. Among them, most studies have examined the relationship between economic growth and carbon emissions in the context of EKC hypothesis. On the other hand, there are some studies which investigated the interaction between digitization in finance and carbon emissions. Thus, this section can be summarized mainly in two groups of empirical studies: a) which are interested in the EKC is valid or not; b) which are focused specifically on the nexus of digitalization in finance and environment degradation.

There are numerous studies that have been conducted for various countries about the EKC hypothesis during the last three decades. In the 1990s, all studies revealed some evidence of the validity of EKC hypothesis by employing per capita income and environmental degradation (Grossman and Krueger, 1991; Shafik and Bandyopadhyay, 1992). Recent studies have included in their analysis such as energy consumption, financial development, trade openness, etc. While some of them provide evidence that the EKC is valid (Say and Yücel, 2006; Zhang and Chen, 2009; Halıcıoğlu, 2009; Oztürk and Acaravci, 2013; Katircioglu, 2014; Albayrak and Gökçe, 2015), some studies do not confirm the EKC hypothesis (Öztürk and Acaravcı, 2010). On the other hand, some studies partially confirmed this hypothesis (Schröder and Storm, 2020). Schröder and Storm (2020) analysed the nexus of carbon emissions and some macroeconomics variables by using the data on OECD countries and found that the EKC hypothesis is valid for some countries albeit it is not validated for others.

There are relatively limited studies originating from developing countries. Jiang and Ma (2019) analysed the relationship between financial development and carbon emissions for 155 countries and showed that financial development increases carbon emissions in many countries. While the results of this analysis for developing countries were significant, the tests for developed countries were found to be insignificant. Çetin and Seyidova (2019) investigated the effects of growth in the Turkish banking sector on environmental pollution with the help of data such as loans extended, energy use per capita and GDP. This study concluded that GDP increases the production of carbon dioxide gas, and the banking sector loans/GDP ratio affects the energy consumption. De Haas and Popov (2020) determined

that lower carbon emissions occur when companies provide their funds through stock issuance rather than borrowing from the credit market. This situation revealed that the form of financial development can also make a difference on environmental pollution. Koca and Sevinç (2022) examined the validity of EKC hypothesis for BRICS-T countries (Brazil, Russia, India, China, South Africa, and Turkey) and revealed that financial development influences reducing environmental pollution, openness of the economy, and exports and imports increasing environmental pollution. showed. In this case, it is seen in the study that the EKC is partially valid for the BRICS-T countries.

Recently, a few studies have focused the investigation of digitalization in finance and its potential effect on environmental degradation for some countries. Sun (2020) determined that the development in digital finance increased the total factor productivity in the coastal provinces of China between 2011 and 2018, increasing the marine ecological efficiency and reducing the environmental pollution. Zhao et al. (2021) examined the interaction between digital finance and carbon emissions at provincial level in China as an emerging market economy and concluded that there is a meaningful reducer effect of digital finance on carbon emissions in almost all cases. Zhong (2022) showed that digital finance is an effective way of promoting environmental sustainability by reducing environmental pollution and promoting social sustainability by mitigating income inequality. Accordingly, Zhong (2022) determined that EKC is validated by the progress in digital finance in his study using the digital finance index prepared by Peking University Institute of Digital Finance.

2 MODEL, METHODOLOGY AND DATA

2.1 Model

This study seeks the influence of digital banking indicators, in particular the total internet and mobile banking active customers number, on greenhouse gas emissions. Apart from the focus of the study, real income is also an important explanatory variable for the environmental degradation. Furthermore, this study endeavours the long-term relationship between digital banking and greenhouse gas emissions by the view of EKC hypothesis. Therefore, the use of real income in the analysis provides more comfortable results and gives more significant findings. The relationship between greenhouse gas emissions and independent variables can be exhibited as follow:

$$ghg = f(GDP, GDP^2, bank, bank^2), \tag{1}$$

where:

ghg – greenhouse gas emissions,

GDP – Gross Domestic Product,

bank – digital banking (the sum of internet banking customers and digital banking customers).

Depending on the previous empirical literature on augmented EKC hypothesis, the long-term relationship between variables can be transformed into a linear logarithmic quadratic form:

$$lnghgt = \beta 0 + \beta_1 lngdp_t + \beta_2 lngdpt^2 + \beta_3 ln_t bank_t + \beta_4 lnbank_t^2 + \varepsilon_t , \tag{2}$$

where: β_0 represents the constant term and ε_t represents the error term, the β_1, β_2, β_3, β_4 indicate the elasticity parameters in the long-term. Here, the expected coefficients of GDP and gdp^2 give some information about the validity of EKC hypothesis but the expected coefficients of bank and $bank^2$ provide the novel explanation in relation to the effect of digitalization in banking sector on the environmental degradation. To promote an environmentally friendly understanding, several agreements, i.e. Green Deal, Paris Climate Agreement, has been carried out recently. Based upon this framework, the using type of banking operations becomes more important. Thus, despite the initial effect of digital banking, which

is represented by β_3, is positive on greenhouse gas emissions, when the β_4 is negative, the greenhouse gas emissions decrease because of the increase in internet and mobile banking transactions (digital banking).

2.2 Methodology

This study employs the Auto-regressive Distributed Lag (ARDL) model to examine whether there is a long-term cointegration relationship between the greenhouse gas emissions, gross domestic product, and digital banking in Turkey. The ARDL model (Pesaran et al., 2001) runs better in the limited observations unlike conventional cointegration tests (Ibarra and Blecker, 2016). The sample size in the data of this study is only thirty-six, thus, we can use the ARDL bound test for the empirical analysis. The ARDL estimation method can only be used on the condition that the variables should be at I (1) or I (0), should not be at I (2) or more. The ARDL bound test method has an advantage due to the estimation of short- and long-term coefficients simultaneously (Haug, 2002). This study utilizes the ARDL approach to analysis the long-term relationship between variables via the following equation:

$$\begin{aligned}\Delta \ln ghg_t = {} & \beta_0 + \Sigma_i = {}_1{}^P\beta_1 \Delta \ln ghg_{t-i} + \Sigma_i = {}_1{}^P\beta_2 \Delta \ln gdp_{t-i} + \Sigma_i = {}_1{}^P\beta_3 \Delta \ln(gdp)^2{}_{t-i} + \Sigma_i \\ & = {}_1{}^P\beta_4 \Delta \ln bank_{t-i} + \Sigma_i = {}_1{}^P\beta_5 \Delta \ln(bank)^2{}_{t-i} + \lambda_1 \ln ghg_{t-1} + \lambda_2 \ln gdp_{t-1} + \lambda_3 \ln(gdp)^2{}_{t-1} \\ & + \lambda_4 \ln bank_{t-1} + \lambda_5 \ln(bank)^2{}_{t-1} + \varepsilon_t ,\end{aligned} \tag{3}$$

where: Δ represents the difference term, β_0 shows the constant term, and ε_t denotes the error term; also the β_1, β_2, β_3, β_4, and β_5 indicate the short-term coefficients while λ_1, λ_2, λ_3, λ_4, and λ_5 are the long-term coefficients in the estimated model; ^{P} shows the optimal lag length, which is determined in the model selection criteria by Akaike Information Criteria (AIC) or Schwarz Information Criteria (SIC) or Hannan-Quinn Information Criteria (HQ). The ARDL bounds test methodology is commonly conducted within two main steps. There is a hypothesis test to determination of any co-integration relationship between variables. So, the null and the alternative hypotheses to be tested by the F-test are as follows:

$$H_0: \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = 0,$$
$$H_1: \lambda_1 \neq \lambda_2 \neq \lambda_3 \neq \lambda_4 \neq \lambda_5 \neq 0.$$

The null hypothesis shows that there is not any co-integration relationship between variables. When the null hypothesis is rejected, it means that there is a co-integration relationship between variables. For any co-integrating relationship, the unrestricted error correction model (UECM) (Pesaran and Shin, 1999) can be estimated as in the following equation:

$$\begin{aligned}\Delta \ln ghg_t = {} & \beta_0 + \Sigma_i = {}_1{}^P\beta_1 \Delta \ln ghg_{t-i} + \Sigma_i = {}_1{}^P\beta_2 \Delta \ln gdp_{t-i} + \Sigma_i = {}_1{}^P\beta_3 \Delta \ln(gdp)^2{}_{t-i} + \Sigma_i \\ & = {}_1{}^P\beta_4 \Delta \ln bank_{t-i} + \Sigma_i = {}_1{}^P\beta_5 \Delta \ln(bank)^2{}_{t-i} + \Theta ECT_{t-1} + \varepsilon_t .\end{aligned} \tag{4}$$

In Formula (4), Θ indicates the coefficient of the error correction term (ECT_{t-1}) and gives an information about the speed of adjustment showing the convergence capabilities of variables to the long-term equilibrium. The error correction model provides the distinguishing effects of short-term and long-term. Besides, the expectation of the coefficient of error correction term is negative and statistically significant value, i.e. between 0 and –1, to get a smooth correction to the long-term equilibrium.

2.3 Data

The analysis of the study uses quarterly data covering the period between 2011/1 and 2019/4. The data starts with the first quarter of 2011 because there is not any data for the mobile banking statistics before that period. The analysis focuses on the following variables on the Turkish economy for the long-term

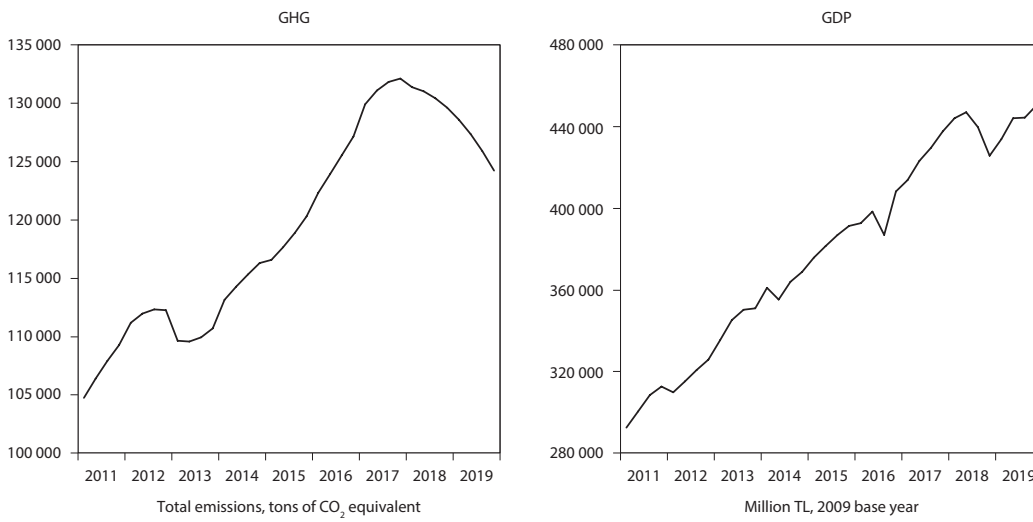
relationship between greenhouse gas emissions (*ghg*), gross domestic product (*gdp*) and digital banking (*bank*). The digital banking data represents the sum of internet banking customers and mobile banking customers in Turkey and was retrieved from the Banks Association of Türkiye databases, the data for gross domestic product was obtained from the Organisation for Economic Co-operation and Development (OECD) database,[3] the data for greenhouse gas emissions was also received from the OECD database. The quarterly data of greenhouse gas emissions is an interpolating version of annual data that have emerged by using E-views 12 package program. These data were calculated as a quadratic sum type. There are many studies in the literature that use this interpolation methodology to convert the data structure from low frequency to high frequency (McDermott and McMenamin, 2008; Shahbaz, Loganathan, Muzaffar, Ahmed, and Jabran, 2016). This study used the logarithmic values of the series. The logarithmic values are

Table 1 The summary statistics

Variables	Notation	Source	Obs.	Mean	Min.	Max.	St. dev.
Greenhouse gas emissions	ghg	OECD statistics	36	119 447.5	104 685.2	132 127.6	8 821.398
Digital banking	bank	the Bank Association of Turkey	36	28 287.97	7 457.815	61 694.66	17 742.13
Digital banking (squared)	bank2	the Bank Association of Turkey	36	1.11E+09	55 619 005	3.81E+09	1.15E+09
Gross domestic product	GDP	OECD statistics	36	379 633.7	292 146.7	450 440.2	49 738.18
Gross domestic product (squared)	GDP2	OECD statistics	36	1.47E+11	8.53E+10	2.03E+11	3.75E+10

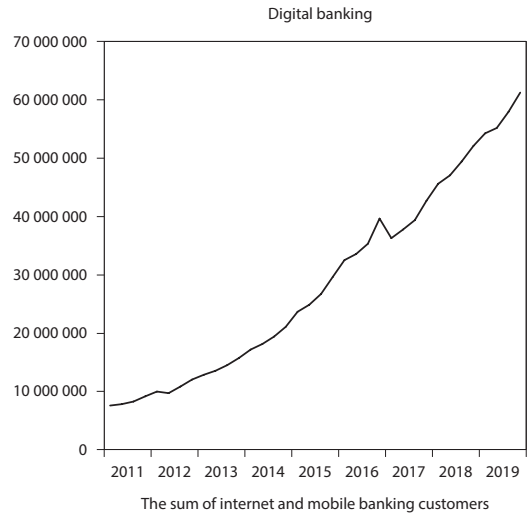
Source: Authors' calculations

Figure 1 The trends in greenhouse gas emissions, gross domestic product, and digital banking, 2011/1–2019/4 (quarterly)



[3] For OECD statistical databases: <*https://stats.oecd.org*>.

Figure 1 (continuation)



Source: OECD, the Bank Association of Turkey, authors' calculations

a percentage changes in the original values. Thus, the results become more interpretative and meaningful for such an analysis. Table 1 summaries the descriptive statistics of the variables.

Figure 1 pictures the greenhouse gas emissions, gross domestic product, and digital banking in Turkey during the period between 2011/1 and 2019/4. The use of digital banking tends to increase remarkably throughout the period. In particular, the increase in the use of mobile banking has significantly increased the number of active customers using digital banking, recently. There has also been a slight increase in greenhouse gas emissions until the first quarter of 2018. However, a considerable structural shift in the greenhouse gas emissions following the 2018/1 is clearly observable in the figure. As this structural shifting gives an important signal for the stability conditions of the variables, we prefer the unit root test with structural break to examine the stationary conditions of the variables. The conventional unit root tests assume that the effects of shocks are temporary and do not affect the series in the long run. Nelson and Plosser (1982) assert that the shocks on series have permanent effect and there exist a structural shift in the time series data. In such a case, breakpoint unit root test assesses the stationary level of the variables considering the structural break points. Also, the conventional unit root tests are unstable when there is a structural break in the time series (Sun, Zhang, and Xu, 2017).

3 EMPIRICAL RESULTS

Table 2 indicates the unit root test results. According to the results, the null hypothesis of unit root for all variables cannot be rejected in their level values albeit the null hypothesis can be rejected for all of them when the variables are transformed in their first difference. So, all the variables are in I (1) process and this result allows us to investigate the long-term cointegration relationship between the variables by using the Autoregressive Distributed Lag (ARDL) model estimation method.

The structural breaks in the time series spread over the whole period. Therefore, there is not necessary to add any dummy variables to control the structural break in the estimated model. Table 3 shows the bound test results. The calculated F-statistic value is above the upper value. Thus, there is a co-integration relationship between variables due to the null hypothesis is rejected. This result obtained reveals

Table 2 Breakpoint Unit Root test

Variables	At level		At 1st difference	
	TBs	T-statistics	TBs	T-statistics
lnghg	2018/3	–3.094 (5)	2017/3	–7.264*** (7)
lnGDP	2019/3	–3.776 (3)	2013/3	–6.297*** (0)
$lnGDP^2$	2016/4	–3.013 (9)	2013/3	–6.039*** (0)
lnbank	2014/2	–3.089 (0)	2016/2	–6.356*** (0)
$lnbank^2$	2013/4	–1.056 (0)	2014/1	–6.387*** (0)

Notes: *** represents significance at 1% level. The maximum lag length is selected at 9 and the breakpoint is based on Dickey-Fuller min-t method. The optimal lag lengths are in the bracket and are based on F-statistic selection.
Source: Authors' compilation

Table 3 Bound test results

Model	F-statistic	Critical values	
ghg = f(GDP, GDP^2, bank, $bank^2$)		I (0)	I (1)
Lag length structure (1, 2, 2, 4, 4)	12.96 ***	4.40	5.72

Notes: The critical values are from Kripfganz and Schneider (2020). *** means statistically significant at 1%.
Source: Authors' compilation

a long-term relationship between the dependent variable, the logarithm of greenhouse gas emissions, and independent variables, the logarithm of gross domestic product, the logarithm of gross domestic product squared, the logarithm of bank, and the logarithm of bank squared.

Table 4 presents the results of ARDL estimation in the long- and short-term. As expected, the bank and the bank squared affect greenhouse gas emissions positively and negatively, respectively. However, by contrast with the previous empirical literature on the validity of EKC hypothesis, the gross domestic product squared showed no significantly negative effect on the greenhouse gas emissions. The data used in the analysis is quarterly structure, therefore it differs from the existing literature. This situation can be shown as a reason for the results to differ from the existing literature. The table demonstrates that all explanatory variables have a significant effect on the greenhouse gas emissions in the long-term at 1 and 5 % level except for the gross domestic product squared, which is not statistically significant at 10 % level. We are basically concerned with the bank and the bank squared coefficients. So, the estimation results show that the coefficients of the digital banking variables are in parallel with our preliminary expectations.

The estimation of the Formula (1) indicates that the bank coefficient was estimated as 2.58. This result means that a one percent increase in digital banking tends to an increase in greenhouse gas emissions by 2.58%. Also, a one percent increase in the growth of digital banking reduces greenhouse gas emissions by approximately 1.74%. Accordingly, while the total number of internet banking and mobile banking active customers, which reflects the number of digital banking customers, initially increases greenhouse gas emissions, the increase in the number of digital banking customers has a reducing effect on greenhouse gas emissions. The results also show that a one percent increase in gross domestic product leads to an increase in greenhouse gas emissions by 0.41% while a one percent increase in the growth of gross domestic product causes a decreasing effect on greenhouse gas emissions by about 2.68%. However, as the negative effect of the increase in the gross domestic product growth was not statistically significant, the findings obtained in the study cannot prove the validity of the EKC hypothesis when quarterly

data are used. Table 4 also indicates the short-term results. The short-term results seem that most of the coefficients are statistically significant at 1 and 5% levels.

Another estimation result presented in table 4 is the error correction mechanism. The error correction term is negative and statistically significant as expected. The ECT coefficient is about 0.77 in the model.

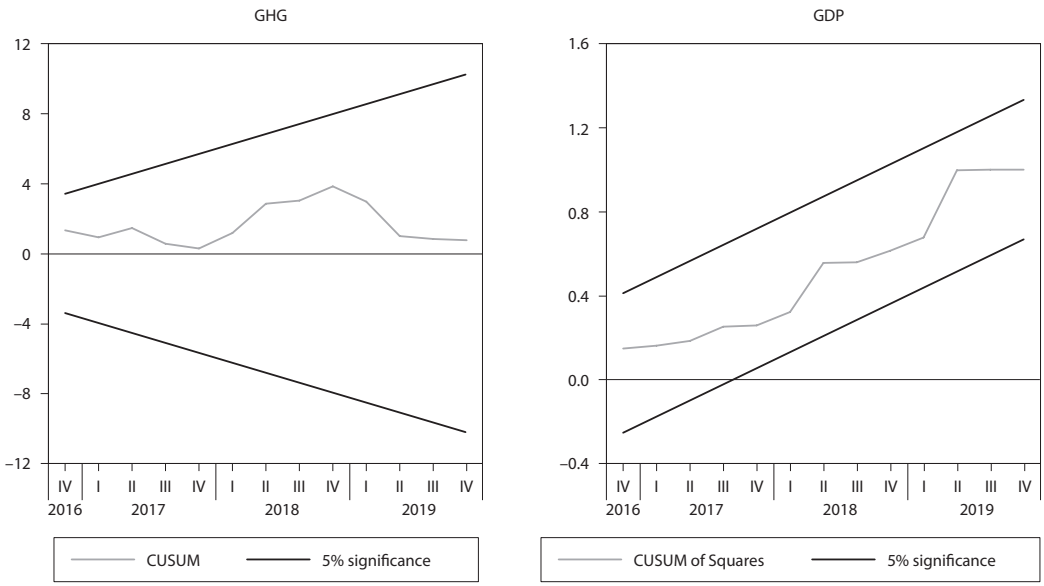
Table 4 The results of ARDL estimation

Variables	
	Long-run
GDP	0.412 (0.181) **
GDP^2	–2.680 (1.890)
bank	2.587 (0.086) ***
$bank^2$	–1.740 (2.520) ***
	Short-run
ghg (–1)	–0.770 (0.129) ***
ΔGDP	–0.084 (0.154)
GDP (–1)	–0.879 (0.136) ***
GDP (–2)	–0.786 (0.148) ***
GDP (–3)	–0.547 (0.149) ***
ΔGDP^2	1.301 (1.890)
GDP^2 (–1)	9.633 (1.701) ***
GDP^2 (–2)	8.303 (1.773) ***
GDP^2 (–3)	5.870 (1.790) ***
Δbank	1.275 (0.384) ***
bank (–1)	–1.088 (0.341) ***
$\Delta bank^2$	–9.583 (4.343) **
$bank^2$ (–1)	1.143 (3.920) **
trend	–2 345.385 (249.116) ***
error correction term (–1)	–0.770
constant	6 078.586 (833.271) ***
R-squared	0.954
N	36
	Diagnostic tests
serial LM	0.193 (0.016)
heteroscedasticity	0.969 (0.890)
J-B normality	2.983 (0.225)
Ramsey RESET	0.169 (0.690)
Durbin-Watson	2.61
Cusum	stable
CusumSQ	stable

Source: Authors' compilation

It means that most of the short-run deviation would clear out in the long-run in the model. Besides, some post-estimation diagnostic tests were performed to determine the validity of the estimated model and variables used in the ARDL methodology. According to these results, there is not any autocorrelation, heteroscedasticity, and normality problem. The Jarque-Bera test result also provides the normality condition. Finally, Figure 2 shows the Cusum test and the CusumSq test results. Accordingly, there is not any stability problem in the coefficients due to the test statistics in between the critical levels.

Figure 2 The Cusum and the Cusum Square test result



Source: Authors' compilation

CONCLUSION

This study is designed to determine the effects of the efforts of the Turkish banking sector on digitalization after 2010 on greenhouse gas emissions in the country. The impact of digitization on greenhouse gas emissions is investigated based on the Environmental Kuznets Curve (EKC) hypothesis. An increase in digital banking user numbers is increasing greenhouse gas emissions. However, an increase in the increasing trend in the number of digital banking users (the square of the number of digital transactions) contributes to the reduction of greenhouse gas emissions. Accordingly, while the number of active customers in internet banking and mobile banking initially increased the greenhouse gas emissions, the increase in the number of active customers because of the widespread use of digital banking transactions has an effect that reduces greenhouse gas emissions. In this case, the Kuznets curve for digital banking is confirmed.

In addition, in the study, it was concluded that an increase in GDP increases greenhouse gas emissions, while an increase in growth rate of GDP reduces greenhouse gas emissions. However, the negative effect of the increase in GDP growth rate was not found statistically significant. According to the findings of the study, it can be said that the environmental Kuznets curve cannot prove its validity when using quarterly data. The findings of the study are compatible with the studies of Çetin and Seyidova (2019), Koca and Sevinç (2022), Zhong (2022), and Sun (2020) in which financial development related data are used in the context of supporting the Kuznets curve. In this case, it can be argued that financial digitalization reduces

environmental pollution. However, the type of financial data used in this study, unlike previous studies, focused on the use of digital banking. Because the widespread use of digital banking eliminates some costs such as transportation, printing and using physical documents, and this creates a reducing effect on greenhouse gas emissions. It seems that the study findings do not generally agree with the findings of Jiang and Ma (2019). However, Jiang and Ma's (2019) dataset is different from these study data.

Considering the positive impact of the prominence of digital service channels on bank profits (Özen and Vurur, 2021), it is an appropriate policy for banks to increase the use of digital channels in service marketing. However, it would be beneficial for users to come up with a product design that will enable financial transactions to be done easily and without errors. The findings of the study have various implications for banks as well as other policy makers, researchers, and citizens.

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Unbiased Variance Estimator of the Randomised Response Techniques for Population Mean

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Abstract

Antoch, Mola and Vozár (2022) proposed recently new randomized response technique for population mean or total of a quantitative variable. The aim of the paper is to solve the open problem to derive unbiased variance estimator of these procedures. In their proposal, unlike other randomized response techniques for population mean or total the randomized response is not a linear function of a sensitive variable. However, standard techniques to derive variance estimators in this setting are based on this assumption. That is why an interviewer needs also to know values pseudorandom numbers (i.e., results of individual randomization experiments). Respondents might perceive this relaxation of privacy protection negative. The performance of the approximate two-sided confidence intervals of distributions with different shape including their coverage is assessed by a simulation study for simple random sampling without replacement.

Keywords	***DOI***	***JEL code***
Unbiased variance estimator, randomized response techniques, survey sampling, Horvitz-Thompson estimator, simple random sampling without replacement, population mean	*https://doi.org/10.54694/stat.2022.38*	*C83*

INTRODUCTION

The concern of respondents of statistical surveys on their privacy on the one hand and growing interested of survey sponsors on sensitive issues (like drug consumption, behavior deviation from society or legal norms like corruption etc.) on the other hand make methodological challenges for survey statisticians. It is natural that participants (respondents) of such a survey tend to refuse to participate (non-response) or to provide strongly biased answers (severe measurement error). As mentioned by Särndal et al. (1992, p. 547), if we ask sensitive or pertinent questions in a survey, conscious reporting of false values would often occur. These issues can not be resolved by standard techniques like model-based regression imputation or reweighting (see also Särndal et al., 1992, p. 547). For detailed discussion of reweighting and imputation see monograph Särndal and Lundström (2005).

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Randomized response techniques (RRTs) are designed to resolve both the high nonresponse and bias due to fabricated answers. Instead of direct questioning, each respondent makes independently a random experiment (its result is unknown to an interviewer) and then answers depending on its result. Eriksson (1971) proposed the first RRT for mean of a quantitative variable. A respondent provides value of a sensitive variable multiplied by a number on the card drawn from a deck of cards. This problem was also studied by T. Dalenius and his colleagues (Dalenius and Vitale, 1979). All the methods are based on providing linear transformation of a sensitive variable instead of its true value (for example Chaudhuri, 1987). The state-of-art of RRT is presented in recent monographs by Chaudhuri (2017) and Chaudhuri et al. (2016).

Notions of survey sampling theory and randomized response techniques for mean are presented in Section 1. Unbiased variance estimator of two mean estimators using RRT by Antoch et al. (2022) are derived in Section 2. Performance of the variance estimators and coverage of approximate normal confidence intervals is assessed by simulation study in Section 3. The last section consists of conclusions of this paper.

1 NOTIONS OF RRTS FOR MEAN OF QUANTITATIVE VARIABLES

Let $U = \{1, \ldots, N\}$ be a finite population of N identifiable units unambiguously identified their labels. The purpose of the survey is to estimate the population total or mean of a sensitive variable Y denoted as $\overline{t}_Y = \frac{\sum_{i \in U} Y_i}{N}$. Therefore, we select a random sample s with probability $p(s)$ describing a sampling plan with a fixed sample size n. Let us define π_i as the probability of inclusion of the i^{th} element of the population in the sample s, i.e., $\pi_i = \sum_{s \ni i} p(s)$. The $\pi_{i,j}$ is defined as the probability of inclusion of the i^{th} and j^{th} element in the sample s, i.e., $\pi_{i,j} = \sum_{s \ni i \cap s \ni j} p(s)$ (note, that $\pi_{i,i} = \pi_i$). In depth overview of survey sampling is given by monograph of Särndal et al. (1992), mathematically rigorous treatment by Tillé (2020).

If the variable of interest is difficult to survey by the direct questioning due to its sensitivity, the interviewers collect randomized response Z correlated to Y. Randomization of the responses must be done for each unit in the sample independently. The randomization procedure should not also depend on the sampling plan $p(s)$.

Then, the survey has two phases. In the first phase a sample s is selected from population U. Then in the sencond phase, given sample s, responses Z_i are obtained using the chosen RRT. The corresponding probability distributions are denoted as $p(s)$ and $q(r|s)$. The notions of expected value, unbiasedness, and variance are derived by a two-fold averaging process. The first averaging is done over all possible samples s that can be selected using the sampling plan $p(s)$. The second averaging is done over all possible randomized response sets r that can be realized given sample s under the randomized response distribution $q(r|s)$. We use the notation of Arnab (1994), Chaudhuri (1992) and denote the expectation operators with respect to these distributions by E_p and E_q.

In survey using direct questioning, if $\pi_i > 0$, $\forall\, i \in U$ and known population size N, the population mean $\overline{t}_Y$ is often estimated by linear unbiased Horvitz-Thompson estimator:

$$\overline{t}_s^{HT} = \frac{1}{N} \sum_{i \in s} \frac{Y_i}{\pi_i} \tag{1}$$

with variance:

$$Var(\overline{t}_s^{HT}) = \frac{1}{N^2} \sum_{i \in U} \sum_{j \in U} (\pi_{i,j} - \pi_i \pi_j) \frac{Y_i}{\pi_i} \frac{Y_j}{\pi_j}. \tag{2}$$

Moreover, if $\pi_{i,j} > 0$, $\forall\, i, j \in U$, then the variance can be unbiasedly estimated as:

$$\hat{Var}(\bar{t}_s^{HT}) = \frac{1}{N^2} \sum_{i \in s} \sum_{j \in s} \frac{(\pi_{i,j} - \pi_i \pi_j)}{\pi_{i,j}} \frac{Y_i}{\pi_i} \frac{Y_j}{\pi_j}. \tag{3}$$

In a survey using RRT instead of direct questioning, the values of Y_i from the sample s are unknown to the interviewers. Instead, they collect randomized responses Z_i correlated with Y_i. Randomized responses Z_i are further transformed into another variables R_i. The transformed variables are more fit to construct the unbiased population mean Horvitz-Thompson's type estimator. It is constructed as:

$$\bar{t}_s^{HT,R} = \frac{1}{N} \sum_{i \in s} \frac{R_i}{\pi_i}. \tag{4}$$

We assume that transformed randomized responses R_i follow model of Chaudhuri (1992):

$$E_q(R_i) = Y_i,\ Var_q(R_i) = \phi_i,\ \forall i \in U,\ Cov_q(R_i, R_j) = 0_i,\ \forall i, j \in U : i \neq j\,. \tag{5}$$

The variance function ϕ_i of a transformed randomized response R_i is a function of Y_i.

The estimator $\bar{t}_s^{HT,R}$ of the population mean is defined as conditionally unbiased if it holds $E_q(\bar{t}_s^{HT,R}|s) = \bar{t}_s^{HT}$. It means, that conditional mean of $\bar{t}_s^{HT,R}$ given the sample s equals to the Horvitz-Thompson estimator $\bar{t}_s^{HT}$, if only direct questioning would take place. If the estimator $\bar{t}_s^{HT,R}$ is conditionally unbiased and estimator $\bar{t}_s^{HT}$ is unbiased, then estimator $\bar{t}_s^{HT,R}$ is also unbiased, becuase $E(\bar{t}_s^{HT,R}) = E_p(E_q(\bar{t}_s^{HT,R}|\mathrm{s}) = E_p(\bar{t}_s^{HT}) = \bar{t}_Y$. Then the variance can be expressed using the standard probability formula as:

$$\begin{aligned} &Var(\bar{t}_s^{HT,R}) = E_p(Var_q(\bar{t}_s^{HT,R}|s)) + Var_p(E_q(\bar{t}_s^{HT,R}|s)) = E_p(Var_q(\bar{t}_s^{HT,R}|s)) + Var_p(\bar{t}_s^{HT,R}) \\ &= \sum_{i \in U} \frac{\phi_i}{\pi_i} + Var_p(\bar{t}_s^{HT,R})\,. \end{aligned} \tag{6}$$

The variance given by (6) is decomposed into two terms. The second term is the variance of the estimator if RRT was not used. The first term represents the increase of the variance caused by the randomization.

2 MAIN RESULTS

Two estimators of mean using RRT by Antoch et al. (2022) are briefly presented. Unbiased plug-in variance estimators using ideas of Chaudhuri (1992) and Arnab (1994) are then derived.

2.1 Two mean estimators using RRT by Antoch et al. (2022)

In the majority of RRT, a respondent masks true value by some algebraic operations (multiplication, respectively adding number for a randomly drawn card). To avoid guessing true value of sensitive variable, Antoch et al. (2002) proposed much safer technique. They assume, that the surveyed variable Y is non-negative and bounded from above: $0 \leq Y \leq M$; the upper bound M of the variable Y is also known. Each respondent independently on the others generates pseudorandom number U_i from the uniform distribution on interval $(0,M)$. To protect privacy, the respondent then answers a question: "Is the value of Y greater than U"?

The response $Z_{i,(0,M)}$ of the *ith* respondent follows the alternative distribution with the parameter $\frac{Y_i}{M}$. It holds $E(Z_{i,(0,M)}) = \frac{Y_i}{M}$ and $Var(Z_{i,(0,M)}) = \frac{Y_i}{M}(1 - \frac{Y_i}{M})$. Then we transform $Z_{i,(0,M)}$ to $R_{i,(0,M)} = MZ_{i,(0,M)}$, for which it holds:

$$E(R_{i,(0,M)} = Y_i,\ \phi_{i,(0,M)} = Var(R_{i,(0,M)} = Y_i(M - Y_i)\ . \tag{7}$$

The unbiased mean estimator takes form:

$$\overline{t}^{HT,R}_{(0,M)} = \frac{1}{N}\sum_{i\in s}\frac{R_{i,(0,M)}}{\pi_i}\ . \tag{8}$$

Antoch et al. (2022) also proposed an estimator on the assumption, that interviewer also knows a value of pseudorandom number U_i (i.e., the question to which a respondent answer). An interviewer transforms the answer of i^{th} respondent as:

$$Z_{i,\alpha,(0,M)} = \begin{cases} 1 - \alpha + 2\alpha\ \dfrac{U_i}{M}, \text{ if } U_i < Y_i \\ -\alpha + 2\alpha\ \ \dfrac{U_i}{M}, \text{ otherwise} \end{cases} \qquad 0 \le \alpha < 1,\ i \in s\ , \tag{9}$$

where α is a tuning parameter. It is set a priori by an interviewer and its value is unknown to respondents. It holds $E(Z_{i,\alpha,(0,M)}) = \frac{Y_i}{M}$ and $Var(Z_{i,\alpha,(0,M)}) = \frac{1-2\alpha}{M^2}\ Y_i(M - Y_i) + \frac{\alpha^2}{3}$. We further transform $Z_{i,\alpha,(0,M)}$ to $R_{i,\alpha,(0,M)}$ $= MZ_{i,\alpha,(0,M)}$ with:

$$E(R_{i,\alpha,(0,M)} = Y_i,\ \phi_{i,\alpha,(0,M)} = Var(R_{i,\alpha,(0,M)} = (1 - 2\alpha)\ Y_i(M - Y_i) + \frac{\alpha^2 M^2}{3}\ . \tag{10}$$

The unbiased mean estimator takes form:

$$\overline{t}^{HT,R}_{\alpha,(0,M)} = \frac{1}{N}\sum_{i\in s}\frac{R_{i,\alpha,(0,M)}}{\pi_i}\ . \tag{11}$$

2.2 Unbiased variance estimator of two mean estimators by Antoch et al. (2022)

Let us assume, it holds $\pi_{i,j} > 0, \forall\ i, j \in U$, then an unbiased variance estimator of Horvitz-Thompson's type estimator for the population mean takes form:

$$\hat{Var}(\overline{t}^{HT,R}_s) = \frac{1}{N^2}\sum_{i\in s}\frac{\hat{\phi}_i}{\pi_i^2} + \frac{1}{N^2}\sum_{i\in s}\sum_{j\in s}\frac{(\pi_{i,j} - \pi_i\pi_j)}{\pi_{i,j}}\ \frac{Y_i}{\pi_i}\frac{Y_j}{\pi_j}\text{, where } E_q(\hat{\phi}_i) = \phi_i, \forall\ i, j \in U\ . \tag{12}$$

To derive variance estimator by standard methods, the second moment of the transformed randomized response R_i must be a function of Y_i^2. Unfortunately, it does not hold for original proposal (8) by Antoch

et al. (2022) (without knowledge of pseudorandom numbers). The reason is, that it holds $(R_{i,(0,M)})^n = M^n Z_{i,(0,M)}$, which implies $E(R_{i,(0,M)})^n = M^{(n-1)} Y_i$. An interviewer needs to know values of U_i to estimate variance of $\overline{t}_{(0,M)}^{HT,R}$, because it holds:

$$E(2R_{i,(0,M)}U_i) = 2\int_0^{Y_i} U_i dU_i = Y_i^2 .$$

Then, using values of U_i, Y_i^2 can be unbiasedly estimated as $2R_{i,(0,M)}U_i$. Variance of $R_{i,(0,M)}$ can be unbiasedly estimated as:

$$\hat{\phi}_{i,(0,M)} = R_{i,(0,M)}(M - 2U_i) . \tag{13}$$

A drawback of that proposal is that if $Y_i > \frac{M}{2}$, the value of $\hat{\phi}_{i,(0,M)}$ can be negative, even if it estimates non-negative quantity. In the same manner, we can construct unbiased variance estimator as:

$$\begin{aligned} \hat{Var}(\overline{t}_{(0,M)}^{HT,R}) = & \frac{1}{N^2}\sum_{i\in s}\frac{R_{i,(0,M)}(M - 2U_i)}{\pi_i^2} + \frac{1}{N^2}\sum_{i\in s}\sum_{j\in s}\frac{(\pi_{i,j} - \pi_i\pi_j)}{\pi_{i,j}}\frac{R_{i,(0,M)}}{\pi_i}\frac{R_{j,(0,M)}}{\pi_j} \\ & + \frac{1}{N^2}\sum_{i\in s}(1 - \pi_i)\frac{R_{i,(0,M)}(2U_i - R_{i,(0,M)})}{\pi_i^2} . \end{aligned} \tag{14}$$

For the second proposal of Antoch et al. (2022) using knowledge of pseudorandom numbers (11) the variance estimation technique of Chaudhuri (1992), because for $\alpha \neq 0$ variable Y_i^2 is one of term of the second moment of $R_{i,\alpha,(0,M)}$, namely:

$$E(R_{i,\alpha,(0,M)}^2) = 2\alpha Y_i^2 + (1 - 2\alpha)\, MY_i + \frac{\alpha^2 M^2}{3} . \tag{15}$$

Using $R_{i,\alpha,(0,M)}^2$and $R_{i,\alpha,(0,M)}$ as unbiased estimator of Y_i, the unbiased variance estimator is:

$$\hat{\phi}_{i,\alpha,(0,M)} = \frac{-(1 - 2\alpha)\, R_{i,\alpha,(0,M)}^2 + (1 - 2\alpha)\, MR_{i,\alpha,(0,M)} + \frac{\alpha^2 M^2}{3}}{2\alpha} . \tag{16}$$

The unbiased variance estimator is then:

$$\begin{aligned} \hat{Var}(\overline{t}_{(0,M)}^{HT,R}) = & \frac{1}{N^2}\sum_{i\in s}\frac{\hat{\phi}_{i,\alpha,(0,M)}}{\pi_i^2} + \frac{1}{N^2}\sum_{i\in s}\sum_{j\in s}\frac{(\pi_{i,j} - \pi_i\pi_j)}{\pi_{i,j}}\frac{R_{i,\alpha,(0,M)}}{\pi_i}\frac{R_{j,\alpha,(0,M)}}{\pi_j} \\ & + \frac{1}{N^2}\sum_{i\in s}\frac{(1 - \pi_i)}{\pi_i^2}\left(\frac{(1 - 2\alpha)(R_{i,\alpha,(0,M)}^2 - MR_{i,\alpha,(0,M)}) - \frac{\alpha^2 M^2}{3}}{2\alpha}\right). \end{aligned} \tag{17}$$

3 SIMULATION STUDY

In the simulation study, we study coverage of approximate confidence intervals:

$$\overline{t}_{(0,M)}^{HT,R} = \pm\, t_{1-\alpha/2}\sqrt{\hat{Var}(\overline{t}_{(0,M)}^{HT,R})}\,, \tag{18}$$

where $t_{1-\alpha/2}$ is the quantile of student distribution with $n - 1$ degrees of freedom.

All simulations and computations were done by the statistical freeware *R*, version 4.2.1 (R Core Team, 2022). We run simulation for three different distributions of variable *Y* with different shape (see Table 1).

Table 1 Distribution of variable *Y*

Indicator	Mean E(*Y*)	Standard deviation sd(*Y*)	$P(0 \le Y \le 3)$
Exponential ($\lambda = 1$)	1.0	1.00	0.950
Normal ($\mu = 1.5$, $\sigma = 0.5$)	1.5	0.50	0.997
Uniform ($U(0,3)$	1.5	0.87	1.000

Source: Own construction

For each distribution, we generate 1 000 populations of size *N*. From each realization of the population, we then draw 1 000 samples of size *n* by simple random sampling without replacement. We generate populations of size $N = \{200, 400, 1\,000\}$ from which we select samples of size ranging from 20 to 100. Populations and samples of these sizes are common in applications of RRT (size of community, village) or any strata from business or social statistics survey. Pseudorandom numbers come from uniform distribution on interval (0,3). This interval covers most of the range of values of the variable *Y* (see the last column of Table 1). Since there is no prior information on distribution of *Y*, we use the default value of the tuning parameter $\alpha = 0{,}75$.

The performance of the variance estimators is assessed by covering the approximate confidence interval with the chosen confidence level. Proportion of simulated samples with approximate confidence interval covering the population mean is compared with prescribed confidence level. All simulation results of coverage of two-sided 90%, 95% and 99% confidence interval for the mean are summarized in Tables 2–4 (see the Annex). Variance estimators works well for symmetric distributions (normal, uniform) for both methods. Approximate confidence intervals then work well even for small sample and population sizes. For distribution skewed from the left (exponential) the coverage of approximate is a bit underestimated. This effect is observed for estimator $\overline{t}_{(0,M)}^{HT,R}$ using the variance estimator by Formula (14). However, the same effect is also present in confidence intervals for estimator (17) with using pseudorandom values $\overline{t}_{\alpha,(0,M)}^{HT,R}$. Preliminary analysis indicates that for skewed sensitive variable its variance estimates are skewed in the same direction. It implies for exponentially distributed sensitive variable, that too many confidence intervals might be too narrow, even if the population mean and its estimate are very closed. Also, presence of negative values of transformed randomized responses *R* or values of *R* exceeding its upper bound *M* of the sensitive surveyed variable *Y* might be the reason.

DISCUSSION AND CONCLUSION

We derived unbiased variance estimators for mean estimators using new RRT proposed by Antoch et al. (2022). Unfortunately, for this, it is necessary to breach respondents' privacy slightly for the first estimator, because the value of the pseudorandom numbers *U* must be available to an interviewer (they also know the questions asked). The reason is that, unlike other RRTs, the randomized response does not contain a transformed sensitive value *Y* (they only provide Yes/No responses instead of a numeric value). For the second estimator, the respondents' privacy can breach less, if the respondents take some effort and calculate the transformed randomized response R by themselves and provide them to an interviewer.

The simulation study was designed to study the coverage of two-sided intervals of the mean for different populations (symmetric, skewed from the let, uniform), using reliability, population and sample size resembling the setting in real-life applications. For symmetric distributions, approximate confidence intervals using proposed variance estimators work well even for small sample and population sizes.

However, performance of variance estimators and confidence intervals seems to get worse if distribution is skewed. For the distribution skewed to the left, the coverage of confidence intervals seems to be smaller than the chosen reliability. The relationship between shape of the distribution and the coverage of approximate confidence intervals is the topic for further research.

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ANNEX

Table A1 The coverage of two-sided 90% confidence interval for mean

N	n	$\overline{t}^{HT,R}_{(0,M)}$			$\overline{t}^{HT,R}_{\alpha,(0,M)}$		
		Y ~ Exp	*Y ~ Norm*	*Y ~ Unif*	*Y ~ Exp*	*Y ~ Norm*	*Y ~ Unif*
200	20	0.885	0.903	0.901	0.894	0.899	0.901
	50	0.877	0.900	0.901	0.886	0.900	0.901
400	20	0.889	0.903	0.894	0.895	0.890	0.900
	50	0.878	0.900	0.901	0.886	0.899	0.901
1 000	20	0.893	0.902	0.886	0.895	0.897	0.900
	50	0.880	0.901	0.900	0.887	0.899	0.901
	100	0.869	0.900	0.900	0.875	0.899	0.900

Source: Own construction

Table A2 The coverage of two-sided 95% confidence interval for mean

N	n	$\overline{t}^{HT,R}_{(0,M)}$			$\overline{t}^{HT,R}_{\alpha,(0,M)}$		
		Y ~ Exp	*Y ~ Norm*	*Y ~ Unif*	*Y ~ Exp*	*Y ~ Norm*	*Y ~ Unif*
200	20	0.929	0.933	0.950	0.948	0.948	0.952
	50	0.929	0.948	0.950	0.941	0.949	0.951
400	20	0.925	0.931	0.955	0.948	0.947	0.951
	50	0.930	0.948	0.950	0.941	0.949	0.951
1 000	20	0.918	0.928	0.958	0.942	0.947	0.951
	50	0.932	0.950	0.949	0.942	0.949	0.951
	100	0.926	0.949	0.950	0.932	0.949	0.950

Source: Own construction

Table A3 The coverage of two-sided 99% confidence interval for mean

N	n	$\overline{t}^{HT,R}_{(0,M)}$			$\overline{t}^{HT,R}_{\alpha,(0,M)}$		
		Y ~ Exp	*Y ~ Norm*	*Y ~ Unif*	*Y ~ Exp*	*Y ~ Norm*	*Y ~ Unif*
200	20	0.974	0.981	0.988	0.990	0.988	0.992
	50	0.978	0.987	0.990	0.987	0.989	0.991
400	20	0.974	0.981	0.988	0.990	0.988	0.991
	50	0.979	0.987	0.989	0.988	0.989	0.990
1 000	20	0.974	0.980	0.988	0.990	0.987	0.991
	50	0.979	0.989	0.989	0.987	0.989	0.990
	100	0.978	0.990	0.990	0.984	0.989	0.990

Source: Own construction

The Usage of State Space Models in Mortality Modeling and Predictions

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Abstract

In demography, mortality modeling with respect to age and time dimensions is often associated with the traditionally used Lee-Carter model. The Lee-Carter model considers a constant set of parameters of age-specific mortality change for forecasts, which can lead to the problem of overcoming the biodemographic limit. The main motivation of this paper is the use of more flexible models for mortality modeling. The paper explores the use of state space models for modeling and predicting mortality in a form not typically used in demography. In this context, it is a generalized Poisson state space model with overdispersion parameters. Concerning the empirical results, a comparison is made between the predictive abilities of the Lee-Carter and the generalized Poisson state space model with overdispersion parameters. The state space Poisson model with overdispersion parameters led to better results with respect to the comparison of modeled and historical observations. However, when comparing the predictions in the cross-validation area, both models were represented with similar overall mean squared error.

Keywords	***DOI***	***JEL code***
Generalized state space models, extended Kalman filter, exponential smoothing, Lee-Carter model, mortality, prediction comparison	*https://doi.org/10.54694/stat.2022.33*	*C32, J11*

INTRODUCTION

The popularity of state space models started to rise in the late 1990s, particularly in the field of systems theory, with their utilization in the Apollo space program as a major highlight (Hutchinson, 1984). Subsequently, these models began to be used in other areas besides economic theory. State space models are based on the assumption that a time series is an output of a dynamic system that is affected by random components. State space models represent a general framework that covers a significant range of statistical models. Among the most well-known applications, one can include modeling of seasonality with a variable

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character or yield curves fitting and predicting. Yield curves are traditionally modeled with respect to the time to maturity, but state space models also allow extending this common approach to a time dimension, making it possible to predict yield curves over time into the future. Another important application is dynamic (generalized) linear models, thus generalized linear models with time-dependent parameters of the explanatory variables. State space models allow the modeling of both univariate and multivariate stationary or non-stationary time series that may contain structural changes, other irregularities, or missing observations. Finally, very popular ARIMA models (Box et al., 2008) can be also represented by state space models.

Mortality modeling plays a crucial role in solving macro and microeconomic optimization problems. From a macroeconomic perspective, it is possible to mention a need to find reliable estimates of future mortality characteristics, which significantly determine the amount of old-age pensions paid with respect to the prediction of the future demographic population structure. From a microeconomic point of view, mortality modeling is mainly dealt with by insurance companies when designing life insurance products for their portfolio.

Nowadays, one can find a large number of models that aim to find the most accurate predictions of future mortality. In this paper, the focus is held on models that describe mortality both in terms of the age structure of the population as well as in terms of the time dimension. One of the most commonly used models is the Lee-Carter model, which is characterized by a good model fit to historical data, unambiguous interpretation of its parameters from a demographic perspective (average age-specific mortality level, age-specific change in mortality interacting with a general mortality trend), and simple computational complexity when obtaining the model parameters estimates. The disadvantages of the Lee-Carter model can be found mainly in situations of very long mortality forecasts, for example for the next 50 years, where future age-specific mortality rates fall at a pace estimated from historical observations, often below the values of the biodemographic limit. According to Carnes et al. (2003), the biodemographic limit in this context is understood as a natural mortality limit, often characterized by a life expectancy that should be biologically impossible to overcome. This problem was noticed by Li, Lee, and Gerland (2013), who proposed an extension of the Lee-Carter model by rotating the age-specific set of parameters of the original Lee-Carter model.

State space models are standardly used to extend the Lee-Carter model to model general mortality trends, see Andreozzi et al. (2011) or Harvey (1990), or to incorporate the Lee-Carter model in a state space representation, see Husin et al. (2015) and Pedroza (2006). However, the application of state space models to model the overall structure of population mortality with respect to age and time dimensions has not been significantly explored so far. The main idea and the motivation of this paper resulted from the specification of the traditional Lee-Carter model, see Lee and Carter (1992). This model provides very accurate estimates of historical, already observed, mortality, however, the age-specific component of the model is considered constant over time, and, therefore, the model is not always able to capture the changing trend in age-specific mortality. For this reason, this paper aims to assess the suitability of using state space models for demographic mortality analyses compared to traditional methods of predicting mortality rates using appropriate diagnostic criteria.

1 RELATED LITERATURE

The theoretical foundations of the state space models in the traditional classical sense were originally addressed by Harvey (1990) and especially Kalman (1960). Kalman was the first who analyzed time series using state space model methodology. In terms of the literature, one can mention in particular the foundational publication by Durbin and Koopman (2012). Hyndman et al. (2008) explored the use of state space models for exponential smoothing and modeling of seasonality with a changing pattern. Petris et al. (2009) explored the Bayesian approach to estimate the parameters of state space models. The prediction of state space models from the Bayesian perspective was also addressed by Harrison and Stevens (1976).

A basic description of state space models as well as an overview of the specific applications can be found in Slavík (2005). The use of state space models in demography was addressed also by Matějka (2017).

There is currently no universal notation of state space models. However, there are two major commonly used notations across statistical and econometric applications. The first, also used in this paper, originally based on the approach to state space models as defined by Harvey (1990), was later used as the most commonly used notation in econometrics by Durbin and Koopman (2012). The second notation is based on the original study of state space models by Harrison and Stevens (1976) and, due to additional use by West and Harrison (2006), is often used primarily in systems analysis and control processes. However, this notation can be encountered in the literature primarily concerning Bayesian approaches to state space models.

The Lee-Carter model, introduced by Lee and Carter in 1992, has become one of the most widely used models in demographic analyses of mortality prediction, affecting both age and time dimensions. Its widespread use implied the need to refine the original model to consider specific case studies. In this context, the extension of the original Lee-Carter model with an additional set of parameters covering not explained age-specific mortality of the original Lee-Carter model (log-linear model, see D'Amato et al. 2011), or the incorporation of cohort dependence of mortality (Age-Period-Cohort, Lee-Carter, see Renshaw and Haberman, 2006) can be mentioned. Another extension of the Lee-Carter model was done by Li, Lee, and Gerland (2013) who introduced time-rotating parameters for age-specific mortality changes.

In demography, state space models are mainly used in the context of population predictions, see Tavecchia et al. (2009). The statistical representation of mortality patterns using a state space model with a Markov process to define state variables was investigated by Fung et al. (2017). Several studies have examined the benefits of combining the state space model approach and the Lee-Carter representation. For example, an extension of the Lee-Carter model in terms of simultaneous estimation and prediction of a time-dependent set of parameters was considered by Reichmuth and Sarferaz (2008), who focused on predicting mortality in the US until 2050. Zakiyatussariroh et al. (2014) focused on comparing the estimates of the Lee-Carter model and the corresponding representation using state space models to model mortality in Malaysia. Husin et al. (2015) subsequently extended this study by comparing the predictions of the two mentioned models concerning short-term and long-term predictions (compared with the original Lee-Carter model). Several studies have also focused on linking the Lee-Carter model and a state space model, where the evolution of specific mortality rates is defined by an observation equation, see Lazar and Denuit (2009) and Pedroza (2006), who additionally used the Bayesian approach to improve prediction characteristics of the general mortality trend. The states equation in this case defines the evolution of the general mortality trend. Fung et al. (2015) considered extending the Lee-Carter model using a Bayesian state space model approach to improve annuity price estimates. State space models are not very frequently used in demography, however, one can mention a study of Abd Nasir et al. (2021) who investigated the prediction of the evolution of under-5 child mortality using a state space local linear trend model. The same model was used by Khedhiri (2021) to predict the evolution of Covid-19 infectivity in the Arab States. Andersson and Lindholm (2021) extended the use of the random walk approach with the Lexis diagram to model and predict mortality using state space models.

The estimation of state space model parameters is a very computationally demanding task from a practical point of view, therefore it is possible to find several libraries implemented in the statistical programming environment R (Team R, 2021) that address this issue, see Petris and Petrone (2011) or Tussel (2011). These are, for example, KFAS (Helske, 2017), dlm (Petris, 2010), dse (Gilbert, 2009), sspir (Dethlefsen et al., 2009). The statistical computing interface EViews (Van Den Bossche, 2011) or the SsfPack libraries in the Oxmetrics computing environment (Mendelssohn, 2011) can also be used to solve state space models.

2 DATASET AND STATISTICAL METHOD

The empirical study in this paper was carried out using the publicly available data from HMD (Human Mortality Database),[3] where the number of deaths (referring to the third main sets of Lexis diagram) and the exposure of risks of the population for males in the Czech Republic are available. The considered models are constructed for the historical years in the training area from 1950 to 2012, while validation data for the period 2013 to 2019 are used to verify the ability of each model to predict accurately future mortality rates. In terms of the age dimension, five-year age categories from 0, 1–4 to 95+ years (21 categories) are considered. Thus, the training dataset has a dimension of (21×63) and the validation dataset has a dimension of (21×7).

The data is applied to the Lee-Carter model and the multivariate Poisson state space model, which will be outlined in the following chapters by moving from the Gaussian state space model to the generalized state space model.

2.1 Gaussian state space model

Linear Gaussian state space models consist of two sets of equations, these are the observation equation and the state equation. The notation of state space models, including state matrices and vectors, is consistent with the definition of state space models used by Durbin and Koopman (2012) and Helske (2017). The first set of p equations explains the behavior of the observed data using observable or unobservable (latent or state) variables and thus can be written as:

$$y_t = Z_t \alpha_t + \varepsilon_t \,, \tag{1}$$

where $t = 1, 2, ..., n$ is the time index, y_t is a vector of a multivariate observation time series (*observation vector*) of a dimension $(p \times 1)$, $\varepsilon_t \sim N_p(0, H_t)$ is a p-dimensional vector of random terms. The vector of observed or unobserved latent variables (*state vector*) α_t of a dimension $(m \times 1)$ explains y_t by a state matrix Z_t of a dimension $(p \times m)$.

The second set of m equations describes the evolution of latent variables over time, again influenced by random terms:

$$\alpha_{t+1} = T_t \alpha_t + R_t \eta_t \,, \tag{2}$$

where $\eta_t \sim N_k(0, Q_t)$ is a k-dimensional vector of random terms affecting the latent variables α_{t+1}. System matrices T_t of a dimension $(m \times m)$ and R_t of a dimension $(m \times r)$ define the relationships within the state and observation equations. Covariance matrices H_t and Q_t determine the covariance structure of the random terms for each equation, see Durbin and Koopman (2012). The covariance matrices H_t and Q_t can be in some cases presumed time-invariant, and thus one can preferably consider only a matrix H of a dimension $(p \times p)$ and a matrix Q of a dimension $(r \times r)$. The random terms ε_t and η_t are assumed to be uncorrelated with each other for the entire time axis t. They are further assumed to be uncorrelated with the initial state vector α_1.

2.2 Kalman filter and smoother

The main procedures used to estimate the parameters of classical state space models are the Kalman filter and the Kalman smoother, see Durbin and Koopman (2012) and Tusell (2011). The Kalman filter refers to a recursive procedure leading to filtered estimates of unknown state variables α_t for observations of (multivariate) time series y_t, for $t = 1, 2, ..., n$. Kalman filter is a procedure that uses filtering as a process where one-step ahead estimates of state variables are made more precise as new time series observations y_t are taken into consideration.

[3] <*www.mortality.org*>.

Kalman smoother is a backward recursive algorithm for $t = n, n - 1, ..., 1$ that uses the estimated state variables of the Kalman filter to obtain smoothed estimates of the state variables based on all observations, see Koopman and Durbin (2001).

As already mentioned, the Kalman filter and the smoother are recursive procedures. In general, a distinction can be made between recursive and non-recursive approaches. In the case of non-recursive filters, the basic idea is to gradually incorporate information from the observed (multivariate) time series to obtain filtered estimates. However, none of the sequentially obtained filtered estimates are taken into account in the calculation of subsequent estimates. In contrast to this approach, recursive filtering methods aim at obtaining filtered estimates of the model parameters at time n, whereby the estimate is constructed based on the already obtained filtered estimates corresponding to time $n - 1$. Both approaches can be iterative, where the filtered estimate at time n is used multiple times (with respect to the same observations) in order to obtain more accurate filtered estimates.

Koopman and Durbin (2001) outline a detailed derivation of the extended Kalman filter and exponential smoothing.

2.3 Multivariate State Space Poisson model with overdispersion parameters

Gaussian state space models can be extended to consider probability distributions of an exponential family of distributions, thus relaxing the assumption of a normal distribution or the linear dependence in Formulas (1) and (2). The observation equation is then expressed in terms of the probability density of the random variables of the observed time series:

$$p(y_t|\theta_t) = p(y_t|Z_t\,\alpha_t)\,, \tag{3}$$

and the state vector is defined as:

$$\alpha_{t+1} = T_t\,\alpha_t + R_t\,\eta_t\,, \tag{4}$$

where $p(y_t|\theta_t)$ is the probability density of the random variables of the observed time series and $\theta_t = Z_t\,\alpha_t$ is referred to as the signal. Thus, the signal is a linear predictor that explains the expected value $E(y_t) = Z_t\,\alpha_t$ of the random variable y_t using a link function $g(u_t) = \theta_t$. The probability density $p(y_t|\theta_t)$ may follow a non-normal distribution or be non-linear, respectively both situations may occur. If the density $p(y_t|\theta_t)$ follows the assumption of a normal distribution and the signal θ_t is a linear function of y_t, then the model represented by Formulas (3) and (4) transfers to the Gaussian state space model defined by Formulas (1) and (2).

For the use of Formulas (3) and (4), it is possible to use the standard procedures that are well known in the field of generalized linear models. For the purpose of this paper, we mention the Poisson distribution with the expected value λ_t, exposure u_t and the logarithmic link function $\theta_t = \log(\lambda_t)$, thus $E(y_t|\theta_t) = D(y_t|\theta_t) = u_t\,e^{\theta t}$.

The core model of the presented paper is a multivariate Poisson linear state space model with overdispersion character (hereafter referred to as the PSSO model). Its theoretical background is the exponential state space model defined by the Formulas (3) and (4), and therefore the PSSO model is defined as follows:

$$\begin{aligned}
&p(y_t|\theta_t) = \mathrm{Po}_{20}(u_t\,e^{\theta_t}),\\
&\theta_t = u_t + \varepsilon_t,\ \varepsilon_t \sim N_{20}(0, Q_\varepsilon),\\
&\mu_{t+1} = \mu_t + \nu_t + \xi_t,\ \xi_t \sim N_{20}(0, Q_\xi),\\
&\nu_{t+1} = \nu_t\,,
\end{aligned} \tag{5}$$

where μ_t is a random walk process, ν_t is a constant slope, and ξ_t is the component capturing the additional variance in the time series (overdispersion). No constraints are being considered with respect to the covariance matrices Q_ε and Q_ξ, thus general matrices are assumed. Dimension of vectors $y_t, \theta_t, \mu_t, \nu_t, \varepsilon_t$ a η_t is (21×1). Dimension of matrices Q_ε and Q_ξ is (21×21) for $t = 1, 2, ..., 63$.

The construction of the model (5) was performed using the KFAS library (Helske, 2017) in the statistical software R (Team R, 2021), using standard functions for the state space model specification.

2.4 Extended Kalman filter and exponential smoothing

In the case of generalized state space models, it is necessary to use the extended Kalman filter that first linearizes the generalized state space model using the Laplace approximation and then applies the standard Kalman filter and smoother. The estimation of the unknown parameters of the model (state variables, covariance matrices, or only their parts) is performed in the traditional way using the maximum likelihood method with respect to the considered probability distribution of the exponential family. Numerical optimization is then performed by the BFGS method, where this abbreviation is derived from the initial letters of the names of the independently published authors Broyden (1970), Fletcher (1970), Goldfarb (1970), and Shanno (1970), or possibly by the Nelder-Mead method, according to Nelder and Mead (1965).

A detailed derivation of the extended Kalman filter and exponential smoothing can be found in Koopman and Durbin (2001).

2.5 Standard Lee-Carter model

A very useful, long-standing, and still popular approach for modeling and predicting mortality rates is the Lee-Carter log-bilinear model (hereafter referred to as the LC model). The method proposed by Lee and Carter (1992) has become a fundamental statistical method used in demographic analyses. The LC model aims to model and predict age- and time-specific mortality rates $m_{x,t}$, which are defined by the model as:

$$\log(m_{x,t}) = \alpha_x + \beta_x \kappa_t + \varepsilon_{x,t}, \tag{6}$$

where t represents a time, x is an age (respectively an age category) for $t = 1, 2, ..., n$ and $x = 1, 2, ..., r$. A matrix $m_{x,t} = D_{x,t} / E_{x,t}$ of a dimension $(r \times n)$ represents age- and time-specific mortality rates. According to Šimpach and Arltová (2016), it is presumed that random terms $\varepsilon_{x,t}$ follow a normal distribution with zero mean, constant variance, and meet the assumptions of the white noise process. The number of deaths at age x at time t is denoted as $D_{x,t}$ and the mean population at age x and time t is denoted as $E_{x,t}$.

The first set of parameters of the model (6) contains r parameters α_x and it defines an age-specific general mortality profile, hence it is a vector of a dimension $(r \times 1)$. The second set again contains r parameters β_x and represents the deviations of the mortality rate from α_x as a result of an interaction with the general mortality trend, which is determined by the third set of parameters κ_t. Thus, the third set contains t parameters, respectively it is a vector of a dimension $(1 \times t)$.

The estimation of the unknown parameter sets of the Lee-Carter model by the maximum likelihood method is based on the assumption that the number of deaths $D_{x,t}$ at age x and at time t is a random variable that follows a Poisson distribution, see Brillinger (1986) or Wilmoth (1993). The expected value of the random variable $D_{x,t}$ as well as the constrains applied due to model (6) parameters unambiguity can be found in the respective literature, see Lee and Carter (1992), Wilmoth (1993), Girosi and King (2007) or Richards and Currie (2009). Other estimation methods, such as singular value decomposition or weighted least squares, can be also alternatively used, see Andreozzi et al. (2011) or Koissi and Shapiro (2008).

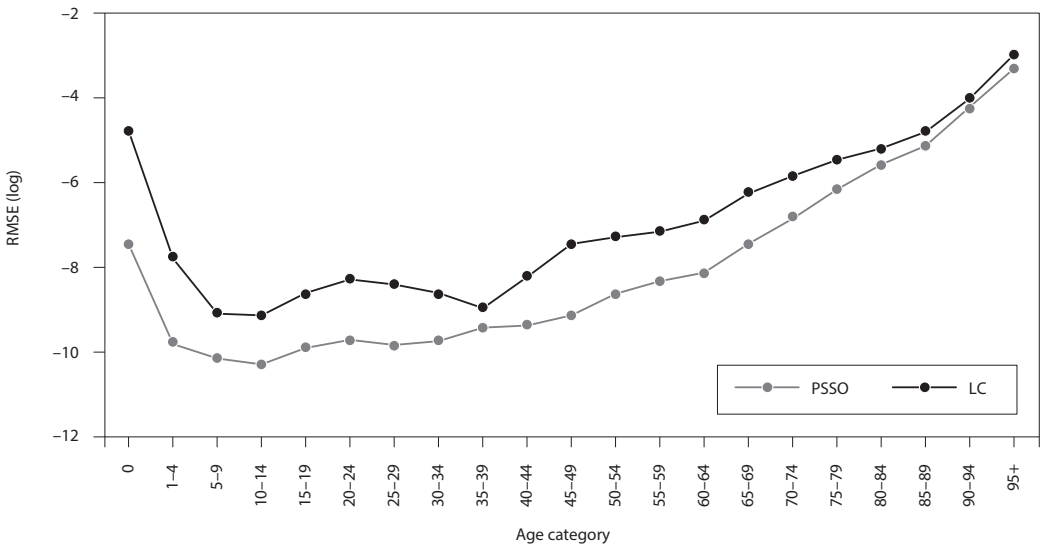
[2] <*www.mortality.org*>.

3 EMPIRICAL FINDINGS

The main purpose of mortality models is their ability to accurately predict future population mortality. This ability may be affected by the presence of a systematic nature of mortality, which can be revealed during a residual diagnosis, but also when comparing modeled and historical observations.

Figure 1 shows the Root-Mean-Square error (RMSE) of the Lee-Carter (LC) and Poisson state space model with overdispersion parameters (PSSO) fitted values compared to the historical data. From the values shown, it is apparent that the PSSO model achieves a more accurate fit of the model mortality rates to historical observations when compared to the LC model for all age categories.

Figure 1 Age pattern of the RMSE in the logarithmic scale of the PSSO and LC models of historical training data 1950–2012



Source: Own construction

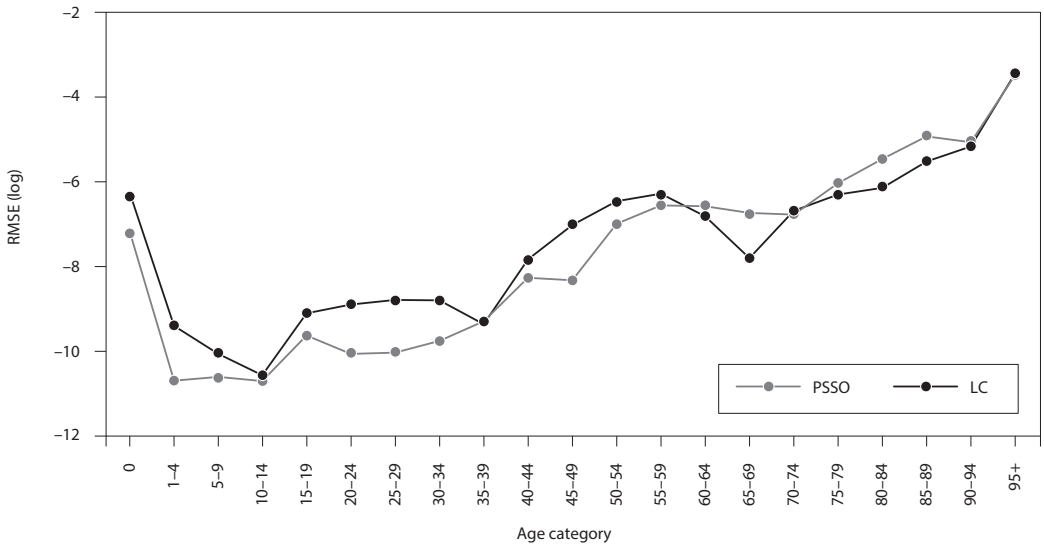
The age pattern of RMSE on a logarithmic scale is illustrated in Figure 1. The first age category of 0 years old is characterized by a higher RMSE value for both models. These deviations subsequently decrease until the age category 10–14 years. For the LC model (darker line), a saddle of RMSE values can be observed which ends with the age category 35–39 years. RMSE values subsequently increase with increasing age categories. According to the age pattern of the RMSE of the PSSO model (lighter line), it can be seen that this model provides lower RMSE values for all age categories and is, therefore, able to provide more accurate modeled values for specific mortality rates when compared to the LC model. The total RMSE of the LC model is 0.10147, respectively 0.06466 in the case of the PSSO model.

As already mentioned, the main motivation for constructing mortality models is to obtain the most accurate mortality predictions. For this purpose, the PSSO and LC models were estimated over the 1950–2012 historical training period and the validation period 2013–2019 was used to compare the predictions of these models with known observations.

Figure 2 shows the age pattern of the RMSE values of the PSSO (lighter line) and the LC model (darker line) on a logarithmic scale for the validation area.

The total RMSE of the LC model is 0.055. In the case of the PSSO model, the average RMSE is 0.057. Figure 2 shows that the evolution of RMSE can be divided into three areas for each age category.

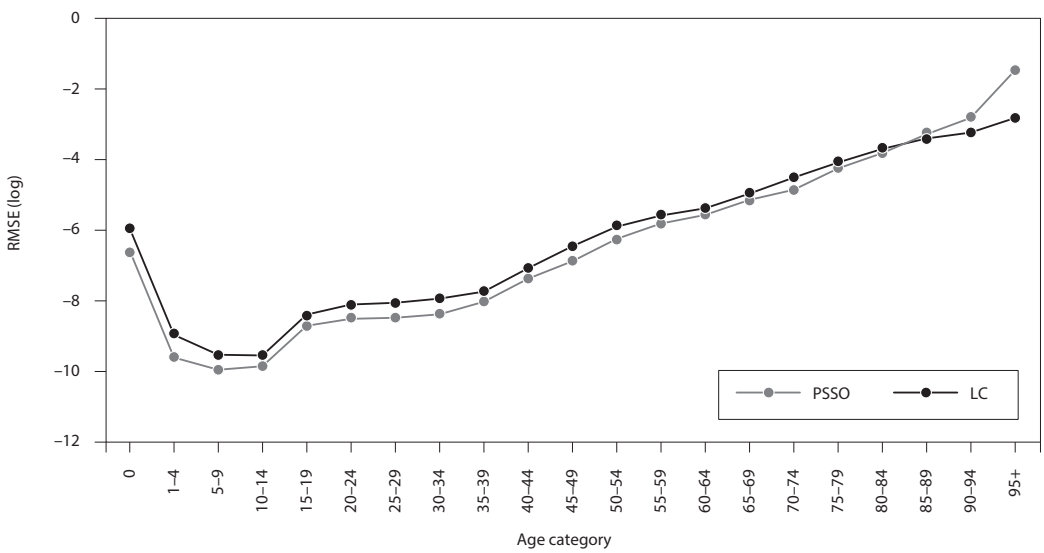
Figure 2 Age pattern of RMSE in logarithmic scale of PSSO and LC models for validation area 2013–2019



Source: Own construction

For the first area, age categories 0 to 55–59, the PSSO model provides a lower RMSE (except for age category 35–39). In the second area from age categories 60–64 to 90–94, the RMSEs are lower for the LC model (except for age categories 65–59 and 70–74). For the last area, the highest ages of 95+ years, the RMSE values are similar but lower for the PSSO model, such conclusion is valid also for the age category

Figure 3 Age pattern of RMSE in logarithmic scale of PSSO and LC models confidence prediction intervals for validation area 2013–2019



Source: Own construction

90–94 with the opposite effect. It can be concluded, that both models are characteristic with a similar total RMSE, however, the PSSO model provides a better fit of predicted values to known observations in two-thirds cases (14 out of 21 time series). Specifically, these time series are 0, 1–4, 5–9, 10–14, 15–19, 20–24, 25–29, 30–34, 40–44, 45–49, 50–54, 55–59, 70–74, and 95+ years, see Figure 2.

Figure 3 shows the age pattern of the RMSE values of the PSSO (lighter line) and the LC model (darker line) on a logarithmic scale for the validation area when comparing the respective confidence intervals of the predictions and the observed mortality rates in the validation period.

The total RMSE of the LC model confidence prediction intervals to the validated mortality rates is 0.206. In the case of the PSSO model, the average RMSE is 0.387. Despite the fact that the total RMSE is lower for LC model, the age pattern of RMSE in Figure 2 shows that the RMSE of mortality rates and confidence prediction intervals of both models is smaller for PSSO model for all age categories expect for the older ages (85–89, 90–94 and 95+) where the accuracy of both models is limited due to less data availability from a demographic perspective.

CONCLUSION

The aim of the paper was to find a more flexible model that would take into account age-specific changes in mortality over time. The Lee-Carter model was chosen as a benchmark to such a model. The Lee-Carter model considers the invariant nature of age-specific mortality change due to the second set of parameters, which interact with the general mortality trend to determine the future predictions of mortality.

In the empirical part of this paper, the generalized state space and Lee-Carter models are applied to Czech mortality data from 1950 to 2012 (training part of the data). Information for the period from 2013 to 2019 (validation part of the data) is then used to assess the predictive ability of both models. The generalized state space model, as specified in this paper, is not standardly used in the field of demographic analysis, and thus the introduction of this model alone reveals a wide range of potential applications of state space models for mortality or other demographic characteristics modeling.

Summing up the results, it can be concluded that this study has shown that both PSSO and LC models show a similar RMSE pattern with respect to the model fit to data. Although the age pattern of RMSE is similar, the PSSO model provides lower RMSE and, therefore, more accurate model values of specific mortality rates for all age categories in the training data area.

When comparing the deviations of the predicted values from the known observations, it can be concluded that the total RMSE deviation is similar for both PSSO and LC models. In terms of the age patterns of RMSE for each age category, three areas can be observed, corresponding to lower RMSE values for the PSSO model, lower RMSE values for the LC model, and, finally, the last area of similar RMSE values for both models. When assessing the RMSE values for all age categories, it can be observed that the PSSO model shows a better fit between predictions and observations in the training area in two-thirds of the cases when compared to the LC model.

Both models were also compared from their prediction intervals accuracy perspective. The respective age specific RMSE revealed that the usage of PSSO model resulted in lower RMSE for all age categories except the oldest three categories (85–89, 90–94 and 95+) which can be summarized as lower RMSE in 85 % of cases for the PSSO model.

The computational complexity of estimating the PSSO model is significantly higher when compared to the time required to obtain the LC model estimates. The computational complexity was reduced by estimating the model first without simulations. These parameter estimates were used as initial values for the Importance sampling method with the BFGS optimization procedure, which provided model estimates in less time when compared to the Nelder-Mead method. The resulting estimates obtained from these two methods hardly differed. However, the computation of the estimation of the state variables of the PSSO model using the above approach takes still several hours, whereas the estimation

of the parameters of the LC model takes only a few seconds. Contrary to LC model parameters where their interpretation is meaningful from a demographic perspective, the interpretation of PSSO state parameters is rather cryptic and hence difficult to interpret.

The use of the PSSO model, in this specific use case, resulted in similar overall RMSE values in comparison to LC model. Despite the fact that age patterns of RMSE were more precise for two-thirds of age categories (respectively in 85% cases when focused on confidence intervals), it cannot be concluded that PSSO model would be recommended for mortality predictions. It worth to be mentioned that the conclusion above was done by using both models on Czech male mortality data, hence further evaluation of more data sets is recommended in order to obtain more conclusive results.

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Conferences

The ***25th Applications of Mathematics and Statistics in Economics Conference (AMSE 2023)*** will take place **from 30th August to 3rd September 2023 in Rájecké Teplice** (hotel Diplomat), **Slovakia**. This year organized by the Faculty of Economics, Matej Bel University in Banská Bystrica. More at: <*https://www.amse-conference.eu*>.

The ***31st Interdisciplinary Information Management Talks Conference (IDIMT 2023)*** on "New Challenges for ICT and Management" will be held **during 6–8 September 2023 in Hradec Králové, Czechia**. More at: <*https://idimt.org*>.

The ***17th International Days of Statistics and Economics Conference (MSED 2023)*** will take place **during 7–9 September 2023 at the Prague University of Economics and Business, Czechia**. The aim of the conference is to present and discuss current problems of Statistics, Demography, Economics and Management. More at: <*http://msed.vse.cz*>.

The ***41st International Conference on Mathematical Methods in Economics (MME 2023)*** will be held **from 13th to 15th September 2023 in Prague, Czechia**. More at <*https://mme2023.vse.cz*>.

European Statistical System Peer Reviews

Eurostat and the national statistical authorities of all the EU and EFTA countries form a partnership called the European Statistical System (ESS). Together, they produce European statistics which respect a common quality framework. One instrument that ensures the implementation of the common quality framework and thus the quality of European statistics is the so-called ESS Peer Reviews.

Code of Practice

The common quality framework of the ESS is based on the *European Statistics Code of Practice*, a set of 16 principles covering the institutional environment, statistical processes, and statistical outputs.

The principles are complemented with a set of 84 indicators of best practices and standards to provide guidance and reference for reviewing the implementation of the Code (or CoP).

ESS Peer Reviews

Quality is the trademark of European statistics and makes them more trustworthy than other data that are readily available through many channels. To guarantee the quality of their statistics, the ESS created a common quality framework. The European Statistics Code of Practice is the cornerstone of this quality framework.

The objective of the peer reviews is to assess ESS members' the compliance with the principles and indicators of the Code. The subsequent recommendations should also help statistical authorities to further improve and develop their statistical systems.

All members of the ESS are reviewed, i.e. Eurostat and the national statistical authorities of the EU Member States and EFTA countries. Peer review expert teams are composed of four European experts in statistics, auditing and governance issues,

including an independent expert, to assess the national statistical authorities. An expert team from the European Statistical Governance Advisory Board (ESGAB) reviews Eurostat.

The peer reviews are carried out on a country-by-country basis according to these steps:

1. Each ESS national statistical authority assesses itself against the principles of the Code through a questionnaire and provides extensive documentation on its functioning;
2. These documents are checked and analysed by an expert team which subsequently carries out an in-country visit during which a further in-depth review is performed;
3. The expert team compiles a final report with recommendations for improvements;
4. This report is submitted to the national statistical authority for approval and the drafting of improvement actions.

The implementation of the improvement actions in the EU and EFTA countries is monitored on an annual basis by Eurostat. The implementation of the improvement actions for Eurostat is monitored by ESGAB.

Peer Review 2021–2023

Two previous rounds of Peer Reviews (2006–2008 and 2013–2015) were focused mainly on compliance with the European Statistics Code of Practice. Peer Review 2021–2023 (round III) will go further and help ESS partners to improve by making future-oriented recommendations that go beyond the current Code. In addition, future-oriented elements could help revise the Code to reflect new developments that experts will identify in this round.

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We publish articles focused at theoretical and applied statistics, mathematical and statistical methods, conception of official (state) statistics, statistical education, applied economics and econometrics, economic, social and environmental analyses, economic indicators, social and environmental issues in terms of statistics or economics, and regional development issues.

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