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CONTENTS

ANALYSES

INFORMATION

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The Impact of Consumption Smoothing on the Development of the Czech Economy in the Most Recent 30 Years

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Abstract

The household final consumption expenditure is an important factor in economic development and, at the same time, a reflection of households' economic behaviour. When economic recession occurs, households respond in their consumption not immediately, but with a certain delay, which somewhat slows down and alleviates the crisis. On the other hand, when recovery comes, a slower growth in consumption delays the economic boom. The Czech economy has undergone four crises in the most recent 30 years. The goal of the present paper is to establish whether the delayed consumption effect has been valid for the turbulent development in the Czech economy and what is the role played by expenditure on assets with different durability. Our source is the publicly available data from the Czech Statistical Office.[4]

Keywords	***DOI***	***JEL code***
Household final consumption expenditure, GDP, consumption smoothing	*https://doi.org/10.54694/stat.2021.40*	*C22, E21*

INTRODUCTION

Evolution of the Czech economy has been rather dramatic since the early 1990s. First there were the problems of the beginning economic transformation (a significant drop in economic performance,

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in particular, in industrial and building operations, as well as a high growth in prices and the unemployment rate); then the economic recovery culminated in 1995 and 1996. Compared with other countries in Central and Eastern Europe, the Czech economy overcame with an admirable speed the obstacles on the way to a market economy. However, that speed concealed unsolved or unresolved problems concerning the processes of privatisation, restructuring the industrial and banking sector, etc. Together with additional factors, those problems contributed to the economic crisis of 1997 and 1998. In 2000, the economic development returned to growth. The beginning six years of the 21st century can be viewed as the most successful period of the Czech economy regarding its evolution.

The recovery phase (2001–2004) and the subsequent phase of peak economic growth (2005–2006) were not quite the same. The period 2001–2004 was characterised by stable economic growth (higher than the average of the EU countries) supported by high growth rates of industrial and construction production, growth of household and government consumption, gradual improvement of foreign trade relations, including exchange rates, strengthening of CZK, stabilisation of CZK, and, respectively, the growth of the economy in the 1990s. In terms of the negative aspects of the development, it is necessary to mention in particular the growing deficit of the state budget, doubling of the general government debt, growth of the general government deficit, deterioration of the balance of revenues, and the increase in foreign indebtedness in relation to GDP towards the end of this period.

In the period 2005–2006, the main factors of growth were changed – foreign trade became the engine of economic growth, CZK further strengthened, the level of general government debt was stabilised, the general government deficit decreased, and the unemployment rate went down. On the other hand, the imbalance in the current account of the balance of payments was deepening, the terms of trade were deteriorating, foreign indebtedness was increasing, consumption was rising and, consequently, household indebtedness was also rising. However, the favourable performance of the Czech economy was brought to an end by the onset of first the global financial crisis in 2008–2009 and the subsequent recession of 2012–2013.

2014 marked a return to recovery with low inflation, low unemployment rate and declining government debt. However, 2020 brought unpredictable problems with the Covid-19 disease pandemic, which undoubtedly led (not only in the Czech Republic but also in other countries) to a significant decline in GDP and an increase in government debt. Government restrictions to combat the pandemic (closure of shops, restaurants, hotels and other services), coupled with household concerns, caused a drastic reduction in household consumption.

In general, under favourable economic conditions (such as economic growth, decreasing unemployment rate, rising real wages, etc.) households spend more. Increased consumption and investments are covered by increasing income. In case of shortages, households incur debt – for consumption in the form of short-term loans, for investment (in housing and dwellings) in the form of long-term loans. However, at times of peak economic growth, household final consumption expenditure generally stabilises and grows at a lower rate than GDP. By doing so, households are actually 'cooling down' an overheated economy.

The unfavourable economic situation leads households to reduce consumption. However, this response comes not immediately, but with a certain time lag. In this context, the phenomenon of deferred consumption is discussed. On the other hand, households respond relatively quickly to the arrival of a recovery and their stable demand mitigates the rapid onset of the boom. Households thus smooth out the phases of the business cycle by their behaviour during the crisis and the boom.

The reasons for, evolution and effects of economic crises are not the same, and this is all the more true with respect to the crises that the Czech Republic has experienced over the most recent 30 years. How have the different causes and evolutions of crises affected the behaviour of Czech households?

What did the economic crisis triggered by the pandemic bring about in their behaviour? How do households cope with the feeling of insecurity in relation to consumption? Do they limit their spending overall or differentiate it according to the durability of consumption items?

Although it is certainly too early to analyse household consumption behaviour during the pandemic, we would like to answer these questions by analysing data for the Czech Republic for the period 1993 to 2020. The source is publicly available data from the Czech Statistical Office.

Section 1 presents the theoretical background and provides a brief overview of the views on a phenomenon called consumption smoothing. Section 2 describes the specifics of the economic development in the Czech Republic since 1990. Section 3 presents the linear dynamic model used and the data to which the model was applied. Section 4 presents the results of the analysis in terms of the response of households to the coming signals of the crisis and shows that whatever the economic cause of the crisis, household consumption behavior is comparable, but differentiated according to durability of goods.

1 THEORETICAL BACKGROUND

Households' behaviour regarding consumption is quantified by the household final consumption expenditure indicator. Household final consumption expenditure includes the value of purchased (new and used) goods and services of short-term and durable consumption, excluding dwellings, houses and land, and also includes a part of unpaid consumption (imputed rents, benefits in kind, agricultural and food products from subsistence farming, domestic services, etc.).

Households are represented by the institutional sector of the national accounts, which is broadly defined as the consumer sector. The main economic function of households is consumption and the main sources of funding for this activity come from labour income or social and property income. However, in addition to consumers, the household sector also includes entrepreneurs (small producers) whose main economic function is the production of non-financial market goods and services and whose resources are derived from the sale of the results of their own activities. Their economic behaviour is therefore different from that of consumers and analogous to that of non-financial enterprises.

Household consumption must be considered in the context of the size and structure of their disposable income and of their saving, since households are important contributors to national saving, which is (according to economic theory) the basis of economic growth and prosperity. Consumers enter the process of income distribution as the entity that pays less than it receives (households mainly have to pay taxes on production and imports, social contributions and receive wages, and social benefits and other income). In this way they generate, in the form of disposable income, sufficient resources to meet their current needs (in terms of final consumption expenditure) and at the same time generate savings (from which they fund their non-financial and financial investments). Households therefore represent a sector that should provide sufficient resources to generate national saving and, at the same time, the entity that should generate sufficient spare resources in the economy to alleviate the deficit to which the economy of the general government traditionally leads, thereby contributing to the reduction of the country's deficit vis-à-vis the rest of the world. Households as consumers thus play an indispensable role in the economy as the entity whose economic result is positive (expressed in the national accounts by the balance of their non-financial account). This means that consumers traditionally act as creditors.

Households as entrepreneurs have the characteristics of the economic behaviour of non-financial corporations (although of course there are differences here too, due precisely to the position of the small producer). For such producers, information on value added and its value structure, as well as on investment, are crucial data. The Czech Statistical Office (as well as other statistical offices) provides data not only for the household sector as a whole, but also for the consumer and entrepreneur[5] subsectors. However, it turns out that the household sector account is primarily a consumer account, so if we assess the economic behaviour of consumers by analysing the data in the household sector account from the level of disposable income generation, we will not commit serious errors of interpretation.

In years of economic prosperity, household final consumption expenditure and investment generally rise, supported by the supply of consumer and mortgage credit. As a result, the savings rate and the financial savings rate fall. Households finance part of their consumption and investment with loans, which leads to an increase in household indebtedness in the form of loans and, together with a falling saving rate and financial savings rate, may, despite a favourable economic climate, lead to households becoming over-indebted and unable to meet their obligations.

Years of recession or even crisis mean a reversal in household behaviour, manifesting itself in a restrained approach to consumption, and a reduced willingness to invest as well as in long-term credit. In years of crisis, households usually reduce their financial investments or try to save their spare funds in less risky assets.[6] However, these changes do not come immediately, but always with a certain delay.

Household consumption is also seen as playing a corrective role in the economy.[7] In times of recession, it is the 'delayed' response of households (when their traditional consumption behaviour persists for a short period of time) that slows down and initially even moderates the onset of the recession. And on the other hand, as the economic recovery begins, it is the slower growth of consumption that helps the recovery but delays the rapid onset of the boom. Economists often speak of a phenomenon known as consumption smoothing.

Consumption smoothing is thus an economic feature that reflects a stable approach to consumption from the household perspective. Households therefore shift their consumption from times of higher income to those with a risk of lower income (that is in times of recession) in order to achieve greater economic stability and predictability. In contrast, in times of uncertainty and adverse economic outcomes, households reduce (or partially postpone) consumption to avoid future adversity and reduce their current uncertainty. This postponement then persists for some time after the beginning signs of economic recovery. In this way, households delay the onset of the recovery.

The issue of deferred consumption's impact was already addressed in the 1950s by, for example, Modigliani and Brumberg (1954). Friedman (1957) showed in his permanent income theory that if permanent income falls, consumption falls as well. Another model that put emphasis on consumption smoothing twenty years later was Hall's model, inspired by Friedman himself, see Hall (1978). To a certain extent, Hall's work opposed the idea, quite common up to that time, that households have only a marginal propensity to consume and therefore current consumption is closely linked to current income. On the contrary, he advanced the idea that, assuming useful and purposeful behaviour, households optimally try to keep consumption stable in the long run, thereby effectively 'smoothing' it.

The issue of household behaviour in different phases of the economic cycle, in particular their response to the arrival and evolution of the crisis, has been addressed by a number of authors in the context of the financial and fiscal crisis of 2008–2009 and the subsequent recession of 2011–2013. For example, Hamburg et al. (2008) addressed the question of the relationship between income, consumption

[5] In the Czech Republic, entrepreneurs account for about two-thirds of the gross value added of the household sector, but only a quarter of fixed capital investment, a tenth of household financial liabilities and only a twentieth of household financial assets – see Hronová et al. (2016).

[6] See Hronová and Hindls (2013).

[7] This is logical, as household final consumption expenditure accounts for more than one-half of gross domestic product in developed countries.

and wealth in Germany and showed that this relationship is dynamic and that it does not settle to a steady state after a certain period of time. Households will not increase their consumption expenditure unless they consider their economic situation to be good and stable. Rising income and rising market prices of their financial and non-financial assets, coupled with economic growth, increase their willingness to spend and invest. Household investment in real estate (or financial assets) is not included in the household final consumption expenditure indicator, but it is a strong signal of a satisfactory economic climate. Conversely, a fall in consumer confidence is one of the signals of a coming recession or crisis. Campelo et al. (2020) investigated this relationship using data from Brazil, showing that indicators of consumer confidence and economic climate are better able to predict trends and changes in household final consumption expenditure, and that improvements in consumer confidence positively affect households' attitudes towards consumption.

The occurrence of recession and crisis leads to an increase in the unemployment rate, and thus to a fall in household income and an increase in household insecurity. Hurd and Rohwedder (2016) showed, using the example of US households, that unemployment is reflected in a decline in household income and expenditure, but the decline in expenditure is significantly less pronounced than the decline in income; in other words, consumption declines more slowly than income. When entering the labour market, that is when income jumps, consumption expenditure rises. It however returns to its original level more slowly.

Jappelli and Pistaferri (2010) have critically reviewed various theoretical approaches to estimating the response of household consumption to changes in income and suggest that the underlying factor influencing household behaviour is the decline in income and the unavailability of credit. This is because households are unable to 'smooth' consumption due to credit constraints. Similar conclusions were reached by Aron et al. (2012), who looked at models of the impact of income growth or decline and credit availability as a kind of financial accelerator. However, using the US, UK and Japan as examples, they showed that the real interest rate had negative effects in the US and UK, but positive effects in Japan. Using Ireland as an example, Gerlach-Kirsten et al. (2013) showed that household consumption responds differently to different types of crises. When (economic and financial) crises are accompanied by problems in the housing market, the effects on consumption are much deeper and especially affect households burdened by mortgage loans.

A new element that has clearly affected the level of household consumption expenditure has been the Covid-19 pandemic, which has restricted not only households' purchases but also their movements, habits and preferences. It is too early to assess the impact of this pandemic on household spending, but some work has already looked at this phenomenon (a summary of existing studies on this topic can be found in Chrislelis et al., 2020) and shows that household consumption expenditure has fallen significantly in all European countries and in the USA. However, this has not only been due to insecurity and partial income constraints, but also to the inability to make certain expenditures in consequence of restaurant and hotel closures, transport and tourism constraints, etc.

There are therefore several reasons why households cut back on consumption in times of economic recession (and crisis). First of all, there are the constraints on resources (due to loss of employment, reduced income, and general uncertainty), and then there is the reduced access to additional resources, mainly credit. These constraints and insecurity are reflected in a cautious approach to the purchase of durable goods and investment (both non-financial and financial).

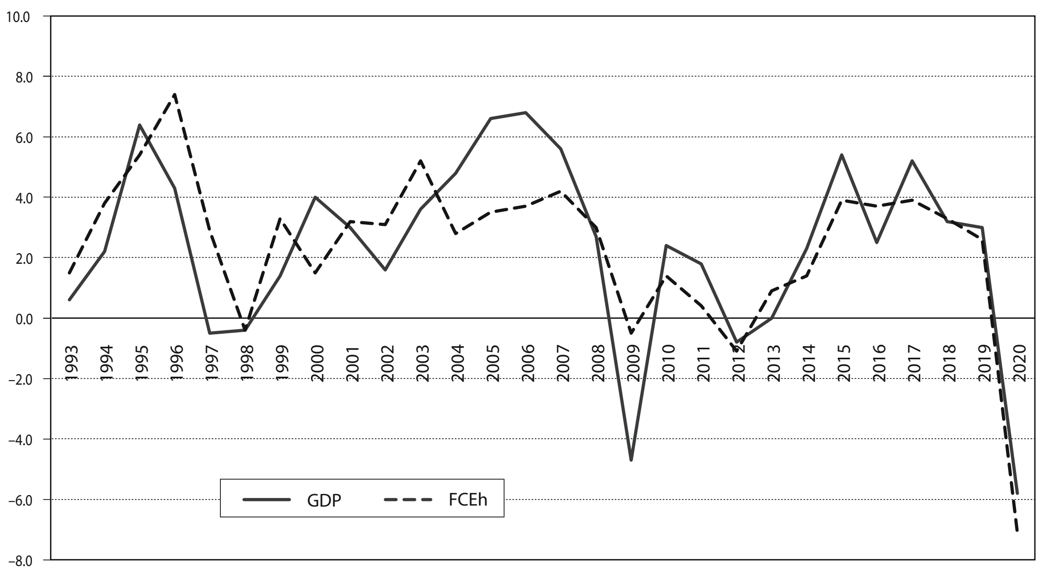
The above findings suggest that the corrective (smoothing) role of household final consumption expenditure is particularly pronounced in the case of expenditure on durable goods. On the other hand, significant changes depending on the phases of the economic cycle cannot be expected for non-durable goods. For expenditure on semi-durable goods, a time dependence closer to that of expenditure on essential (that is non-durable) goods can be expected. We would like, by analysing data for the Czech

Republic, to confirm this hypothesis, namely, that the household spending on durables plays a dominant role, while spending on non-durables is independent of the economic growth rate. At the same time, we would like to show that, regardless of the differences in economic reasons for the crises, the response of households manifested in final consumption expenditure is analogous.

2 SPECIFICS OF CRISES IN THE CZECH REPUBLIC

In the analysis presented here, we will examine the response of Czech households to the crises that have accompanied the Czech economy since 1993. As already mentioned in the Introduction, these crises included the post-transition crisis in 1997–1998, the financial and fiscal crisis in 2008–2009; and overly restrictive fiscal policy meant a renewed fall into recession in 2012–2013. These facts are documented in the chart of GDP development in the Czech Republic. The addition of a chart of annual growth rates of household final consumption expenditure shows that the response of households to changes in the economic situation has smoothed out the reversals in GDP development.

Figure 1 Year-to-year GDP growth rates (%, real terms) in the Czech Republic and final consumption expenditure of Czech households



Source: <*https://apl.czso.cz/pll/rocenka/rocenka.presmsocas*>

However, it is clear that households' responses in terms of changes in final consumption expenditure are not the same in all phases of a crisis; this observation undoubtedly stems from the different initial conditions, causes, evolution and depth of each crisis. As mentioned above, the Czech Republic has experienced four crises since 1990.

The first crisis was purely domestic and resulted from the rapid economic transformation and the desire to move from a centrally planned to a market economy as soon as possible. In this period of relatively free market conditions, in the absence of a number of legislative measures, the drafting and approval of which were delayed by the privatisation process, new economic entities were created that had no chance of winning recognition in international competition; former large state-owned enterprises were not restructured in time; and a number of monetary institutions were created without adequate capital backing. After the initial shock of price liberalisation,[8] with an acceptable unemployment rate,[9] and with real wages rising, households have, since 1993, been willingly increasing their final consumption expenditure. Although signs of an impending crisis were already coming in 1997 (reflected in a 0.5% fall in GDP), household final consumption continued to grow (by a 2.9% year-to-year increase). The fall in final consumption expenditure came as late as in 1998 (by 0.4%, with an equally significant decrease in GDP), but already in 1999 households helped to kick-start the economy, increasing their spending by 3.3%.

The period after 2000 was a period of prosperity in the Czech Republic, with economic growth peaking in 2006 (with a GDP growth by 6.8%). This growth was mainly driven by investments and foreign exchange. The Czech Republic's accession to the EU (in 2004) has had a significant impact on the economy, the domestic currency was strengthening, an acceptable inflation rate did not significantly worsen the position of households, even despite a higher unemployment rate.[10] The signals of the coming global financial and fiscal crisis hit the Czech economy with a delay (as late as in 2009, GDP dropped by 4.7%, with a high government deficit amounting to 5.4% of GDP and a jump in government debt by 6 percentage points). Households again cushioned this drop by a decrease in their final consumption expenditure by only 0.5%. However, with a pro-growth economic policy, the Czech economy would undoubtedly have recovered quickly from the crisis, even at the cost of not improving the government deficit. The reality was, however; different: the government's unwillingness to support economic growth and a harshly restrictive fiscal policy meant a new fall into recession in 2012 (with a 0.8% decrease in GDP) and stagnation in 2013. The pressure to restrain government spending (government debt reached 49% of GDP in 2012) and the climate of fear created around high government debt affected households' behaviour, and their final consumption expenditure fell more significantly than GDP in 2012 (namely, by 1.1%). As in 1997–1998, the cause of this recession was domestic; namely, it was inappropriate economic policy (too much optimism in the 1990s, too much pessimism after 2009).

After 2014, another period of prosperity came. Key sectors (industry, construction, services, and foreign trade) prospered, the growth was supported by business and government investments, the government already reported a positive balance in 2016, government debt relative to GDP was declining, real wages were rising, and inflation and unemployment rates remained below 3%. An unexpected external factor – the arrival of the Covid-19 pandemic – caused a sharp decline in economic activity in all spheres. Production cutbacks in a number of large industrial enterprises, closure of shops and services, restricted population movements and the resulting losses in transport and tourism, reduction of household consumption to only basic products, etc. The government mitigated the impact of the pandemic on enterprises and households through a system of subsidies and compensations. This approach prevented a spike in unemployment and business failures, but at the cost of a government deficit amounting to 6% of GDP (up from surplus 0.3% in 2019) and a rise in government debt to 38.1% of GDP (up from 30.3% in 2019); GDP fell by 5.8% year-to-year, and household final consumption expenditure by 7.1%. The causes of this crisis are neither domestic nor economic. The pandemic situation froze the global economy. Life and health insecurity, in addition to economic insecurity and the inability to 'spend', marked the consciousness of households. As a result, their final

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8 The average annual inflation rate in the Czech Republic in the first year of the economic transformation (1991) was 56.6%, in 1993 (as a result of the tax reform) it was 20.8%, and in the remaining years (1992, 1994 to 1998) it was around 10%. Compared to other former socialist countries, these figures can be considered a success (in 1991, the annual rate of inflation rate in Bulgaria was around 330%, in Romania around 160%, in Poland around 70% and in Hungary around 35%).

9 Between 1991 and 1997, the unemployment rate in the Czech Republic remained below 5%.

10 In the period 1999–2008, the average annual inflation rate was around 3% and the average annual unemployment rate around 8.5%.

consumption expenditure fell more than GDP. Concerns about rising prices, speculative demand for real estate and the existence of unrealised purchasing power on the consumer goods market caused that the demand for real estate (including for holiday accommodation) significantly increased in the Czech Republic, which led to a significant rise in property prices.[11]

3 DATA AND METHODS USED

The aim of our analysis is to demonstrate the dampening nature of household consumption in terms of the phases of the business cycle, in other words the dampening of the downturn by a delayed decline in consumption. In carrying out the analysis, we will use data on GDP growth for the Czech Republic and on the evolution of household final consumption expenditure in total, as well as of its components sorted by durability.

Analysis of this data should confirm the interdependence between the quarterly GDP time series and the time series of household final consumption expenditure, as well as identify lags, if any, in this dependence (see *www.czso.cz*). For this analysis, we have used the values of both indicators in current prices for the period 1995–2020 (a total of 104 data items for each quarterly time series). We also have year-to-year quarterly indices based on the values of both indicators in the previous year's chained prices.

In order to confirm the hypothesis that expenditure is dampening the household final consumption, it is necessary to:

- test the interdependence between these two series;
- detect any time lags in this interdependence; and
- describe this dependence with the aid of an appropriate model.[12]

We have used the cross correlation function (CCF) – Box et al. (1994), or Pankratz (1991) – to demonstrate the linear dependence between the time series analysed. The CCF has the advantage of determining not only the intensity but also the direction of the linear dependence including time shifts. The CCF is defined as:

$$\rho_{XY}(k) = \frac{\gamma_{XY}(k)}{\sigma_X \sigma_Y}, \tag{1}$$

where X_t and Y_t are the analysed time series. The value of CCF at k is then defined as the covariance between X_t and Y_{t+k} for $k = 0, \pm 1, \pm 2, \ldots$, divided by a product of the standard deviation values of both series; here σ_X and σ_Y stand for the standard deviation values of the series X_t and Y_t (respectively). The following formula obviously holds for the CCF:

$$\rho_{XY}(k) = \rho_{XY}(-k). \tag{2}$$

The CCF definition and properties can be found in Wei (2006), or Box et al. (1994). In developing the model, we used the theory of transfer function models (TFM) – again, see Box et al. (1994), or Pankratz (1991). This class of models allows us to model the interdependence of the respective time series and describe it with the following stochastic model:

$$Y_t = c + \nu_0 X_t + \nu_1 X_{t-1} + \nu_2 X_{t-2} + \ldots + \nu_K X_{t-K} + \frac{1}{(1-\phi_1(B))(1-\Phi_1(B^L))}\varepsilon_t, \tag{3}$$

where the variables are compliant with the standard usage met in the relevant literature: Y_t is the output series, X_t is the input series, c is constant, ν_i are unknown parameters for $i = 0,\ldots,K$, $\phi_1(B)$

[11] A 12% year-to-year increase in apartment prices occurred.

[12] The entire analysis has been carried out in SCA software.

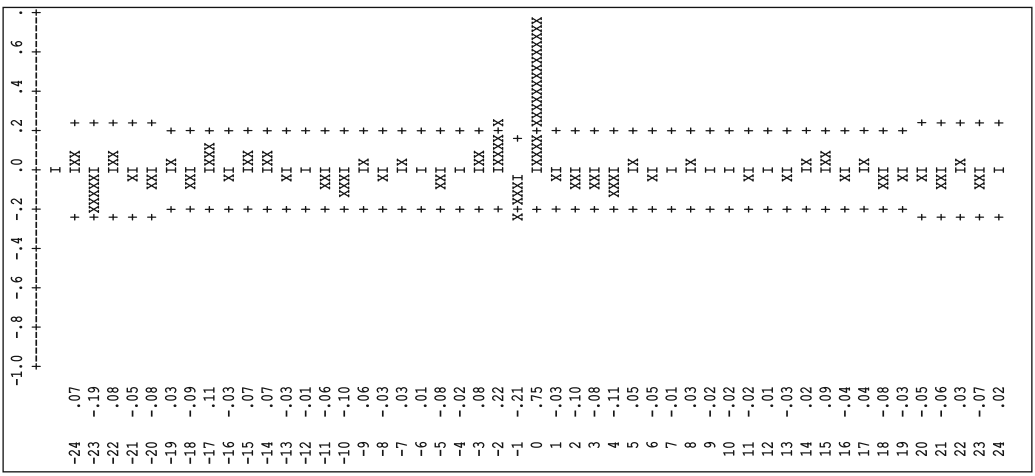
is the autoregressive operator of order 1, $\Phi_1(B)$ is the seasonal autoregressive operator of order 1, ε_t is the random variable (white noise), B is the shift operator ($BY_t = Y_{t-1}$), and L is the length of season (see, for exemple, Box et al., 1994).

The input X_t series is in our case the GDP series; the output Y_t series is that of final consumption expenditure values. The model is based on the idea that households' final consumption expenditure depends on the GDP values but responds to them with a certain time lag. It means that the expenditure value at time t depends on the GDP values at times t, t–1, t–2, …

4 RESULTS OF ANALYSES

We have first studied the interdependence between the quarterly time series with regard to possible time lags contained in this interdependence. To this end, we determined the CCF values and immediately tested their significance. Both series must, as a pre-processing step, be transformed to achieve stationarity. We have used current and seasonal differentiating of order 1 to obtain stationary series. The results are clearly visible in Figure 2.

Figure 2 Cross correlation between household final consumption expenditure (t) and GDP (t–1)



Source: Own calculations, <*www.czso.cz*>

The chart indicates that CCF takes on significant values at t, t–1 a t–2. In words, household final consumption expenditure at time t depend on the GDP values at times (quarters) t, t-1 and t-2. Prior our calculations, both series have been stationarised as already described.

The described dependence allows us to construct a linear dynamic model of the form:

$$Y_t = 0.3268X_t - 0{,}0509X_{t-1} + 0.1532X_{t-2} + \varepsilon_t - 0.6301\varepsilon_{t-1} \quad (4)$$

where Y_t is the time series of households' final consumption expenditure (delayed) values, differentiated both currently and seasonally, X_t is the time series of the GDP values, also differentiated both currently and seasonally, and ε_t is the white noise.

It should be noted that this model has passed a battery of tests (tests of residue, the unit root, homoscedasticity, and Dickey-Fuller tests) and has been proved to be fully adequate. An important indicator of its quality is the linear independence between the residuals of the TFM model and the stochastic output series model. We have built this stochastic model, computed the residuals and then calculated the CCF between the residuals of these two models. The CCF values are not significantly different from 0, so this important quality criterion for the TFM model also provides an argument in its favour.

The quality of the model constructed using the data on household final consumption expenditure and GDP at current prices is excellent, as indicated by the value of R-SQUARE = 0.999. The results of our analysis are illustrated by the output of the SCA program (see Table 1).

Table 1 SCA software output (time series in current prices)

PARAMETER LABEL		VARIABLE NAME	NUM./ DENOM.	FACTOR	ORDER	CONS- TRAINT	VALUE	STD ERROR	T VAL
1	V0	GDP	NUM.	1	0	NONE	.3268	.0221	14.56
2	V1	GDP	NUM.	1	1	NONE	-.0509	.0223	-2.98
3	V2	GDP	NUM.	1	2	NONE	.1532	.0245	6.71
4	PHI4	SPOTREBA	MA	1	4	NONE	.6301	.0997	6.99

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EFFECTIVE NUMBER OF OBSERVATIONS . .          97
R-SQUARE . . . . . . . . . . . . . .        .999

RESIDUAL STANDARD ERROR. . . . . . .   .474429E+04
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Source: Authors' own calculations, <*www.czso.cz*>

We reach similar conclusions if we use the time series of the corresponding year-to-year quarterly indices instead of the original time series. The analysis and calculation procedures are completely analogous to the previous case. The interdependence in the *t, t*–1 and *t*–2 quarters is again identified. The results of the analysis based on year-to-year quarterly indices taken as the input data are again illustrated by the output of SCA software (see Table 2).

Table 2 SCA software output (time series of year-to-year quarterly indices)

PARAMETER LABEL		VARIABLE NAME	NUM./ DENOM.	FACTOR	ORDER	CONS- TRAINT	VALUE	STD ERROR	T VAL
1	V0	KGDP	NUM.	1	0	NONE	.5707	.0668	12.48
2	V1	KGDP	NUM.	1	1	NONE	-.1440	.0668	-3.01
3	V2	KGDP	NUM.	1	2	NONE	.2892	.0693	5.98
4	PHI4	KSPOTREB	MA	1	4	NONE	.7923	.0675	6.12

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EFFECTIVE NUMBER OF OBSERVATIONS . .          89
-SQUARE . . . . . . . . . . . . . .         .798
RESIDUAL STANDARD ERROR. . . . . . .   .119044E+01
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Source: Authors' own calculations, <*www.czso.cz*>

The resulting model's form is analogous, but the parameter values are, of course, different:

$$Y_t = 0.5707X_t - 0{,}1440X_{t-1} + 0.2892X_{t-2} + \varepsilon_t - 0.7923\varepsilon_{t-1}, \quad (5)$$

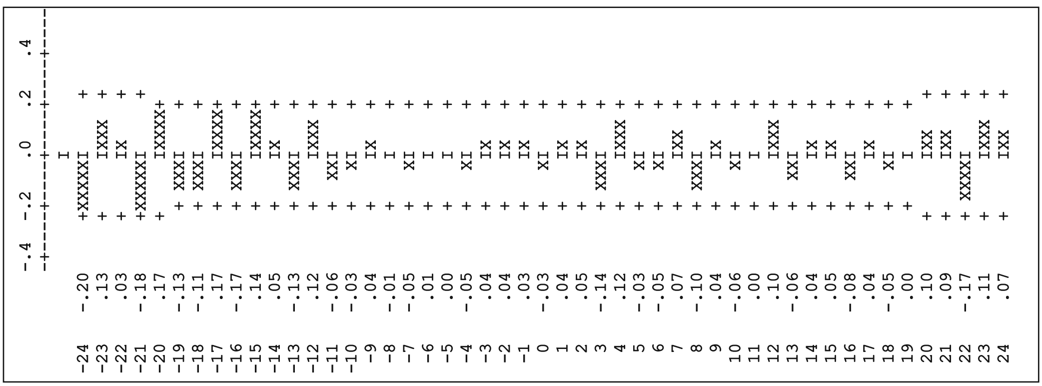
where the Y_t time series contains the year-to-year quarterly indices for households' final consumption expenditure, differentiated both currently and seasonally, the X_t time series contains the GDP year-to-year quarterly indices, again differentiated both currently and seasonally, and ε_t is the white noise. This model has also gone through a battery of tests (tests of residue, the unit root, homoscedasticity, and Dickey-Fuller tests) and has been proved to be fully adequate. Results of a test for independence between the TFM model residua and the stochastic model for year-to-year quarterly indices for households' final consumption expenditure also indicate that the quality of the TFM model is good.

Our data analysis has thus confirmed the dependence between the quarterly time series of total household final consumption expenditure and GDP, including time lags of one and two quarters. We have derived a linear dynamic model that describes this dependence well. The model has been proved to be perfectly adequate, passing all quality tests. We have obtained the same model (with different parameter estimates, of course), even if we, instead of the original series, analysed the time series of year-to-year quarterly indices of household final consumption expenditure and GDP.

From the perspective of households' response to the incoming crisis signals, it is undoubtedly important to classify expenditure on consumption items according to their durability. We have at our disposal values for expenditure on durable, medium-term and non-durable goods (and, by analogy, the corresponding year-to-year quarterly indices). Expenditure on non-durable goods (food, beverages, tobacco, pharmaceuticals, cosmetics, fuel, etc.) is not expected to change significantly with the coming crisis, as it represents expenditure to cover essential needs. By contrast, expenditure on durable goods (motor vehicles, furniture, refrigerators, washing machines, music equipment, computer equipment, jewellery, etc.) is expected to respond to the coming crisis in a manner analogous to household final consumption expenditure in total. This is because it is expenditure on 'surplus' items (and usually pre-planned items, the purchase of which can be postponed and the expenditure made only when the economic development of the national economy has been stabilised). A certain degree of caution on the part of households may be assumed for expenditure on medium-term consumer goods (clothing, footwear, household goods, sports equipment, books, toys, etc.) when the symptoms of the crisis appear; however, purchases of medium-term consumer goods cannot be postponed significantly. Some delay in final consumption expenditure can therefore be expected, but it will undoubtedly not be as significant as in the case of expenditure on durable goods.

Our analysis (again based on CCF) has fully confirmed the described assumptions concerning households' responses to a coming crisis: the expenditure on non-durable goods is independent of changes in GDP. The CCF chart (see Figure 3) also confirms this observation.

Figure 3 Cross correlation between expenditure on non-durable goods and GDP

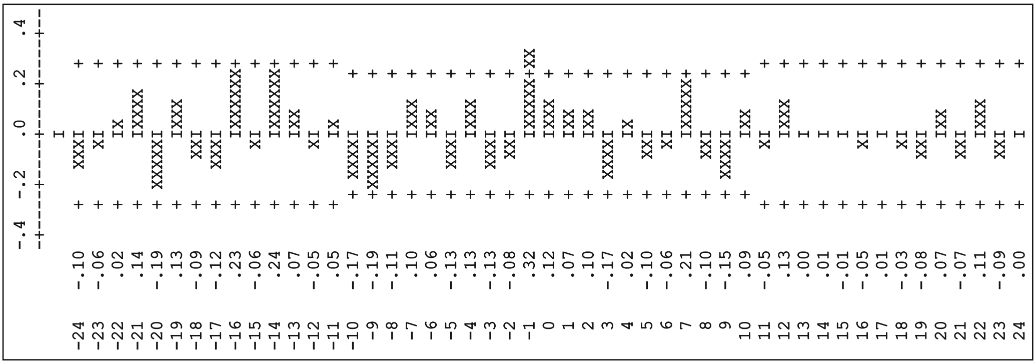


Source: Authors' own calculations, <*www.czso.cz*>

In other words, everyday items are purchased by households regardless of the coming or ongoing economic crisis. It therefore makes no sense to formulate a dependency model as in the other cases analysed here.

In the case of households' spending on medium-term consumer goods, it turns out that this series depends on GDP values only at the t–1 quarter and not on thee values at t or t–2. This means that it responds to changes in GDP with a lag of exactly one quarter. This can be clearly seen in the graphical output showing the CCF (see Figure 4). This illustrates the specific nature of these products – they are not necessities (especially clothing, footwear), but their acquisition cannot be postponed for a long time.

Figure 4 Cross correlation between expenditure on medium-term consumer goods and GDP



Source: Authors' own calculations, <*www.czso.cz*>

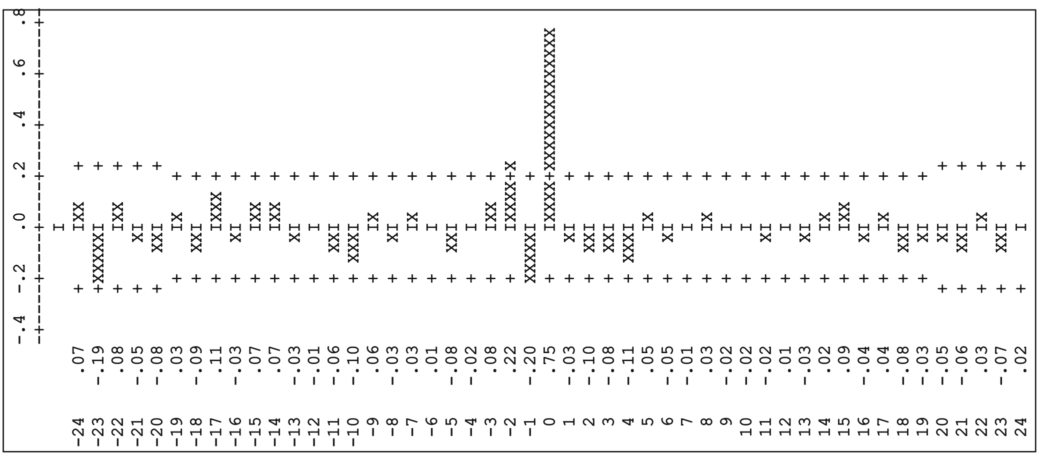
The adequate model takes on the form:

$$Y_t = 0.0313X_{t-1} + \varepsilon_t - 0.8266\varepsilon_{t-1}, \qquad (6)$$

where the Y_t time series contains the values of expenditure on the medium-term consumer goods, differentiated both currently and seasonally, the X_t time series contains the GDP values, also differentiated both currently and seasonally, and ε_t is the white noise.

For durable goods spending, this time series at quarter *t* turns out to depend on GDP values at quarters *t*, *t*–1, and *t*–2. This fact confirms the assumption that the character of the dependence and lags is the same as in the case of total household final consumption expenditure. Again, we have calculated the CCF and the graphical output (see Figure 5) shows a linear dependence including a time lag of one and two quarters.

Figure 5 Cross correlation between expenditure on durable goods and GDP



Source: Authors' own calculations, <*www.czso.cz*>

Based on this observation, we have derived a model with the following transfer function:

$$Y_t = 0.0575X_t - 0.0234X_{t-1} + 0.0175X_{t-2} + \varepsilon_t - 0.4976\varepsilon_{t-1}, \quad (7)$$

where the Y_t time series contains the expenditure on durable goods values, differentiated both currently and seasonally, the X_t time series contains the GDP values, also differentiated both currently and seasonally, and ε_t is the white noise.

CONCLUSIONS

Although the economic crisis caused by the Covid-19 pandemic in 2020 did not have economic causes, it again raised a number of questions about the nature of economic development, the links between the evolution of the values of macroeconomic aggregates, the predictability of crisis turning points in the economy and, last but not least, the role of household economic behaviour in exacerbating or smoothing the unevenness in the national economic development.

The Czech economy has not escaped the turbulent development occurring in the most recent 30 years. The initial problems associated with the transition from a centrally planned to a market economy, coupled with the rapid privatisation of industry, the rapid development of the banking sector, the collapse of Czechoslovakia and the slow revision of existing legislation in the early 1990s, were seemingly quickly resolved. However, the harsh realities of the market economic environment brought about a rapid sobering up from the 'successful' economic transformation in 1997 and 1998, when the Czech Republic's GDP fell by around 1% in each of those years. To restart economic growth, it was necessary to create favourable conditions for foreign investors, as domestic entities lacked the necessary financial resources and technological facilities.

The change in economic policy (finalising the restructuring and modernisation of industry, recovery of the banking sector, and stabilisation of monetary policy) marked a turning point in economic development and, around the year of accession to the European Union (2004), the Czech Republic was at the peak of economic growth. Initially, the financial and credit crisis, which spilled over from the USA to the whole world, marked the end of the economic growth phase and the plunge into crisis, the consequences of which the Czech economy recovered from only very slowly. The government's overly restrictive budget policy, in particular, the refusal to support the modest recovery in 2010 and 2011, was partly to blame. It made the country fall back into the recession in 2012 and 2013. The decline in household final consumption expenditure and business investment was then only a reflection of the climate of the overall distrust prevailing in the economy at that time.

From the perspective of the Czech economy, the period after 2014 can be assessed as a period of prosperity and rising living standards. Although in 2018 and 2019, the annual GDP growth slowed down (to around 3% of annual growth in both years under review) in comparison with 2017, the Czech economy did not show any warning signs of the coming crisis. Non-economic factors, such as the pandemic, were not provided for. The drastic anti-epidemic measures (closure of borders, shops, restaurants, hotels and a number of manufacturing companies) meant that GDP fell by 5.8% and fixed capital investment by 7.2%. Household concerns about health risks, together with the closure of shops and services, led to a 7.1% fall in final consumption expenditure. It is too early to assess the full impact of the 2020 crisis, but there is no doubt that its causes were not economic. At the same time, household behaviour and its impact on economic development cannot be assessed in the same way as in the case of crises caused by economic reasons.

The causes of the crises that the Czech economy went through were various; in 1997–1998, the reasons for them can be found exclusively within the Czech economy. The crisis in 2009 had external causes; it came from the USA as a credit and financial crisis, which turned into an economic crisis, with symptoms of an economic slowdown already coming in 2008. The crisis of 2012–2013 again had internal causes, that is the wrong economic policy; and the crisis of 2020 was the result of non-economic factors.

The variety of causes of the crises in the development of the Czech economy leads us to try to confirm or refute the hypothesis about the corrective role of household economic behaviour in the development of the economy. We assume that, in years of economic growth, household spending on final consumption and investment increases. In terms of the nature of consumption, (with a slight increase in spending on short-term items) they are mainly oriented towards the purchase of durable items. By contrast, in years of recession and crisis, households first cut back on spending on durable goods, but still with a certain delay. Demand for non-durable items (food, beverages, tobacco, pharmaceuticals, cosmetics, fuel, etc.) remains unchanged.

If we are to confirm or reject the hypothesis that, whatever the economic cause of the crisis, household consumption behaviour is comparable yet differentiated by durability, we use a linear dynamic time series model. By analysing the data, we have confirmed the dependence between the quarterly time series of total household final consumption expenditure and GDP, including time lags of one and two quarters. The model has been proved to be perfectly adequate, passing all quality tests. The same conclusions have been reached when modelling the dependence of the year-to-year quarterly growth rates of household final consumption expenditure and GDP.

When we analyse the time series of quarterly household final consumption expenditures by durability and GDP, our hypothesis is confirmed, as it turns out that expenditures on non-durable items are independent of changes in GDP. Thus, households purchase everyday items regardless of the upcoming or ongoing economic crisis.

On the other hand, for expenditure on durables, this time series at quarter t has been shown to depend on GDP values at quarters t, t–1, and t–2, confirming our hypothesis of the same dependence and lag as for household final consumption expenditure in total.

In the case of household expenditure on medium-term consumer goods (clothing, footwear, household goods, sports equipment, books, toys, etc.), this series turns out to depend on GDP values only at quarter t–1 and does not depend on the value at time t or on the value at time t–2. This one-quarter interval only confirms the specific character played by the medium-term consumer goods in household expenditure. These products cannot be regarded as superfluous and their purchase cannot be postponed for a longer period. In this sense, spending on durable goods is relatively weakly smoothing. The dominant role in the corrective effect of lagged final consumption expenditure is, therefore, in line with our assumption, played by expenditure on durable goods.

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Productive Population and Czech Economy by 2060

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Abstract

The paper brings a deeper outlook at the development of productive population by 2060 in the Czech Republic. The Czech Republic will be strongly confronted with population ageing and suitable mix of different policies will be needed. The crucial issue is, how much the development of labour productivity as well as technical progress can prevent radical increases in statutory retirement age. Capping this fundamental economic parameter at the age of 65 years will shift economic burden on productive population that will have to respond. We bring a deeper view on the structure of current labour force and its possible development by 2060. This comes from the combination of official demographic projection and computable general equilibrium model based on Leontief input-output principles. We prove that economic sustainability of such parameters is more than uncertain since the estimates of the potential burden incurred by population ageing is significant despite the compensation by the changes in labour productivity and technological growth.

Keywords	***DOI***	***JEL code***
Demographic ageing, labour force, productivity, CGE	*https://doi.org/10.54694/stat.2021.29*	*J11, C68*

INTRODUCTION

Population ageing and its consequences affect lots of areas of human society. The most discussed issues include retirement pensions, health and social care system. Economic impacts are often discussed from the perspectives of resources for retirement pensions. Besides, we should also consider the impact of ageing on the potential capacities to produce goods and services that will always be needed for satisfying population needs. It is very difficult to predict any development in a long perspective and current pandemic situation with coronavirus emphasises that. However, that does not mean that these thoughts and concerns are not justified. Sober look on the demographic projection by 2100 prepared by the Czech Statistical Office (CZSO) should not leave us calm (CZSO, 2018). We raise the question of how to secure resources for ageing population. We think that all extremes are counterproductive such as no changes in statutory retirement age or completely voluntarily based pension systems. Our question is simple,

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what is the necessary development of productivity for ensuring enough resources for the population. Of course, the question is partly theoretical since the Czech Republic is not an isolated island and financial transaction may solve lots of shortages in both material and human capacities. The ageing problem of the Czech Republic and its regions is also mentioned in Šimková (2021).

When studying the structure of labour supply, we still consider capital assets, as well. We do not want to tackle futuristic scenarios in terms of significant substitute of labour by robots or computer since it seems that in many areas of human life the labour is irreplaceable. At least for now. Ongoing progress will reduce the necessity of labour in many industries of the economy but in some others the labour will still be needed. To date we cannot imagine many of human related services (health, education) without active participation or presence of a human being. The discussion about productive population and its future is not without context with demographic ageing. IMF estimates of total productivity growth, loss and estimated development of a share of prime age workers do not provide an optimistic view, see Aiyar et al. (2016).

Our paper focuses on the expected changes in the size and structure of labour supply that will result in changes of the Czech economy. The size and structure of employment (labour supply) is not steady in time. Since the radical changes at the beginning of 1990s, labour supply changed significantly and it was not only due to the changes connected with economic transformation. Availability of computers and technological progress boosted labour productivity but should we expect the same development in next 40 years? Currently, the demographic process of ageing is starting to influence the Czech labour market. Ageing influences both labour supply (the possibility to find suitable worker) and labour demand (older patients require more health and social services).

All changes connected with labour supply and ageing can be expressed by the development of productive population. For our purposes, productive population is hypothetical labour supply affected by structure, health status, education, productivity and rate of economic activity. These parameters are separately estimated and used as an input for computable general equilibrium (CGE) model, see Johansen (1963). The Johansen system of equations is based on the same framework as IOA, on Keynes theory, see Goga (2009), or Taylor (2016). We put the emphasis on the input-output approach (CGE based on input-output framework) as described in Ronson (1991). In our estimates, we combine Ronsons´ works and standard CGE model, see Hosoe et al. (2010) and Sue Wing (2004). Alternatively, Gawthorpe uses input-output DSGE (Gawthorpe, 2019) and Gawthorpe and Šafr (2019) for estimation of a well-being of ageing population.

We present the outcomes from our CGE in relative terms, by indices comparing current and potential state of art in 2060. Under classic CGE condition, we are able to estimate different scenarios with necessary requirement of labour productivity growth. The main aim of CGE model consists in the evaluation of the exogenous effect of parameters of model (Mardones, 2015). An example of the combination of the input-output approach and CGE can be found in Kim and Hewings (2009).

1 METHODOLOGY AND DATA

Our model of productive population is based on both official statistical data and research data from our models. Official statistical data comes from the Czech Statistical Office, namely Labour Force Survey (LFS) used for the expression of labour supply and data on population and demographic projection. With respect to the specifics of the data, we successfully combine macroeconomic data (CZSO, 2021), social statistics data and demographic data. Macro-aggregates come from Czech national accounts.

Research data comes from own-designed Computable General Equilibrium model programmed in R. Within the Section 5, we use only fragments of our CGE model since this paper is focused on productive population and its ageing consequences only and it is not devoted to the description of specifically built CGE.[3] Generally, CGE models use lots of data as well as other sophisticated models. Among the most important data inputs, we defined estimates of labour productivity, development of the population and its consumption structures, inter-industry mobility of workers, estimates of the development of health condition of population, estimates of activity rates and development of the technology. For those who are interested in CGE modelling, the list of main assumptions is presented in the Annex I.

The specifics of our CGE model lie in the use of Leontief production function (Šafr, 2017) and corresponding limits consisting of fixed structure of production. The model is prepared on the level of 21 industries (sections) of CZ-NACE. The idea of the model lies in the maximisation of fictitious following utility function (U) and computation of Cobb-Douglas (C-D) production function (x):

$$U = \sum {y_h}^{\alpha_i}, \tag{1}$$

$$x = f\left(y, A\right), \tag{2}$$

where:

- U utility,
- α_i input coefficients,
- y_h final use – household consumption expenditures,
- x output,
- A matrix of input coefficients from input-output tables.

Utility comes endogenously from the CGE computation respecting both the level and the structure of household consumption. As consumption and structure varies during the time, utility changes, in fact Formula (1) expresses weighted consumption according to the input coefficients and therefore it also reflects consumption non-linearly by products. Output (x) endogenously affects utility under the condition of maximisation. All the inputs described above (population estimates, health status, development of the productivity,...) come as exogenous variables under our control. In other words, under a give set of parameters, we receive maximisation task –> max U.

With reference to the above, we define productive population (*pp*) as:

$$pp_{t,s} = p_{t,s} h_{t,s} e_{t,s} q_{t,s}, \tag{3}$$

where:

- pp productive population,
- p total population,
- h health condition index,
- e education status index,
- q labour productivity index,
- t index for time,
- s index for specific group (age and education).

Computation is done on the level of three age groups (15–49, 50–64, over 65) for three educational levels (elementary and lower, secondary and higher than secondary). Detailed description of these inputs goes far beyond the purpose of this paper and therefore we use just some model outcomes. For the consequences of ageing and its mutual linkage to productive population this brief description is sufficient.

[3] We intend to prepare a special paper devoted to the methodology of construction CGE model describing population ageing in a detail.

With respect to the definition of standard demographic indicators such as economic dependency ratio, we use our own computations since we focus on economic side of the changes on labour supply and we must consider the rate of activity in different age groups. In Section 3, we present our estimates of these rates that reflect future participation of older people in the labour market, estimated population structure, estimated development of educational status and gradual growth of statutory retirement age to 70 years in 2060.

Mainly, we focus on the quantitative side of labour. Qualitative issues must be considered, as well. It would be ridiculous to say that the nature and the qualitative aspects of labour remain steady. The evidence from the comparison of Czech society and economy when comparing 2019 and 1990 is obvious. But, on the other side, some works (jobs) can be hardly handled without human beings. We do not have consider only nurses, doctors etc. It means that the most serious reflection of our study is indicative impact on the quantity of work (labour supply) that will definitively affects our population.

2 LABOUR SUPPLY AND EMPLOYMENT IN THE CZECH REPUBLIC

Currently, the structure of labour supply in the Czech Republic is going to be at the beginning of a serious ageing problem. The lack of different (and human demanded) professions such as doctors, dentists, nurses, masons, plumbers etc. is observable everywhere. Anyway, the situation is at the stage of exhaustion demographic dividend, the issue described by Der Gaag and De Beer (2014). The structure of the Czech population has been continuously changing from the beginning of 1990s. The growth of the population from 10.3 million to 10.7 million in 2019 was due to the migration increments and prolongation of life expectancy, which moderated population decrease by natural change. In economic words, it means that while the population is growing, the number of economically active is not increasing adequately, see Table 1.

Table 1 Structure of the population in the Czech Republic, 1990–2019 (persons, in %)

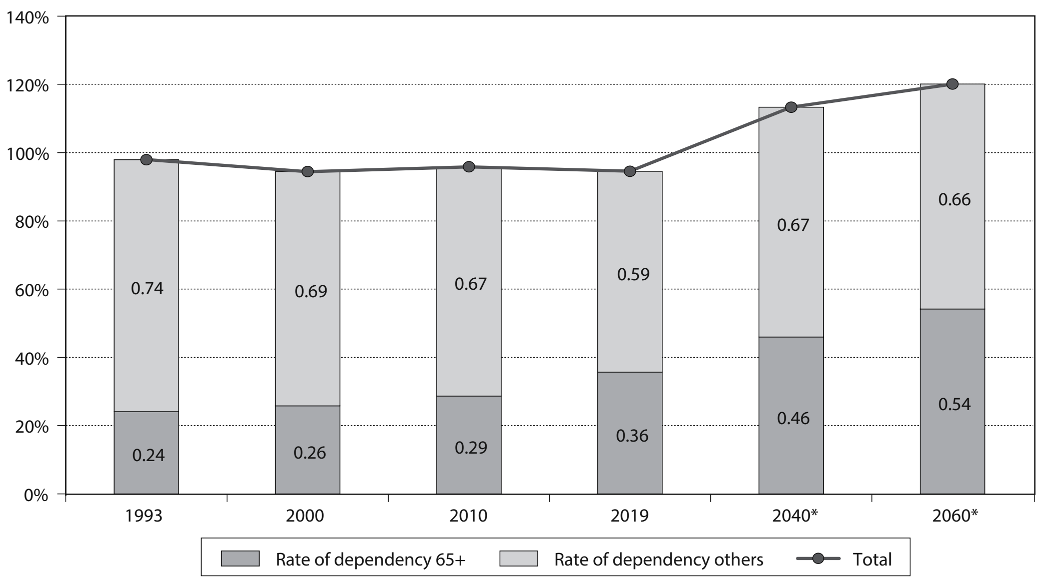
Year	1990	1995	2000	2005	2010	2015	2019
Total population	10 362 257	10 330 759	10 272 503	10 234 092	10 517 247	10 542 942	10 669 324
Economically active population	5 418 006	5 253 753	5 283 581	5 266 713	5 370 318	5 435 384	5 483 945
Total employment – national concept	5 378 627	5 045 702	4 829 069	4 856 559	4 986 668	5 167 112	5 374 873
of which employees	5 265 870	4 443 909	4 124 640	4 114 220	4 180 829	4 403 571	4 617 438
of which self-employed	112 757	601 793	704 429	742 339	805 839	763 541	757 435
Rate of economic activity	51.9%	48.8%	47.0%	47.5%	47.4%	49.0%	50.4%

Source: Own computations based on the CZSO figures

The number of both employees and self-employed is around 5.4 million people and this figure together with unemployed people form economically active population. The rate of economic activity (economically active divided by total population) decreases from 52% to 50% between 1990 and 2019. It means that the increase of the population does not result in the support of economically active people and labour supply.

The substance of the problem lies in the growth of dependency ratio in following years. Demographers usually compute the economic dependency ratio as the ratio of population of selected age groups (0–19, over 65) on productive category, e.g. 20–64 years. It represents the number of people dependent on one economically active person. In other words, how many people one economically active person has to provide. But we compute the rate of dependency in a slightly different way[4] since the life expectancy is changing as well as economic life. Currently, we can easily find people working (that means economically active) at the age of 70 or 80. That was very scarce in 1990s. In our approach, we reflect only economically active population (irrespective of their age) and dependent (inactive) people. Overall dependency ratio indicates possible negative development in the future even if it is still below the value 1.00 by 2020. But when we split it between the elderly and others (children + all other reasons for inactivity), we get more serious information, see Figure 1. The rate of dependency of the elderly increased from 0.24 to 0.36, correspondingly the rate of dependency of others (young and medium age disabled people) declined from 0.74 to 0.59. When we add figures from demographic projection (more in Section 4), we estimate that the overall rate will rise to 1.13 in 2040 and 1.20 in 2060. Negative trend will be observable in the structure since the share of dependent elderly will form 45% in 2060 while 38% in 2019. The 20% increased burden imposed on active population will require adequate resources and it will boost concerns about future development.

Figure 1 Estimates of dependency ratio in the Czech Republic, 1993–2060 (in %)



Source: CZSO, own computations based on the CZSO figures

4 We consider only economically active people. These people are working or they are unemployed. Inactive group contains students, maternity leaves and people excluded from the labour market for all reasons.

Economic activity is highly connected with the structure of the workforce that lies behind, see Table 2. In line with modern trends, people tend to spend more years in schools and the increase of the qualification of the population is one of the most positive factors (investment into the future). On the contrary, it means that more people depend on the parents for longer time. In the beginning of the 1990s, about 6% of the population were employed by the age of 20. In 2019, this group makes about 0.5%.

Table 2 Employment structure in the Czech Republic, 1993–2019 (in %)

Year	1993	1995	2000	2005	2010	2015	2019
Age group	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
15–19	5.8%	4.5%	1.4%	0.7%	0.5%	0.4%	0.5%
20–24	10.1%	11.6%	11.2%	7.1%	6.2%	5.6%	4.6%
25–29	10.9%	10.6%	13.0%	13.4%	11.2%	10.3%	9.8%
30–34	11.2%	11.6%	11.5%	14.1%	14.3%	11.3%	10.7%
35–39	14.1%	12.7%	12.3%	12.3%	15.0%	15.1%	12.7%
40–44	15.4%	14.9%	12.8%	12.5%	12.7%	15.3%	16.1%
45–49	14.5%	14.9%	14.6%	12.6%	12.5%	12.5%	14.3%
50–54	9.8%	10.8%	13.6%	13.5%	11.9%	11.9%	12.0%
55–59	4.6%	5.0%	6.7%	10.0%	10.4%	10.4%	10.5%
60–64	1.9%	1.9%	1.7%	2.8%	3.8%	4.9%	5.9%
65+	1.5%	1.5%	1.2%	1.1%	1.5%	2.1%	2.9%

Source: Own computations based on the CZSO figures

The rate of economic activity for the group 15–19 declined from 35.5% in 1993 to only 6.3%, see Table 3. Significant decrease is also observed in the group 20–24. The lowest changes are observed for the people between 25 and 49 years but after 50 the rates changed dramatically. In line with the changes in the statutory retirement age, rate of activity increased in the group 60–64. It is very interesting that activity rates and number of people over 65 show that such group counts about 7.3% of the workforce in 2019 while just about 4.8% in 2010. The ageing of the workforce is clearly evident from these data. We have to consider that the absolute number of people in the age group 15–19 declined by 48%, from 909 thousands to 473 thousands only. Such decrease in line with increase of total population caused the decline of the share of this group from 9% to 4%. In relative terms, lower activity rate is addressed to lower number of potential workers and direct economic contribution (from the labour) of this group is negligible.

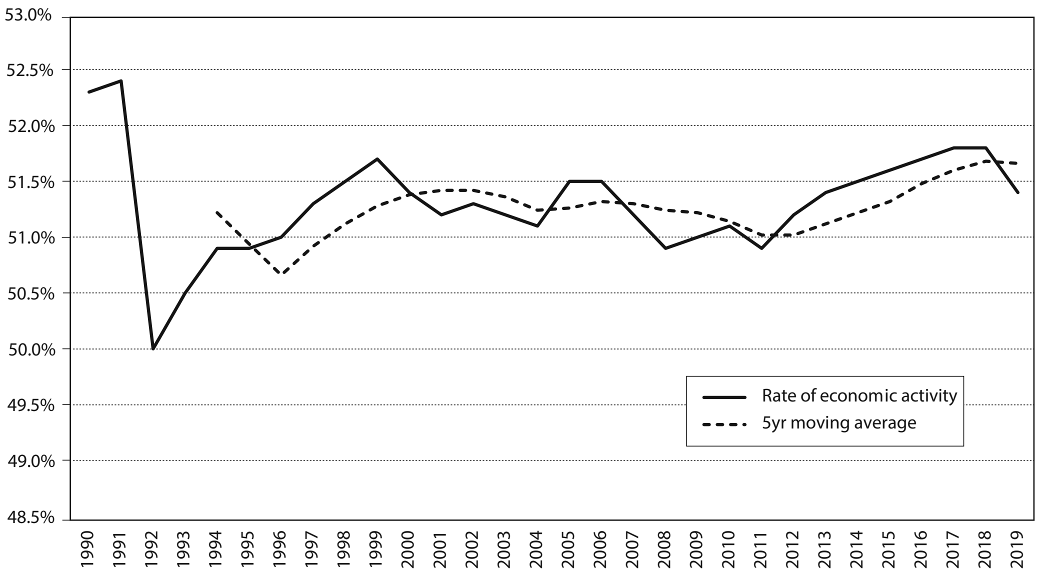
Table 3 Estimates of the rates of economic activity, Czech Republic, 1993–2060 (in %)

Age group	1993	2000	2010	2019	2040	2060
15–19	35.5%	15.0%	6.9%	6.3%	9.5%	9.3%
20–24	70.4%	70.8%	51.5%	52.3%	49.7%	49.6%
25–29	80.8%	80.3%	80.0%	81.2%	75.3%	75.2%
30–34	89.1%	87.2%	81.8%	80.4%	80.9%	81.0%
35–39	93.6%	92.1%	89.5%	88.7%	85.2%	85.2%
40–45	94.1%	93.8%	93.7%	93.1%	90.8%	90.7%
45–49	92.7%	92.9%	93.8%	94.9%	92.5%	92.5%
50–54	83.2%	85.9%	90.3%	93.8%	91.2%	91.2%
55–59	47.4%	53.3%	72.4%	89.2%	82.8%	83.2%
60–64	18.8%	17.7%	26.3%	47.6%	48.7%	51.5%
65+	6.0%	4.1%	4.8%	7.3%	14.2%	17.8%

Source: Own computations – based on the work of Ondřej Nývlt (Nývlt, 2019) and his assistance – and on the CZSO figures

It is very difficult to compare current society with the early 1990s. Radical changes in the society caused lots of more or less voluntary exits from the workforce (to retirement) and the overall rate of economic activity was very volatile by 2000, see Figure 2. Despite smoothing with a 5 years moving average, the development seems very flat. Since 2000, the development is smoother and we can clearly observed the impacts of the economic crises that affected the Czech Republic in 2001/2002 and 2008/2009. The behaviour of the people is very difficult to predict since their decision whether to stay or leave labour market depends on many incentives ranging from expectation of immediate development of the economy to the reaction on the changes given by the policy makers. But what has to be taken into account is the improved health condition of people since the future development of healthy life expectancy in relation to total life expectancy is very important.

Figure 2 Overall rate of economic activity in the Czech Republic, 1990–2019



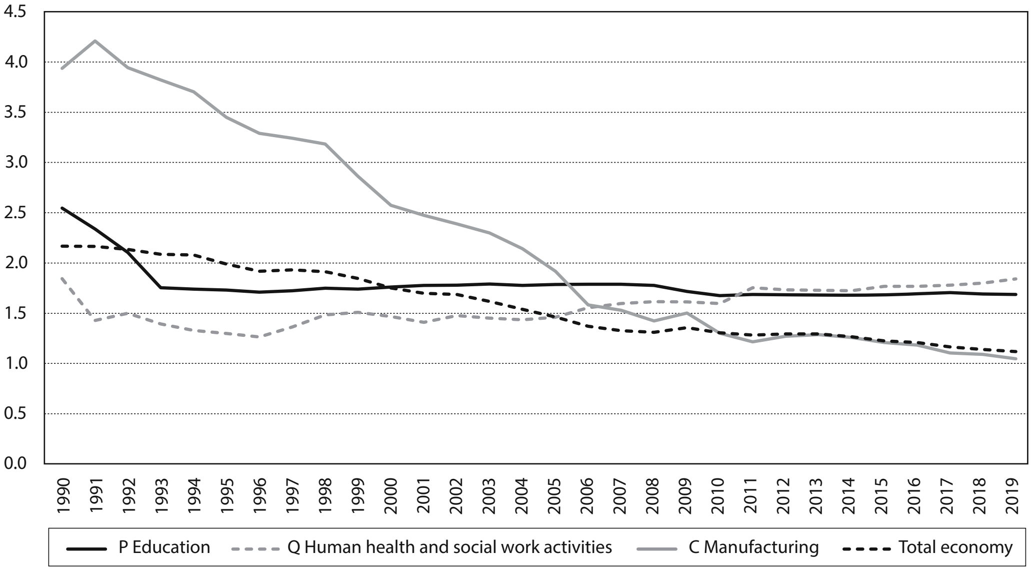
Source: Own computations based on the CZSO figures

Over the last three decades, the development of the labour input required for a unit of gross value added (labour input) shows that there are significant differences among industries. Technological progress resulted in a sharp decline in labour needed in manufacturing industry (CZ-NACE code C), see Figure 3 where we present labour inputs expressed in full time equivalents per one million of gross valued added at constant[5] prices of 2015. If we compare such development with education industry (code P) and health and social services (code Q), we get completely different picture. It shows us that in services of P and Q the demand for labour is very steady.[6] The exception was the economic transformation in the beginning of 1990s but after that the necessary labour input fluctuates between 1.5 and 2 full time equivalent worker per one million of value added.

[5] In fact, the aggregates are expressed in chain-linked prices but this information is interesting to skilled statisticians only. The economic interpretation of constant prices and chain-linked prices is identical.

[6] For better understanding it is necessary to mention that the output of these industries is based on the cost approach, where labour costs (compensation of employees) form major part of output. That means that labour stability is also given by statistical reasons.

Figure 3 Labour inputs to selected industries, 1990–2019 (persons per million of value added)



Source: Own computations based on the CZSO figures

Figure 3 shows the basis for the negative expectation in a few years. On the level of a total economy, the changes and absorption of both positive technological development and negative demographic trend may smoothly compensate. But some services such as education, health and social services may face more serious problems.[7] Moreover, the development in these services in mostly in the hand of the governments. Especially health and social services may soon face serious problems, more people requiring assistance and less students in medical faculties, nurses or people willing to work for social services.

3 DEMOGRAPHIC BASE IN THE ECONOMY

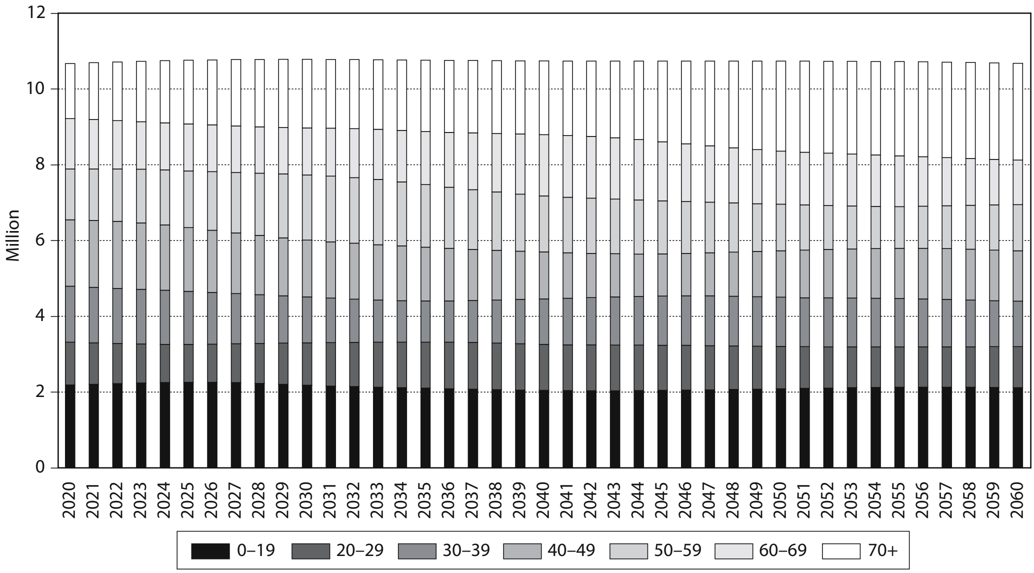
Demographic situation and its development will influence future development of the economy. When observing current trends in the Czech Republic, they do not provide any reason for optimism. The key question is how these trends will be present in the future economic development. The total figures of the population represent only one part of the problem but the structure is the second and more serious part. Demographic development will be reflected in the rate of economic activity. Of course, real demographic situation is unknown but the experts from the Czech Statistical Office published demographic projection (we use middle variant in our model) describing potential development, see Figure 4 and Figure 5 showing relatively constant share of youth and increasing share of the elderly. In other words it means that the burden of productive population increases significantly.

The main "economic base", people between 20 and 59 years, decline their share from 53% in 2020 to 48% in 2040 and just 45% in 2060. On the contrary, despite the increase of economic activity, in some professions employees over 70 seem unlikely. And the age group over 70 will increase between 2020 and 2060 the most dramatically. The share of people aged over 70 years will rise from 14% in 2020 to 18% 2040 and to 24% in 2060. In nominal terms, it means the increase from 1.5 million people to 2.6 million people, more than 1 million people increment. The possibility of participation of older people on the

[7] Some of the problems appeared during current pandemic situation but this is not the case of the Czech Republic only.

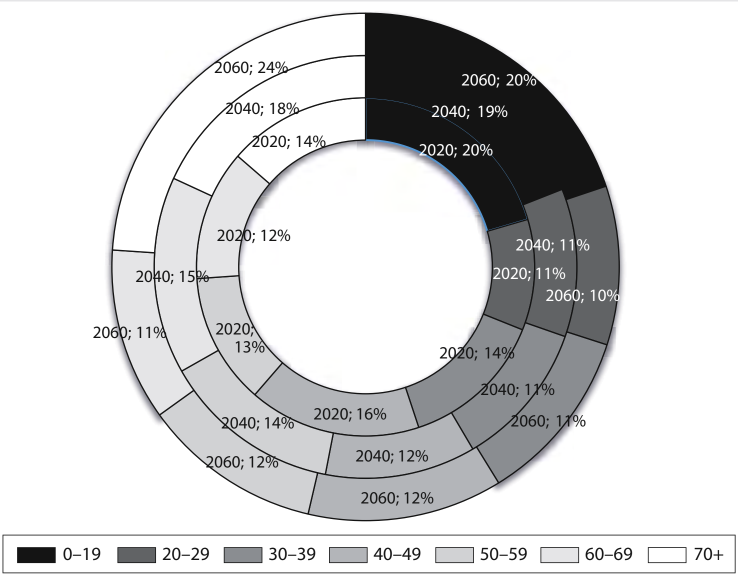
labour market will be dependent on their health condition and socio-market conditions but this can be hardly applied for physically demanding profession. This means that people forming "economic base" from demographic component of the economy will provide less power than nowadays. The question is how to accept it and if possible find some solution helping to overcome it. In the following section we implement CGE approach for quantification of a potential loss of power.

Figure 4 Demographic projection of the Czech Republic (2020–2060)



Source: Own computations based on the CZSO figures

Figure 5 Changes in the structure of the Czech Population (2020, 2040 and 2060)



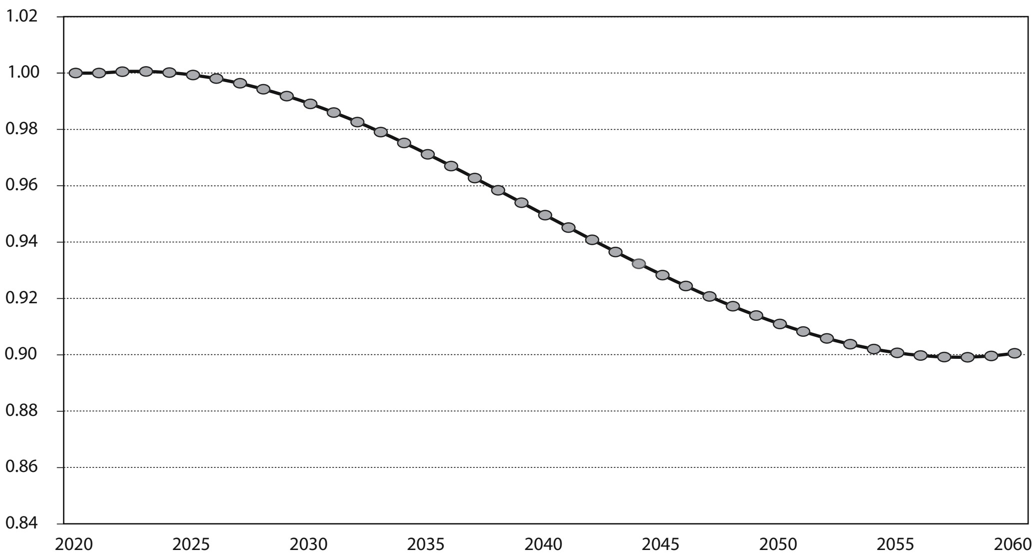
Source: Own computations based on the CZSO figures

4 ESTIMATES OF PRODUCTIVE POPULATION AND PRODUCTIVITY

Currently observed economic activity and present demographical base make a starting point for following estimates of the productive potential of Czech population within our economy. We use existing labour supply, economic activity and demographic development described in previous sections as input assumptions for our CGE model and we added estimates of changes of labour productivity, health condition of population and general technological progress.[8]

We suppose that the development of productive population is a key factor affecting our society. Since the age structure is significantly changing, CGE simulation shows important impacts in all main economic indicators. With respect to the presentation purposes, we focus mainly on base indices (2020 = 1.00) to express the impacts on Czech economy. We used standard CGE model with key targeting indicator total utility expressing both the volume and structure of consumption. In our research, we focused on the description of demographic trends and their impact on the economy by the CGE model where the key driving factor productive population ($pp_{t,s}$), see Figure 6. Development of productive population is influenced by expected demographic trends and despite some positive effects such as continuously increasing health condition of Czech population, negative demographic trends prevail and after 2030 and more significantly after 2035, we expect sharp decrease by 2060. Between 2020 and 2060, demographic data shows 16% decrease of the share of people between 20 to 69 years. Due to the changes in the employment structure and increase in activity rates that will slightly compensate this situation, we estimate that productive population will decline by 10% by 2060.

Figure 6 Forecast of the productive population, 2020–2060 (index 2020 = 1.00)



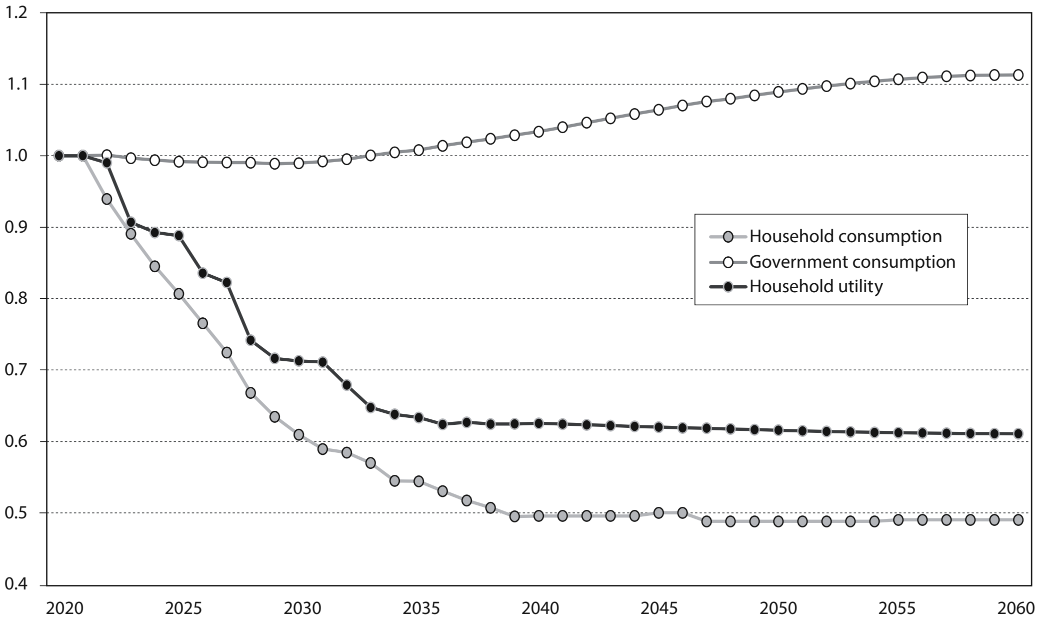
Source: Own computations based on the CZSO figures

For the CGE computation, we count with continuously improving health condition of population, annual increase of labour productivity exceeding 2% and annual overall technological progress improving capital assets by over 1.2%, see the Annex II. We are also convinced that statutory retirement age will rise

[8] The description of all CGE assumptions goes far beyond the possibilities of our contribution. We also provide their overview in the Annex I. Those who interested can find details in Šafr (2017). Since this is the first time, we publish our results, authors can be contacted, as well.

at least to the level of 70 years, irrespective of any future government promises. Under the condition of fixed parameters of our CGE model described above, we estimate that population ageing may have significant impact on different areas of our economy. This results from the analysis of the productive population that is supplemented by expected government expenditures. In other words, if nothing changes, the overall household utility will decline by 40% between 2020 and 2060, see Figure 7.

Figure 7 Results from CGE modelling under fixed assumption (2020 = 1.00)

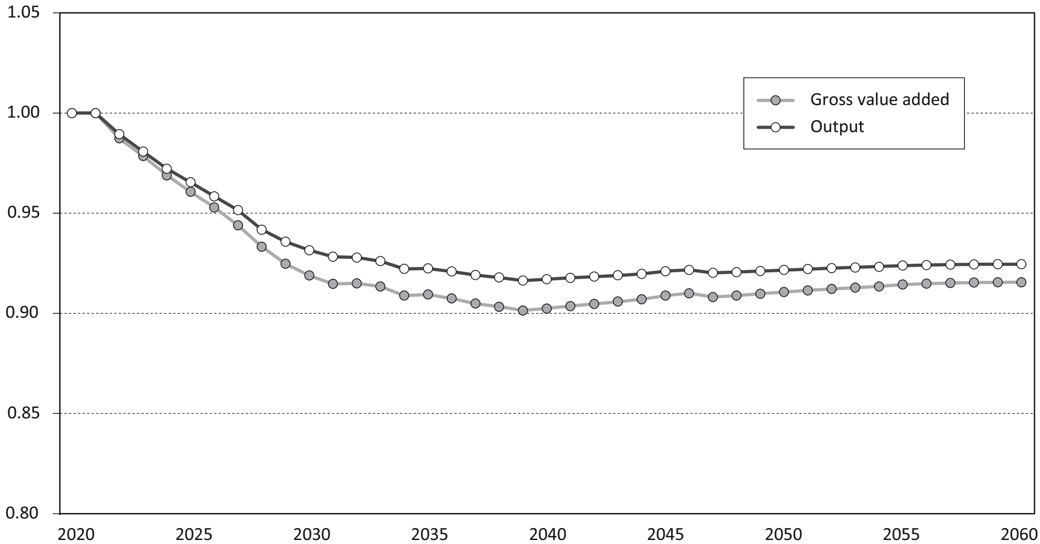


Source: Own computations based on the CZSO figures

More significant is the decrease of household consumption (–50%) because of the crowed out effect of government expenditures covering mainly mandatory expenditures (government consumption) induced by older population requiring more health and social services. It means that despite a moderate drop (–10%) of productive population, increased demand for goods and services required by securing the elderly, will result in significant drop of household utility (–40%) and consumption (–50%). Both negative effects on supply and use side ceteris paribus may result in observable reduction of household living standard. This is very radical and unrealistic result given by the Leontief´s model constraint emphasizing current state of art. In other words, the pressure on the economy will be very strong and it will result from ageing and without fundamental technological progress, the costs would be hardly affordable. Similarly, in line with the Leontief production function (2), we estimate the impact on production and value added (Figure 8). Resulting development has a form of a U-curve since firstly rapidly decreasing (–9%, –10% respectively) by 2035 and then slightly rise again back to 93%, 92% respectively of 2020 value.

With respect to the estimated demand of population, ageing labour force operating in current industries will not be able to produce the same amount of goods and services as nowadays ceteris paribus. Most of experts estimate moderate continuous increase of the technology and productivity. But if this expectation becomes true, economic costs will be significant. The economic loss may account for about 10% of gross value added in 2035 in comparison with 2020, ceteris paribus. Household may face continuous decrease of their utility exceeding 35% by 2040. Between 2040 and 2060, the decrease of the utility will be very moderate by final 60% of initial 2020 value.[9] Again, these results are very strict and probably not realistically connected with Leontief' production function restricted substitution of inputs that can inhibit the overall productivity of the factors. Real economic development will hopefully smooth the development but the message from the model is clear. If the economy worked under current conditions covering increasing productivity, affected labour supply will lead to a significant decrease of both household utility and consumption. All the positive effects such as improving health condition, ongoing increase of labour productivity and overall technological progress will not be enough.

Figure 8 Results from CGE modelling under fixed assumption (2020 = 1.00)



Source: Own computations based on the CZSO figures

The size of potential crowding out effect of household consumption by government consumption can be discussed on a theoretical level, and in fact, due to strong growth in recent decades, no one has paid much attention to it. Under the condition of stable and relatively strong growth rate of labour productivity and technological progress, CGE model shows that demographic factors simply outweigh. We also consider unfair distribution of negative effects since they fully refer to households and all the needs of the post-productive population will be fully met.

Fortunately, negative consequences may be compensated by positive economic development in technology and science but these results should alarm us that rational behaviour of policymakers is necessary and the structure of the government budgets, mainly expenditures should be carefully checked. It is also possible that demographic situation may change in terms of significantly higher migration increase or fertility.

CONCLUSION

Population ageing will affect different areas of Czech society and the impacts on the economy should not be neglected. Ageing is a complex issue that is not possible to describe within a single paper and we

[9] The horizon of our CGE model is 2060 where we expect the peak of the negative ageing effects on the economy. After 2060, demographers estimate slight smoothening of ageing since the share of the most productive population (20 to 64) is expected rising about 2 p.p. Of course, these moderating effects cannot significantly compensate ageing effects.

are aware of issues ranging from pensions schemes and health system to the impact on future youth. We focused on the introduction of labour driven changes in the economy under the condition that labour supply will be affected directly by ageing. We do not tackle the consequences for educational systems such as required professions and composition of future students but we take into account growing activity rate across all the occupations.

Each model is simplification of a complex reality and our CGE model is not an exception. Despite its relative complexity, it has lots of limitations. We prefer using Leontief´s production function since it is directly connected with current economy via input-output tables but its limitation of fixed structure inputs is obvious. Despite all limitations of the model, the development of labour supply resulting from official demographic projections is rather negative. At first sight, it seems that the aggregated indicators such as dependency ratio and estimated employment do not indicate serious problems. But the core is hidden in the structure. The burden on economically active population is shifting from a current mix of dependent children and pensioners to the stage where dependent older people may outweigh and the increase of productivity may not be enough to compensate it. Moreover, the development of the productive population will be declining due to its ageing and productivity of older workers. All this will result in a serious pressure on the government budget if future governments try to compensate the decline of household consumption possibilities (household utility). Our CGE model provides estimates by 2060 and despite expected moderating effects beyond 2060, we do not expect feasible differences by 2100, which is the last year of current demographic projection.

In our opinion it is clearly obvious that each government will have to admit significant increase of the statutory retirement age that will exceed the age of 70 years. The problem is that these unpopular measures should be communicated to the public sooner than later and these measures should be accompanied with clear ageing strategy reflecting availability of health and social care, attractiveness of study in necessary fields and prevention and maintenance of good health. Otherwise the decline of our living standards (expressed by utility in the CGE) by 2060 is not unrealistic.

ACKNOWLEDGEMENT

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ANNEX 1: List of Main CGE Model Assumptions

Nb.	Item	Description
1	Symmetric Input-Output Tables	Standard tool for modelling
2	Labour productivity by industries	Estimates by 2070 with continual increase based on IMF and MoF predictions
3	Population projections by age groups and education level	Estimates based on the CZSO data and dr. Nývlt estimates
4	Rate of workers fluctuation by industries	Estimates based on past data reflecting the possibility of workers´ willingness to change work
5	Household consumption by products and age groups	Own estimates based on national accounts
6	Health status indices by age and education groups	Estimates derived from EHIS survey based on dr. Vrabcová
7	Technological progress indices	Estimates by 2070 with continual increase based on IMF and MoF predictions
8	Division of government expenditures between mandatory and non-mandatory	Own estimates based on national accounts
9	Rate of economic activity by age groups and education	Estimates done by dr. Šimková

Source: Own elaboration

ANNEX 2: Technology and Labour Productivity Assumptions (2020 = 1.00)

Year	Technological Progress Index	Labour Productivity Index
2020	1.00	1.00
2025	1.07	1.11
2030	1.14	1.23
2035	1.22	1.36
2040	1.30	1.52
2045	1.37	1.66
2050	1.45	1.82
2055	1.54	2.00
2060	1.62	2.19
2065	1.72	2.41
2070	1.81	2.65

Source: Own elaboration based on the International Monetary Fund and the Ministry of Finance of the Czech Republic

Deviations between Government Debt and Changes in Government Deficit, why They Tend to Persist

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Abstract

Government deficit and debt represent one of the most prominent statistical aggregates playing a major role in the fiscal surveillance and in the assessment of fiscal sustainability. Achieving fiscal sustainability commonly requires a certain level of surplus/deficit to maintain a sustainable level of debt. When doing so, a close relation between both key aggregates is implicitly expected. Long-term evolution of both aggregates however does not confirm that it is the case. By analysing the data for the period 2001–2020 and by discussing the underlying statistical methodology, the paper aims to scrutinise the key factors contributing to rather counterintuitive findings where the debt is growing at a faster pace, even in the long-term, than the government deficit/surplus would suggest. The paper thus discusses the methodological causes behind the observed deviation.

Keywords	***DOI***	***JEL code***
Government deficit, government debt, stock-flow adjustments, fiscal sustainability	*https://doi.org/10.54694/stat.2021.25*	*H11, H60, E62*

INTRODUCTION

Fiscal sustainability has become one of the main challenges for governments around the globe. After dealing with the consequences of the financial crisis erupting at the end of the first decade of the 21st century, the governments are currently coping with the consequences of the COVID-19 pandemic. In doing so, the governments have routinely expanded their expenditure along with higher activity on the financial market where the government's aim is to raise additional funding by way of issuing debt instruments or acquiring loans. On the top of that, the supra-national institutions such as the European Commission step in the recovery process. By starting to issue their own debt instruments, the need for a thorough fiscal surveillance was further reinforced.

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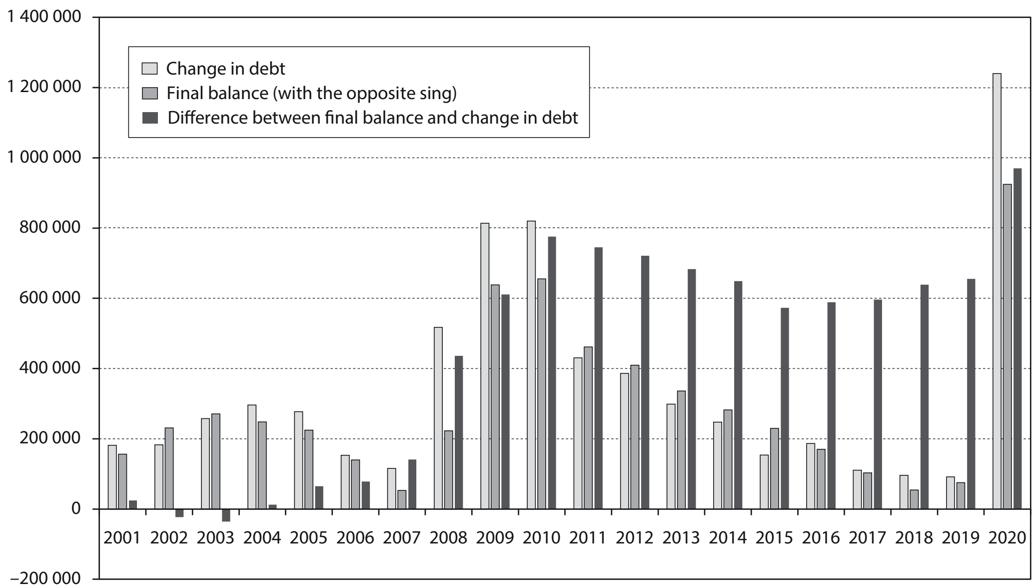
The approach towards sustainability of the public finance generally presupposes that there is a close correlation between government debt and changes in surplus/deficit. However, the construction of the relevant statistical system delivering this information leaves a wide room for deviations. As the actual evolution of the relevant aggregates signifies, sizeable disparities between the dynamics of both major aggregates tend to exist even in the long-term. Against this background, to monitor the development of the government net lending/borrowing (hereinafter: 'B.9')[2] does not necessarily suffice to conclude whether government manages its revenue and expenditure in a way which allows government to maintain its debt and the debt service at a sustainable level.

The paper thus deals with the key driving forces of existing deviations between B.9 and changes in debt, as provided by the statistical model of national accounts. The first part of the paper refers to the most recent research carried out in this field and the implication for the robustness of its conclusions. The second part concisely describes the key elements on which the statistical system is built, with a special attention paid to the sources of deviations further demonstrated by currently available data. The third part then discusses explanatory power of available public finance data and the corollaries of the existing disparities for macroeconomic analysis. The final aim of the paper is to identify whether specific operations may account for the diverting development of both aggregates.

To demonstrate the scope of this issue by using the respective data published in the context of the April 2021 EDP notification, the following figure reveals the evolution of the accumulated difference between B.9 and changes in debt for the EU-27 over the period 2001–2020. From the plotted data, we can infer that the nominal differences have been growing, which concerns mainly the years when the countries experience economic downturns, otherwise being broadly stable. Over the analysed period, the accumulated difference reached EUR 970bn that corresponds to 7.2% of the 2020 GDP of the EU-27.

Figure 1 Final balance (B.9), change in debt, the difference between final balance and change in debt (EU-27), 2001–2020 (in EUR)

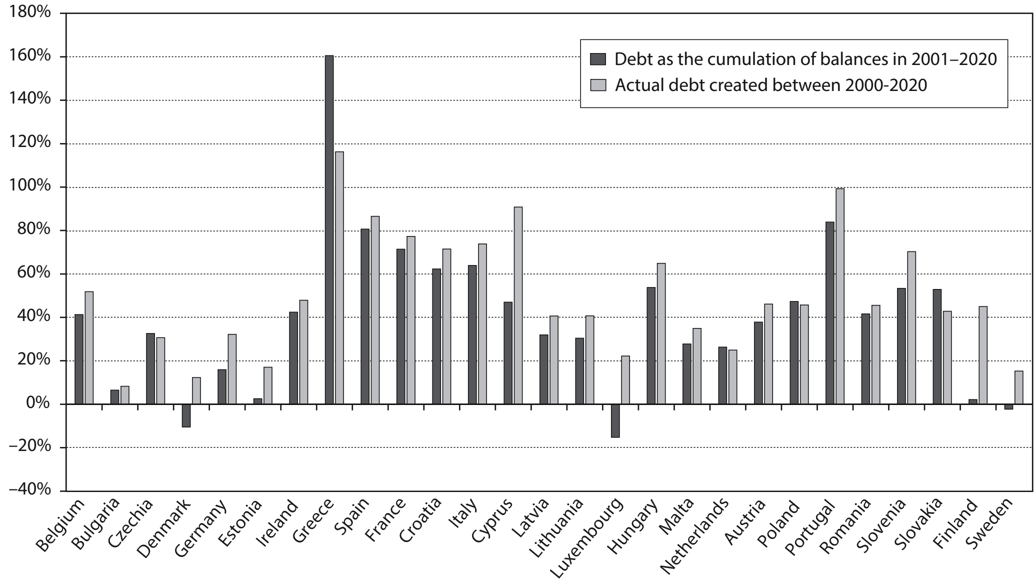


Source: Eurostat, own calculation

[2] Here the coding as introduced in the ESA 2010 is followed.

Although the extent of differences, in relative terms, may appear to be not that sizeable, this is not always the case at the level of individual countries. In the following figure, plotting the relative values of the accumulated deficits and the debt increases over the period concerned,[3] striking differences are observable in several cases such as Greece, Luxembourg, Finland, Sweden, Cyprus and Denmark. In those individual cases, the evolution of both aggregates provides, to a certain extent, somewhat different signals about the evolution of debt against the evolution of B.9.

Figure 2 The comparison between the actual debt and the accumulated surpluses/deficits by countries (EU-27), percentage of GDP



Source: Eurostat, own calculation

Taking Luxembourg as a textbook example, were all expenditures or revenues coupled with a corresponding transaction in debt instruments, the debt would have been by 15 percentage point lower or the said country would have accumulated assets reflecting the surpluses achieved in the analysed period. However, this was not the case. The debt ratio of Luxembourg has increased by 22 percentage points over the period 2001–2020, making the difference between both macroeconomic indicators standing at 37 percentage points. For the sake of the fiscal sustainability assessment, this admittedly poses a challenge, as the stabilisation of debt is obviously not only a matter of improvements in the management of the government budget. The aim of this paper is thus to analyse the reasons as to why differences of this kind not only exist but also tend to persist or even grow in their size.

1 LITERATURE REVIEW

As elaborated in detail in part 3 of the paper, the transition between the government net lending/net borrowing (B.9) and the change in debt is generally designated as 'stock-flow adjustments' (hereinafter 'SFA'). The importance of the SFA in understanding of the mutual relation between B.9 and changes in debt has been extensively investigated in numerous studies, e.g., Rybáček and Musil (2020), Weber

[3] The value of GDP, to which both values are related, is reckoned as the sum of the nominal GDP values created in all years in the period concerned (2001–2020).

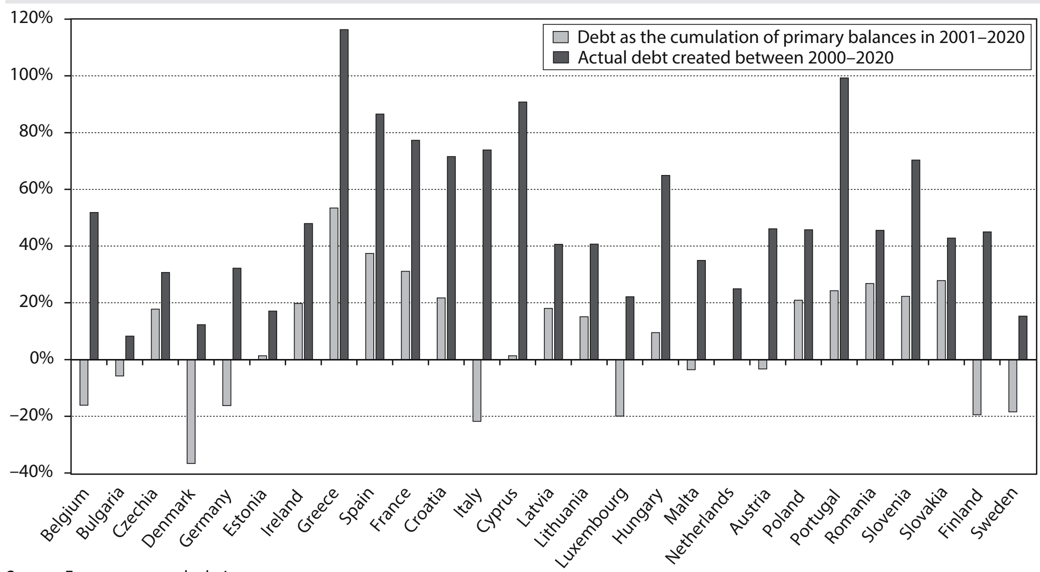
(2012), Alfonso and Jalles (2020), Milesi-Ferretti (2003), Izák (2008, 2009), or Dvořák (2010). Some perceives the aggregate 'SFA' as a blind spot in the government statistics (Jaramillo et al., 2017), which is however contributing to the growth in the government debt (Alfonso and Jalles, 2020; Weber 2012).

These findings are of significance for fiscal surveillance and for the considerations concerning the debt sustainability. When referring to the sustainability of the fiscal policy or of the debt DG ECFIN, the institution responsible for the monitoring of fiscal sustainability in the European Union, refers to the present value of future primary balances to be equal to the current level of debt. In other words, the intertemporal government budget constraint is to be satisfied (DG ECFIN, 2020; Krejdl, 2006). In similar vein, the International Monetary Fund considers the debt sustainability as a situation where the government can meet its current and future obligations without exceptional financial assistance or going to default (Hakura, 2020; Chalk and Hemming, 2000).

As analysed in Rybáček and Musil (2020), the aggregate of 'government debt' suffers by several shortcomings which may be overcame by use of an alternative aggregate such as net worth, as previously suggested by Buiter (1985). Following this suggestion, Buiter considers the fiscal policy stabilising the net worth-to-GDP ratio as a hallmark of sustainable fiscal policy. Nevertheless, as correctly objected by Groce and Juan-Ramon (2003), the existing availability of reliable net-worth data does not allow to rely on the net worth indicator. Using the net worth indicator would also bring rather more complications into the fiscal analysis (Rybáček and Musil, 2020). The existing practice thus rely on to the stabilisation of debt-GDP ratio, as suggested by Blanchard (1990).

The development in the debt ratio is assumed to be linked with the evolution of B.9, which is technically the difference between the total government revenue and expenditure. However, when assessing fiscal sustainability, economists rather refer to the concept of primary balance to reflect the actual fiscal behaviour independent of the debt accumulated in the past. The primary balance stands for the total net lending/borrowing (B.9) net of interest expenditure on the already existing debt (Pikhart et al., 2015; Ostry and Abiad, 2005; Balassone and Franco, 2000; Komárková et al., 2013). Following this approach, the debt sustainability is routinely defined as the magnitude of primary balance required for the debt-to-GDP ratio to achieve a pre-defined target by a specified date (Burnside, 2005).

Figure 3 The actual debt vs the accumulated primary balances by countries (EU-27), percentage of GDP



Source: Eurostat, own calculation

It is noted that when leaving the interest expenditure aside, the modified differences between the accumulated final (primary) balances and the change in debt would further grow compared to those presented in Figure 3 where striking differences are observable for even most of the countries. Figure 3 further reveals that when a country run an accumulated primary deficit, the growth in debt more or less substantially exceeds the theoretical growth in debt if fuelled by the accumulated primary balances, confirming the observation that the relation between both aggregates is less tight than one would expect.

2 METHODOLOGY OF THE STATISTICAL SYSTEM

Construction of the said indicators follow directly or in a slightly modified way, the definitions contained in the system of national accounts, more commonly known as 'ESA 2010' in the European Statistical System. At the European level, the methodology has a nature of regulation act (Regulation (EU) No 549/2013). The overall purpose of national accounts, which in essence is a macroeconomic model, is to provide a description of the economic behaviour and the on-going processes in the entire economy. Public sphere obviously encompasses only a part of the whole economy and of this statistical model. Public sphere is commonly understood as embracing all government-controlled units[4] operating on the non-market basis.[5] In technical terms, those units constitute so-called general government sector (S.13), as defined in the methodology of national accounts.[6]

The reporting of the relevant fiscal indicators of deficit and debt however further follows Council Regulation (EC) No 479/2009, as amended by European Regulation (EU) No 679/2010 and Commission Regulation (EU) No 220/2014 (hereinafter: 'EDP regulation'). Although the concepts are broadly the same as defined in ESA 2010, a substantial difference is the way the government debt is estimated for the EDP purposes. While ESA 2010 does not define the debt itself and the valuation of liabilities follows primarily the market concept, the EDP regulation requires the debt to be reported at its nominal value. To avoid a confusion with the basic concept in the ESA 2010 where the notion of nominal value has different meaning, for the fiscal reporting, nominal value is assimilated with face value. In terms of the scope of the instruments, the EDP debt is defined as the sum of 'currency and deposits', 'debt securities' and 'loans', all being recorded on the liability side of the government balance sheet.[7]

As the EDP data are incorporated in the assessment of fiscal sustainability, the following analysis thus employs the debt valued at nominal (face) value and its dynamics is assessed against the development of the total government net lending/borrowing (B.9) instead of the primary balance. Incorporating the total B.9 may be justified by at least two reasons. Irrespective of the concept of the final balance, the major methodological causes for the existing deviations stand for both. Furthermore, our aim is to discuss the main sources of the existing deviations which are evidenced in the EDP notification tables, namely Table 3A decomposing the SFA into single components, where B.9 is the very key input. Using the total B.9 will thus also allow us to formulate clearer conclusions as the transition between the government net lending/borrowing and the change in debt contains numerous interest-related adjustments that should have been deducted otherwise.

When analysing the extent and the nature of the SFA, it is also essential to bear in mind the distinction between non-financial and financial transactions in national accounts, as defined in the ESA 2010.[8] While the former is recorded 'above the line' in the sense that they shape the size of the B.9, the latter

4 Par. 20.08 ESA 2010.
5 Par. 2.111 ESA 2010.
6 Par. 20.19 ESA 2010.
7 The methodology of the fiscal indicators is further elaborated in the Manual on government deficit and debt (MGDD).
8 Par. 5.01 ESA 2010.

are recorded 'below the line' and have no impact on the B.9. As explained elsewhere (Rybáček, 2015), the transactions 'above the line' are coupled with transactions in financial accounts (except for barters), but the transaction 'below the line' change only the structure of financial assets and liabilities.[9]

For the analysis of the SFA, several eventualities need to be considered. First, government revenue or expenditure might be coupled with transactions in financial assets or with transactions in non-debt liabilities. If this is the case, there is no impact on the debt but the SFA would reach a non-zero value. Second, a government revenue or expenditure may take a form of a pure financial transaction. In this case, there is no impact on B.9, however if a transaction in debt instrument is involved, the value of 'SFA' is non-zero with a change in debt exceeding the amount of B.9. Third, a combination of both above-mentioned cases can be considered. Concretely, a single transaction, either revenue or expenditure, can be partitioned into its non-financial and purely financial part.

To illustrate the partitioning, let us consider a situation where government issues debt securities (100) to exploit the cash received to assist a bank in financial difficulties. Let us further assume that the bank benefitting from the government assistance runs the accumulated loss in the amount of 50. As it is routinely the case, the amount corresponding to the accumulated loss is considered in national accounts as capital transfer negatively affecting B.9 while the remaining 50 is booked as purely financial transaction without any impact on B.9. When this recording is applied, we arrive at an increase in debt by 100 while the B.9 ends up in the deficit of 50, leaving the SFA at 50. Only were the entire 100 recorded as non-financial transaction, the SFA would be zero. To sum up, a transaction might be split in the part weighing on B.9, with the remaining adding to the SFA.

To generalise this observation, any cash raised on the financial markets from the debt issuance which is not used to finance government expenditure 'above the line', gives rise to a non-zero 'SFA'. Conversely, any surplus generated by government, which is not used to amortise the existing debt, adds to the aggregate of the 'SFA' as well. Time difference between the year in which debt securities were placed on the market and when the cash raised is intended to be spent may, of course, also exist. Given the twenty-year long period used in our analysis, this element should not have a disruptive effect on our conclusions. Moreover, the intended expenditure does not need to take the form of transactions affecting the B.9 or to be expensed at all. Government may simply issue debt securities to increase its cash holding in expectation that the market situation may worsen or the economy may shrink. If this expectation is not confirmed, government may use the cash to reduce again its debt, bringing however a volatility into the evolution of debt which would be fully independent of the development in B.9.

The eventual amount of the aggregate SFA further reflects the fact that the EDP debt is valued at nominal (face) value. To arrive at nominal (face) value, as requested by the EDP regulation, a few methodological adjustments in the EDP Table 3 are to be introduced, such as issuance above/below nominal values, accrued interest or redemption of debt above/below nominal value. This class of adjustments revalued the debt-related transactions recorded in national accounts at arm's length into their nominal value. To illustrate this issue, let us consider that government repurchased its own debt securities (100) from the market whereas the transaction was carried out above par (110). When the transaction is completed, the reduction in the nominal debt must reflect the nominal value of repurchased debt (100) and not the cash expensed on this operation (110). The adjustment (10) thus reflects the difference between both value concepts.

3 ANALYSIS OF THE SFA

To facilitate the analysis and demonstrate numerically the conclusions drawn from the data, the following table groups the results in a similar way as those published officially (Table 3A in the EDP notification

9 Par. 5.33 ESA 2010, par. 5.34 ESA 2010.

tables). Although Table 1 is an abridged version of Table 3A, it conveys the key indicators decomposing the transition from the general government net lending/borrowing (B.9) to the change in its debt. As the sufficiently detailed data covering the whole period 2001–2020 were available for only some of the EU Member states, the figures in Table 1 cover nine Eurozone countries (Belgium, Greece, Spain, Latvia, Lithuania, Luxembourg, the Netherlands, Portugal and Slovenia) and four non-Eurozone countries (Czechia, Hungary, Poland and Romania) for which the figures converted in EUR are used.

Table 1 EDP Table 3 for selected countries, 2001–2020 (in EUR)

	All countries	Eurozone countries	Eurozone countries excl. Greece
Net lending (–)/net borrowing (+) (B.9) of general government (S.13)	**2 301 231**	**1 777 302**	**1 511 100**
Net acquisition (+) of financial assets	**431 296**	**335 356**	**278 193**
Currency and deposits	197 511	123 110	95 569
Debt securities	9 065	4 510	41
Loans	122 480	102 454	101 369
Equity and investment fund shares/units	–30 573	17 280	8 160
Financial derivatives	–38 557	–32 746	–32 778
Other accounts receivable	170 356	120 128	105 806
Other financial assets	1 012	619	25
Adjustments	**–300 184**	**–218 407**	**–90 218**
Net incurrence (–) of liabilities in financial derivatives	9 429	5 340	1 729
Net incurrence (–) of other accounts payable	–221 333	–105 157	–90 000
Net incurrence (–) of other liabilities	–7 908	–4 969	–4 159
Issuances above (–)/below (+) nominal value	–107 602	–106 288	–108 305
Difference between interest accrued (–) and paid (+)	21 056	25 805	32 735
Redemptions/repurchase of debt above (+)/below (–) nominal value	–106 841	–109 364	8 479
Appreciation (+)/depreciation (–) of foreign-currency debt	32 804	2 007	605
Changes in sector classification (+/–)	78 910	72 307	66 786
Other volume changes in financial liabilities (–)	1 301	1 912	1 912
Statistical discrepancies	–19 043	–17 275	–14 905
Change in general government (S 13) consolidated gross debt	**2 413 302**	**1 876 978**	**1 684 172**
Difference between the change in debt and the deficit/surplus	**112 071**	**99 676**	**173 072**

Source: Eurostat, own calculations

Obviously, the group of financial transactions in assets constitutes the major source of the deviation between B.9 and the change in debt. In fact, the totals for financial transactions do exceed the overall difference indicated in the last row in Table 1, meaning that if the financial transactions in assets were the only constituent of the SFA, the debt would be even higher than it currently stands. However, the second main group covering the methodological adjustments compensates to a certain extent the impact of the financial transaction on growth in debt. This stands mainly for the transactions in 'other account payables' which serve as a counterpart to transaction where there is a time difference between these transactions and the corresponding payments (par 5.230 ESA 2010).[10] In other words, a certain part of the government expenditure, either non-financial or financial such as an acquisition of financial assets, are financed by an incurrence of non-debt financial liabilities.

Interestingly, a relatively significant influence is observable also for the adjustments related to the accrual interest and the issuances of debt above or below nominal value of debt instruments. For the former, the nominal debt is valued leaving aside the interest accrued on existing debt. Thus, while the accrued interest weighs on B.9, it does not add to the nominal value of debt. The contribution of this adjustment can be either positive or negative, depending on the relation between the interest actually cashed and accrued. Over the analysed period, the total for the countries concerned reached a positive amount of 33 billion implying that the interest actually paid (cash) exceed that accrued over the period in question.

For the latter, governments often raise more cash than is the nominal value of debt securities placed on the market. Although going usually unnoticed, such favourable market condition causes a certain disparity in B.9 and change in debt, even if the entire proceeds from the issuance is available to government to expense. Assuming that government issues the 100 bonds above par (110) whereby raises a cash in excess of the nominal value of debt instrument, government can now spend 110, while the adding to the government debt is only 100. Therefore, if the interest rate or the price of bonds are such that it allows the government to receive additional cash more than the nominal value of bonds, the discrepancy between deficit (110) and the increase in debt (100) occurs (10). That amount is consequently included in the adjustment depicting the transition between B.9 and the change in debt. Generally speaking, different pricing applied in the valuation of B.9 and debt also adds to the eventual value of the aggregate SFA.

Except for the adjustments concerning accrual interest and the issuances above/below par, EDP Table 3 provides also an information on the effect of redemptions/repurchases of debt above or below nominal value. Although the value in Table 1 above is not negligible, the extent of this adjustment is dominated by the transaction with the Greek bonds carried out in 2012, further discussed in the following chapter. Were this particular transaction left aside, the overall impact of the said adjustment falls into insignificance. Just the opposite is however true for the item 'changes in sector classification' whose contribution to the growth in debt is significantly positive. This adjustment itself can explain more than one third of the overall difference between deficit and debt.

The effect of changing sector classification should be also considered as the definition of the government sector has been developing quite dynamically and it is a current practice of the statistical offices that the sector classification of units is regularly reassessed. If a reclassification takes place, either inside or outside general government, the impact depends on the economic situation of the unit to be reclassified. If reclassified inside general government, the debt incurred by the unit in the past will add fully or partly to the total government debt, depending on the extent of consolidation. However, the economic activity creating the debt is not necessarily reflected in the government accounts in its entirety as the unit might be reclassified only starting the year in which it fails to meet the criteria of being considered as non-government unit. If this is the case, then B.9 in the previous years is not affected by the reclassification while the entire debt accumulated over years is transferred to the government accounts. It is of note that the reclassification may also concern debt assumption if the debt is assumed along with a certain asset. If this is the case, then B.9 is impacted only up to the value of gap between assumed assets and debt.

[10] Church restitutions in the Czech Republic can serve as case in point. In this context, a sizeable amount has been booked as capital transfer, weighing on the 2013 deficit of the government. In the financial accounts, the counterparty of this expenditure was the item 'other accounts payable', leaving the change in debt intact.

4 DISCUSSION

In the paragraphs below, we will mention some of the measures undertaken by the governments in Europe in the past, which led to substantial increases in the SFA. The aim is to pinpoint that kind of transactions and government measures which may stand behind the deviations between the key fiscal aggregates and, by divorcing the development of deficit from that of debt, may bring certain noise into the fiscal sustainability assessment which is normally based on the analysis of both major aggregates. The operations described below concerned Cyprus, Luxembourg, Greece and Hungary.

In the analysed period, sizeable aggregates of the SFA were observable in Cyprus. This holds mainly for the years 2012 (7.4),[11] 2013 (11.6), 2014 (–7.1), 2018 (7.9) and 2020 (12.8). For the period 2012–2014, the large values are clearly attributable to the operations carried out by the Cypriot Government in the wake of the financial crisis which forced the government to take on debts. In addition, by several capital injections into failing banking institutions, the government increased its holding in equities which was partly financed by the deficit-increasing operation, up to the accumulated losses of the benefitting institution, with the remaining part being considered as an acquisition of equity without any impact on deficit. In 2018, an asset management company then acquired a loan portfolio from a failed bank which accounts for the significant 'SFA' in this year. Relatedly, the impairment of these loans lead to the record value reported in 2020.[12] It follows that extraordinary measures aiming to cope with the consequences of the financial crisis triggered the striking 'SFAs'.

In case of Luxembourg, the most striking difference appears in the year 2007 (10.9). However, except for the years 2004 and 2020, incrementally increasing debt were regularly surpassing the contributions of the government net lending/borrowing which ended up in surpluses in most of the years concerned. The reason for the deviation between both aggregates is regular investment activities of the Luxembourgish government institutions, chiefly in the form of the acquisition of equities explaining 41% of the difference between the total deficit and change in debt. The similar holds true for the purchases of debt securities which can explain further 40% of the difference. In this case, the difference in the development of both aggregates is thus attributable to the investment behaviour of the government institutions.

Other interesting example, which lead to a sizeable adjustment reaching 11.1% of GDP, is observable in Hungary in the year 2011. In that year, the Hungarian Government overtook the second pillar pension fund's equity assets. As the recipient of the portfolio was the Pension Reform and Debt Reduction Fund, a unit classified in the general government entity, and the related transactions were booked in non-debt instrument in the balance sheet, the adjustment of 'SFA' reached a strikingly high value. Introduction of a pension reform is however not an exceptional, the most recent case happened in Greece in 2019, an unbalanced transfer[13] of pension assets and liabilities. However, these cases are an example of situations where the increases in debt lack behind the deficit run by the government because a sizeable expenditure as coupled with transactions in non-debt instruments.

In case of Greece, the source of the deviation can be traced down quite reliably. It is the debt restructuring consisting in bond exchanges carried out in 2012, whereby Greece managed to reduce its debt by EUR 51 billion. By doing so, the investors lost 53.5% of the nominal value of bonds.[14] It is thus this one-off measurement which constitutes the main source of the deviation. As shown in Table 1, the total difference

[11] Positive value implies the growth in debt exceeding the contribution of the government net lending/borrowing in given year. Negative value implies the opposite, i.e., the debt increase was lower than that which would correspond to the government net lending/borrowing.

[12] <https://ec.europa.eu/eurostat/documents/1015035/12665809/SFA-PR-2021-Apr.pdf/4673ffe8-73d4-67b2-c082-bfb-64c1ed422?t=1618235209605>.

[13] In a sense that the value of transferred assets does not match the value of the transferred liabilities. If so, the gap between both has an impact on the government net lending/net borrowing.

[14] European Commission (2020b).

stood at 44 percentage points. This might be interpreted so that if it were not for this debt haircut, the Greek Government debt ratio would be by 44 percentage points higher. From the perspective of our analysis, were this transaction not realised, the accumulated deficits and the change in debt over the analysed period would almost perfectly match, with the difference only 1 percentage point.

CONCLUSION

Faster growing debt or even divergent development in both major indicators might be thus triggered and steadily fuelled by several factors. As shown above, transactions with financial assets represent the most significant source of deviation and the source of the debt growing at faster pace than that indicated by the government net lending/borrowing. As further discussed and evidenced in several countries, this is primarily linked to investment activities of the government institutions. This can be materialised in operations related to the measures in the wake of economic crisis such as capital injections into troubled companies, investing of surpluses that are not used to amortise the existing debts or the debt management with the volatility in the cash holding, although the last factor is of rather temporary nature. As these debt-related transactions are not intended to finance expenditure that enter B.9 or only partly as discussed above, the SFA and a certain divergence between B.9 and debt inevitably occurs.

The second group of factors driving the deviation of B.9 and debt is more of a methodological nature. This concerns the reconciliation of market transactions entering B.9 with the nominal valuation of debt. Admittedly, these adjustments deserve to be monitored, as their size is dependent on the prevailing market conditions and the monetary environment. Furthermore, reclassifications of units or debt assumptions should be mentioned as another important cause of the divergence. Reclassification of units into the general government is a regular practice of the statistical institutes and in addition to that, the methodology itself is still evolving towards the general government sector encompassing still wider population of government-controlled units. While these factors regularly affect the deviation, the debt haircut carried out in 2012 is rather an exceptional case that may however also pose a significant impact on the relation between B.9 and the change debt.

We can conclude that the relation between government net lending/net borrowing and debt is not straightforward, a wide range of factors are entering between the evolutions of both. The aim of this paper was not only to provide quantifications of the accumulated differences, but not least to identify the major causes behind the observed deviations. In addition to those factors analysed in the paper, rising interest rate, economic cycle or even high rates of inflation should be also noted and further investigated in economic research. Generally, the finding that government debt may grow in the long-term independently of the actual net lending/borrowing run by the government, brings certain uncertainty into the considerations concerning the fiscal sustainability of which analysists and researchers should be aware.

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Income and Inequality Measures in Households in the Czech Republic and Poland based on Zenga Distribution

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Abstract

Income is one of the appropriate indicators for the evaluating of living standards of people, so it is important to examine the distribution of income and its degree of differentiation in society. A lot of research has been directed at describing empirical distributions by the theoretical model. In 2010 Zenga proposed a new three-parameter model for economic size distribution. The aim of this paper was to apply Zenga model to income distribution in the Czech Republic and in Poland. The results of conducted approximations obtained by means of D'Addario's invariants methods confirm that the Zenga distribution is a good income distribution model which can be successfully applied to income inequality analysis and income distribution comparisons both in the Czech Republic and in Poland.

Keywords	DOI	JEL code
Household income, Zenga distribution, Gini inequality index, Zenga income inequality index	*https://doi.org/10.54694/stat.2021.12*	*C10, C13, C15*

INTRODUCTION

Since Pareto proposed his first income distribution model, many economists and mathematicians tried to describe empirical distributions by simple mathematical formulas with a small number of parameters. For a majority of countries we observe similar, characteristic shape of the income distribution. For many countries income distributions are single-modal with right-sided asymmetry. Theoretical models can be used for the approximation of empirical distributions, in order to obtain information from the data by the parameter estimates and their interpretation. After the one parameter Pareto model (Pareto, 1987), the two-parameter models such as the log-normal model (Gibrat, 1931), the gamma (Salem and Mount,

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1974), and the Weibull model (Bartels and Van Metele, 1976) were introduced. The three-parameter models appeared, such as the generalized gamma (Taille, 1981), Singh-Maddala (Singh and Maddala, 1976) and Dagum (Dagum, 1977). The four-parameter models called the generalized beta of the first and second kind (GB1 and GB2) were introduced by McDonald (1984). Descriptions of many income distributions and approximation methods are included in the papers (Kleiber and Kotz, 2003; Brzeziński, 2013). For many countries the three-parameter distributions have represented a good approximation of income distribution (Ćwiek and Ulman 2019).

In this paper a new three-parameter model for distributions by size proposed by Zenga (2010) is analyzed. Zenga distribution is a Beta mixture defined for non-negative distributions, that has positive skewness and Paretian right tail. Zenga model is particularly indicated for describing income, financial and actuarial distributions. The parameters of Zenga distribution separately control the location and inequality. Zenga distribution is obtained as a mixture of Poliscchio distributions with mixing function given by the Beta density with μ constant and $k \in (0,1)$. Zenga model has three parameters: is a scale parameter and it is equal to the expected value, and are shape parameters that inequality depends on. This has implications in parameter estimation, because the restrictions on the expected value and on inequality measure can be imposed separately (Arcagni and Porro 2013). The estimate parameters of Zenga distribution can be found, through D'Addario's invariants method or by imposing restrictions on numerical optimization. These methods have been applied by (Zenga et al., 2010b) and (Arcagni, 2011) to estimate the parameters of Zenga distribution. Due to the Paretian right-tail, Zenga distribution can fit the income distributions for large values. This model can embrace several shapes and this feature allows a good fitting also for small incomes. The model can be zero modal and unimodal although it has only two shape parameters and the expected value of Zenga model is always finite. This is an advantage, because if the expected value of fitted model is not finite, it does not have economic interpretation. Studies performed in various countries show that Zenga distribution exhibit high conformance to empirical distributions of incomes, (Zenga et al., 2010b; Arcagni and Porro, 2013).

Various theoretical distributions were used to approximate the income distributions of the Czech Republic and Polish population (Bartošová and Bína, 2009; Bílková, 2008; Duspivá and Spảcil, 2011; Malá, 2011; Malá, 2013; Matějka and Duspivová, 2013; Kordos, 1990; Brzeziński, 2013; Ostasiewicz, 2013; Salamaga, 2016; Jędrzejczak and Pekasiewicz, 2018; Ćwiek and Ulman 2019). Zenga probability distribution has not been used so far to analyze income distributions in the Czech Republic. The density function of the Zenga has a number of interesting statistical properties and thus easily adapts to various types of empirical income distributions. The aim of this paper is to apply the Zenga distribution to the analysis of income distributions of households in Czech Republic and Poland, which have been distinguished by means of the main or leading source of maintenance.

This paper is organized as follows. Zenga income distribution is presented in Section 1 providing probability density function, distribution function and some other main features. Section 2 is devoted to the description of the Lorenz curve and the Zenga curve. The application of Zenga model to empirical income distributions for the Czech Republic and Poland is shown in Section 3. In the same section, an analysis of income inequality in both countries was presented. In the last section some final remarks are discussed.

1 ZENGA INCOME DISTRIBUTION

The three-parameter income model was introduced by Zenga (Zenga, 2010a; Zenga, Pasquazzi, Polisicchio, 2010b; Zenga, Pasquazzi, Zenga, 2012). The density function $f(x:\mu;\alpha;\theta)$ in Zenga probability distribution has been obtained as a mixture of Poliscichio's (Poliscichio, 2008) following truncated Pareto density:

$$v(x:\mu;k)=\begin{cases}\frac{\sqrt{\mu}}{2}k^{0.5}(1-k)^{-1}x^{-1.5}, & \mu k\le x\le\frac{\mu}{k};\quad \mu>0,\quad 0<k<1,\\ 0, & \text{otherwise,}\end{cases}\tag{1}$$

with a fixed $\mu > 0$ and all the values of k in the interval (0; 1). The density on the parameter k is given by the beta density and has the following form:

$$g(k:\alpha;\theta)=\begin{cases}\frac{k^{\alpha-1}(1-k)^{\theta-1}}{B(\alpha;\theta)}, & 0<k<1;\quad \theta>0,\ \alpha>0,\\ 0, & \text{otherwise}\end{cases},\tag{2}$$

where B (α; θ is the beta function.

The model is characterized by the probability density function $f(x:\mu;\alpha;\theta)$ for non-negative variables:

$$f(x:\mu;\alpha;\theta)=\int_0^1 v(x:\mu;k)\,g(k:\alpha;\theta)\,dk$$
$$=\begin{cases}\frac{1}{2\mu B(\alpha;\theta)}\left(\frac{x}{\mu}\right)^{-1.5}\int_0^{\frac{x}{\mu}}k^{\alpha-0.5}(1-k)^{\theta-2}\,dk, & \text{for}\quad 0<x<\mu,\\ \frac{1}{2\mu B(\alpha;\theta)}\left(\frac{\mu}{x}\right)^{1.5}\int_0^{\frac{\mu}{x}}k^{\alpha-0.5}(1-k)^{\theta-2}\,dk, & \text{for}\quad x>\mu.\end{cases}\tag{3}$$

The parameter α is an inverse inequality indicator and θ is direct inequality indicator. In particular the bigger value of the parameter α the less unequal the distribution and the bigger the value, the more unequal the distribution (Porro, 2015).

In the case $\theta > 0$, the distribution function $\mathrm{F}(x:\mu;\alpha;\theta)$ is described by the formula:

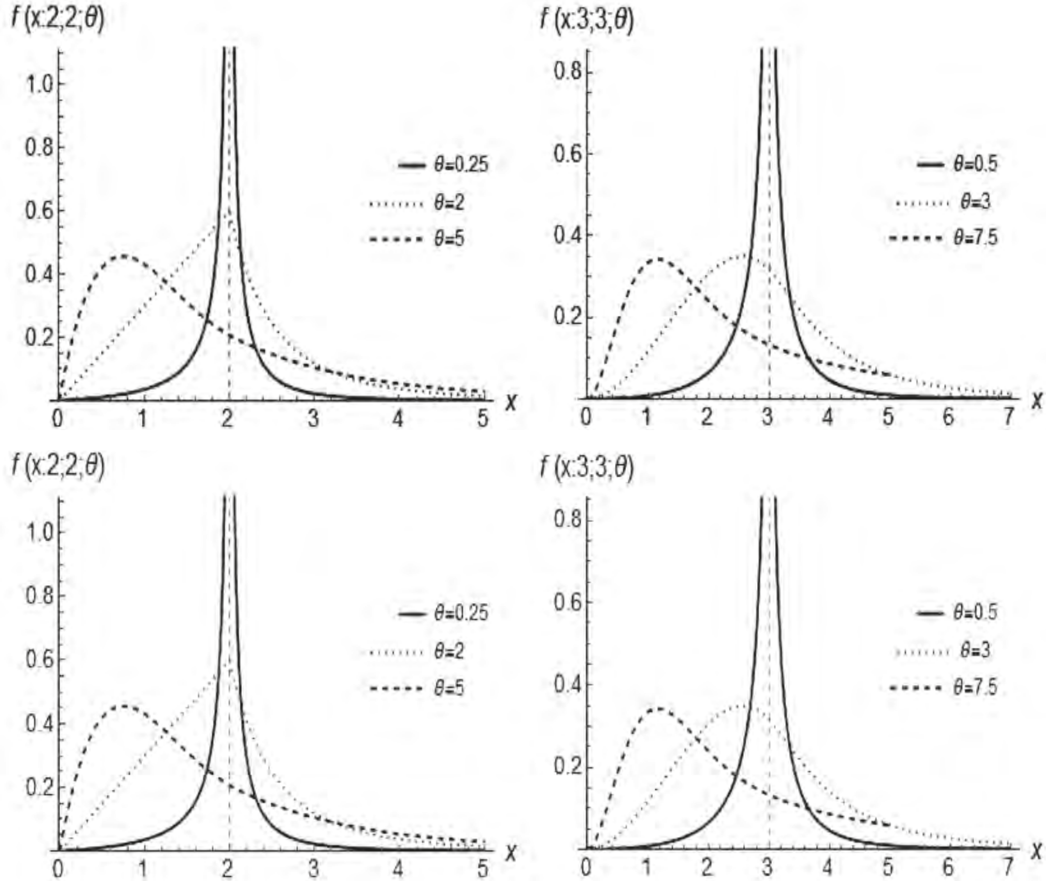
$$F(x:\mu;\alpha;\theta)=\begin{cases}\frac{1}{B(\alpha,\theta)}\sum_{i=1}^{\infty}\left\{IB\left(\frac{x}{\mu};\alpha+i-1;\theta\right)-\left(\frac{\mu}{x}\right)^{0.5}IB\left(\frac{x}{\mu};\alpha+i-0.5;\theta\right)\right\}, & \text{if } 0<x\le\mu\\ 1-\frac{1}{B(\alpha,\theta)}\sum_{i=1}^{\infty}\left\{\left(\frac{\mu}{x}\right)^{0.5}IB\left(\frac{\mu}{x};\alpha+i-0.5;\theta\right)-IB\left(\frac{\mu}{x};\alpha+i;\theta\right)\right\}, & \text{if } \mu<x.\end{cases}\tag{4}$$

where:

$$IB(x;\alpha;\theta)=\int_0^x t^{\alpha-1}(1-t)^{\theta-1}\,dt,\quad 0<x<1,\tag{5}$$

is the incomplete beta function.

Figure 1 Density plots of the Zenga income model for some parameter values



Source: Authors' calculations

It is easy to see that density functions in Figure 1 and distribution functions in Figure 2 are very flexible and its plot can have different shapes depending on the values of the parameters. The Zenga density function and distribution function allow for a wider variety of shapes than traditional three-parameter models of income distributions.

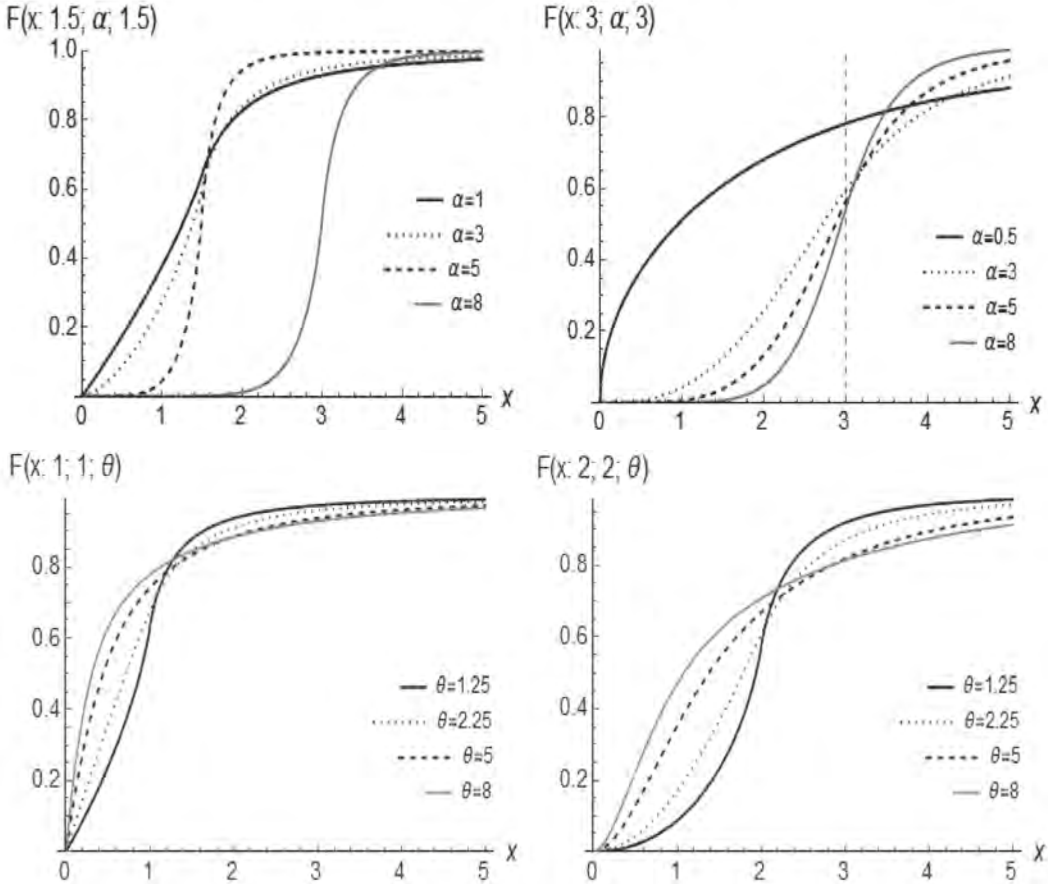
The Zenga income distribution meets the criteria set of the theoretical income distribution. The most important are the following:

- Convergence to the Pareto law for high income groups.
- Existence of only a small number of finite moments of a distributions (heavy tails).
- Goodness of fit for a whole range of a distribution.
- Simple interpretation of parameters.
- Simplicity (or small number of parameters).

2 POINT INEQUALITY CURVES

The analysis and the graphical representation of inequality play a very important role in economics. Inequality curves are graphical methods used to analyse, characterize and to generally relate to inequality indexes. The Lorenz curve (Lorenz, 1905) and the Zenga curve (Zenga, 2007a) are the most used inequality

Figure 2 Distribution function plots of the Zenga income model for some parameter values



Source: Authors' calculations

curves these days. The Zenga curve (Zenga, 2007a, 2007b) can embrace different shapes, which allow to distinguish different situations in terms of inequality. We obtain for the Zenga density function $f\left(x:\mu;\alpha;\theta\right)$ the graphs of the Lorenz curve and of Zenga's point inequality measure (Zenga, 2007a). These point measures are invariant to scale transformation, so it is enough to consider this case $f\left(x:1;\alpha;\theta\right)$. To obtain the graphs of these point measures we need to evaluate the first incomplete moment $H(x)$.

The first incomplete moment of the density $f\left(x:\mu;\alpha;\theta\right)$ is given by:

$$H(x{:}\,1;\alpha;\theta)=\begin{cases} H_1(x{:}\,1;\alpha;\theta)=\dfrac{1}{B(\alpha;\theta)}\sum\limits_{i=1}^{\infty}[x^{0.5}IB(x{:}\,\alpha+i-0.5;\theta)+ \\ \qquad -IB(x{:}\,\alpha+i;\theta)], \\ \qquad \text{if } 0<x\leq 1 \\ H_2(x{:}\,1;\alpha;\theta)=1-\dfrac{1}{B(\alpha;\theta)}\sum\limits_{i=1}^{\infty}[IB\,(\dfrac{1}{x}{:}\,\alpha+i-1;\theta)+ \\ \qquad +x^{0.5}IB\,(\dfrac{1}{x}{:}\,\alpha+i-0.5;\theta)], \\ \qquad \text{if } 1<x. \end{cases} \tag{6}$$

The graphs of the Lorenz curve can be obtained putting in abscissa $F(x)$ and in ordinate $H(x)$ for a sufficient number of values of x. Zenga's point inequality (Zenga, 2007a) has the form:

$$A(x) = \frac{F(x:1;\alpha;\theta) - H(x:1;\alpha;\theta)}{F(x:1;\alpha;\theta)\left[1 - H(x:1;\alpha;\theta)\right]}.$$

The graphs of Zenga's point inequality can be obtained putting in abscissa $\mathrm{F}(x:1;\alpha;\theta)$ and $A(x)$ on the ordinate axis for a sufficient number of values of x.

Figures 8 to 12 contain the graphs of the Lorenz curve L(p) and the Zenga curve $I(p)$-where $p = F(x)$.

3 ANALYSIS OF INCOMES

In this paper all calculations are based on the data from research European Quality of Life Surveys (EQLS), whose purpose is to measure both objective and subjective indicators of the standard of living of citizens and their households. The analyzed data of monthly household income has been recalculated into the income per member of the household expressed in Euro. The Zenga model for the Czech Republic and Poland was used for two periods: 2007 and 2016.

The results of the approximation of the empirical income distributions in the Czech Republic and Poland by means of the Zenga income model, together with the goodness of fit measures $A_{1,}$ and W_p and estimated standard errors of point estimates are presented in Table 1 and in Figures 3–6. The approximation methods for the Zenga income distribution have been analysed in paper (Zenga, 2010a; Arcagni and Porro, 2013). Table 1 contains the parameter estimates obtained by means of D'Addario's invariants methods which gave the best fitting.

To find a degree of adjustments of a theoretical distribution to the empirical one, we have calculated the goodness of fit measures: the Mortara index $A_{1,}$:

$$A_1 = \frac{1}{n}\sum_{j=1}^{s}\left|n_j - \hat{n}_j\right|, \tag{7}$$

where n_j and $\hat{n}_j$ are respectively the observed and the estimated frequencies of the j-th interval. The n observations are grouped into s = 10 intervals, where $j = 1, ..., s$. The smaller the value of , A_1 the higher the consistency of compared distributions.

The coefficient of distributions similarity W_p for the empirical data arranged into a grouped frequency distribution with s-class intervals can be calculated by the formula:

$$W_p = \sum_{i=1}^{s} min(w_i\ ; w_i^{'}), \tag{8}$$

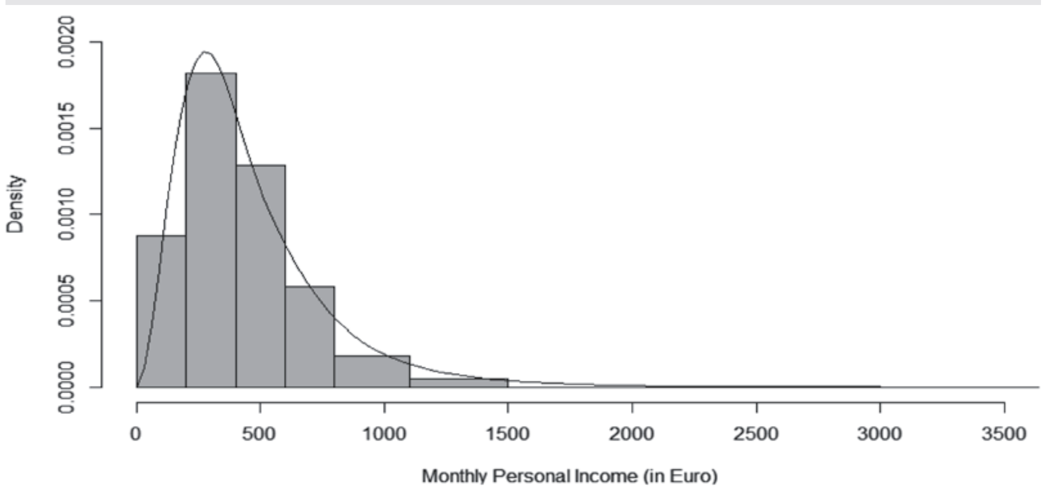
where w_i and $w_i^{'}$ represent empirical and theoretical frequencies, respectively. The bigger the value of W_p, the higher the consistency of compared distributions. The presented measures of distributions similarity has a clear interpretation. The data aggregation was necessary to calculate indexes of goodness of fit. Aggregation was applied using methods presented in the papers (Zenga, 2010a; Porro, 2015; Brzeziński, 2013). In order to obtain personal income distributions, in all our estimations we have to recalculated original data. Observations with zero incomes and the data gaps were excluded from the analysis, but this affected less than 1.5% of all observations for all of our data sets. It is worth noting here that the removed observations are few in the scale of the entire sample. Moreover, it is necessary to apply the Zenga income model. Note that the Zenga probability density function is defined for non-negative income. This approach can be useful for many reasons. Firstly, applying the theoretical income model simplifies the analysis. Knowledge of the model of income distribution, which is a simple approximation of empirical distribution and knowledge of tendency of its parameters development may be used to predict behavior of the particular variable in the following period of time. Moreover, the approximation of the empirical wage and income distributions by means of the theoretical curves can smooth the irregularities coming from the method of data collecting. Table 1 presents estimation results for income distributions based on the data coming from EQLS. The table contains the parameters estimates obtained by means of D'Addario's invariants method, as it is described in (D'Addario, 1939; Zenga, 2010). The distribution of estimators has been analyzed by parametric Bootstrap resampling. Numerical methods of optimization and Bootstrap resampling were carried out using Mathematica program.

Table 1 Estimation results for income distributions in the Czech Republic and Poland based on the data coming from EQLS

Country	Year	Estimated values of parameters and standard errors			Indexes of goodness of fit	
		$\hat{\mu}$	$\hat{\alpha}$	$\hat{\theta}$	A_1	W_p
Czech Republic	2007	472.2562 (10.7448)	2.8870 (1.1222)	4.5943 (1.9652)	0.1044	0.9478
Poland	2007	309.9459 (8.4357)	1.5561 (0.0816)	3.4597 (0.0929)	0.0661	0.9668
Czech Republic	2016	822.0742 (16.6443)	2.0000 (0.1364)	3.0000 (0.2848)	0.1397	0.9309
Poland	2016	553.4071 (22.4882)	1.5183 (0.3439)	3.5151 (1.0528)	0.0796	0.9595

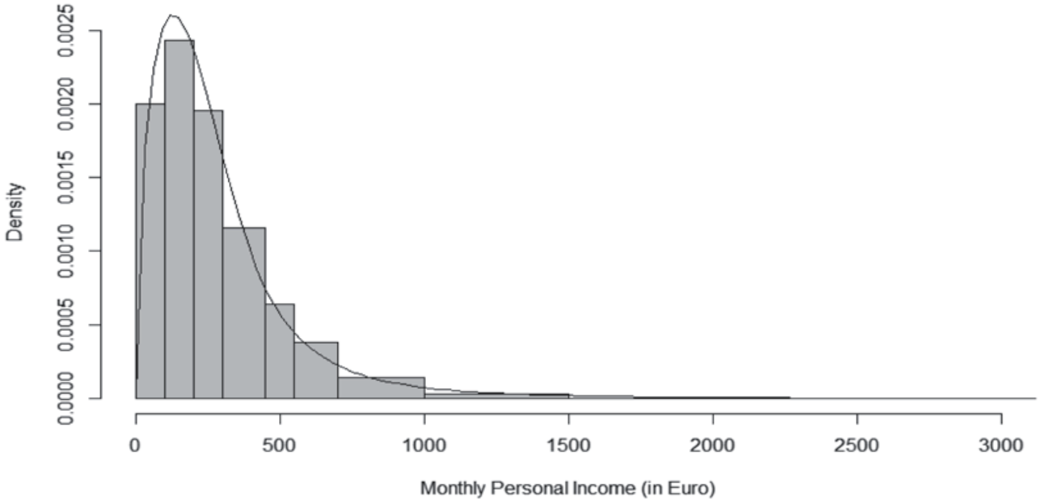
Note: Standard errors are given in parentheses.
Source: Author's calculation

Figure 3 Zenga density fitted to empirical the Czech Republic household income distribution in the year 2007 (787 observations)



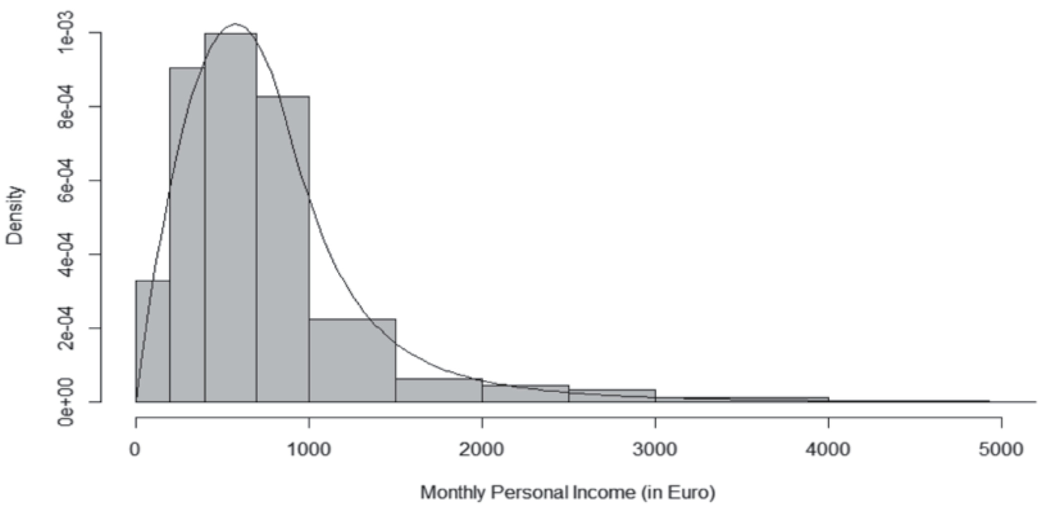
Source: Authors' calculation

Figure 4 Zenga density fitted to empirical Poland household income distribution in the year 2007 (1 065 observations)



Source: Authors' calculation

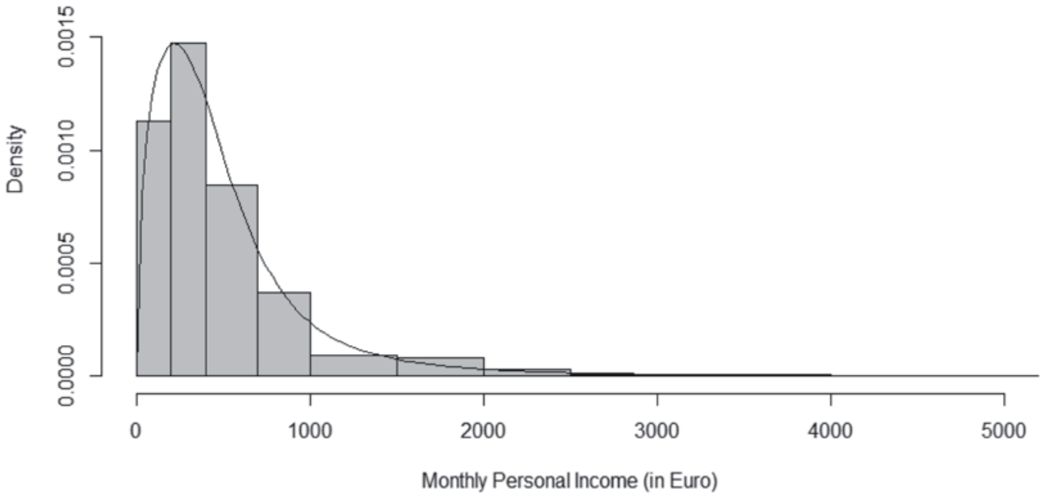
Figure 5 Zenga density fitted to empirical the Czech Republic household income distribution in the year 2016 (686 observations)



Source: Authors' calculation

The Zenga income model is characterized by the high flexibility. The results of the calculations presented in Table 1 and in Figures 3–6 confirm good consistency of the Zenga probability distribution with the empirical income distribution in the Czech Republic and Poland. Which is consistent with our previous work (Jędrzejczak and Trzcińska, 2018; Trzcińska, 2020). The consistency is slightly worse for the Czech Republic and Poland in the year 2016. Note that in 2016 the distributions for both countries are more asymmetrical (Figures 5 and 6). The precision of the estimation is presented in Table 2.

Figure 6 Zenga density fitted to empirical Poland 2016 household income distribution in the year 2016 (733 observations)



Source: Authors' calculation

Table 2 Empirical and fitted characteristics for the Czech Republic and Poland

Country	Year	Mean	Median	Cumulative value for the mean	Variance	Quantile 0.1	Quantile 0.25	Quantile 0.75	Quantile 0.95
Empirical values									
Czech Republic	2007	472.2562	376.3158	0.6404	143 554.2	153.5088	256.4912	565.2047	966.6667
Poland	2007	309.9459	234.2262	0.6488	153 295.6	64.7081	114.5833	385.1191	802.3810
Czech Republic	2016	822.0742	636.9987	0.6837	69 7699	243.2596	403.4325	891.7981	2 277.2702
Poland	2016	553.4071	370.7712	0.6767	576 099.9	119.7876	219.7162	652.5573	1 065.8505
Fitted values									
Czech Republic	2007	472.2562	383.4131	0.6281	13 5347	161.3726	248.8456	560.5548	909.4761
Poland	2007	309.9459	223.7590	0.6640	17 7134	62.8428	109.6341	373.3617	801.9741
Czech Republic	2016	822.0742	682.3778	0.6286	540 645	257.2524	409.4761	810.6297	2 112.3873
Poland	2016	533.4071	378.2716	0.6678	621 056	106.9415	212.4333	666.5040	1 009.4761

Source: Author's calculation

The compared descriptive statistics values in Table 2 are very similar in most cases. It is worth noting that the Zenga income distribution fits the mean very well. The analysis of the indexes of fitting and estimated standard errors of point estimates the Zenga income distribution to the empirical data shows that it confirms goodness of fit for a whole range of a distribution. This proves that the Zenga income distribution well describes the empirical data for the Czech Republic and Poland. Convergence to the Pareto law for high income groups and existence of only a small number of finite moments of a distributions was described in papers (Zenga, 2010a, 2010b; Zenga, Pasquazzi, Zenga, 2012). Moreover, the transparent economic interpretation of the Zenga density parameters is an additional argument to use this model to describe income distribution.

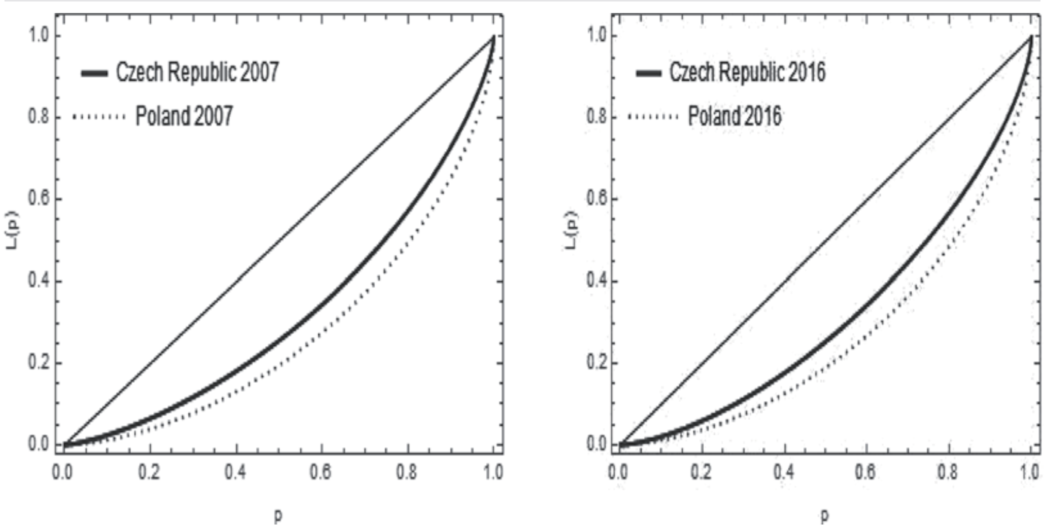
Figures 7 to 11 report graphs of the Lorenz curve *L(p)* and the Zenga curve *I(p)*. The synthetic Gini and Zenga indexes *G* and *Z* are summarized in Table 3. These coefficients were calculated on the basis of the Zenga income distribution. The values of Gini and Zenga index estimators were obtained by means of numerical integration based on the Lorenz and Zenga curves.

Table 3 Estimation results for income distributions in the Czech Republic and Poland based on the data coming from EQLS in two period 2007 and 2016

Country	**Year**	**Gini coefficient**	**Zenga coefficient**
		G	**Z**
Czech Republic	2007	0.3591	0.7008
Poland	2007	0.4610	0.8001
Czech Republic	2016	0.3683	0.7169
Poland	2016	0.4707	0.8075

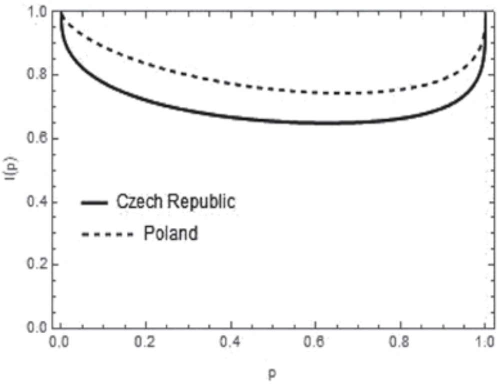
Source: Author's calculation

Figure 7 Comparison Lorenz curves *L*(*p*) for the Czech Republic and Poland in two periods 2007 and 2016



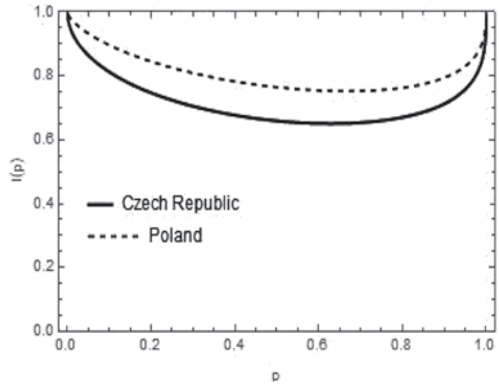
Source: Authors' calculation

Figure 8 Zenga curves *I(p)* for the Czech Republic and Poland in 2007



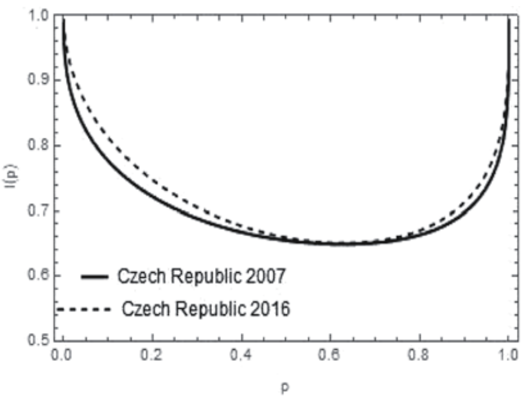
Source: Authors' calculation

Figure 9 Zenga curves *I*(*p*) for the Czech Republic and Poland in 2016



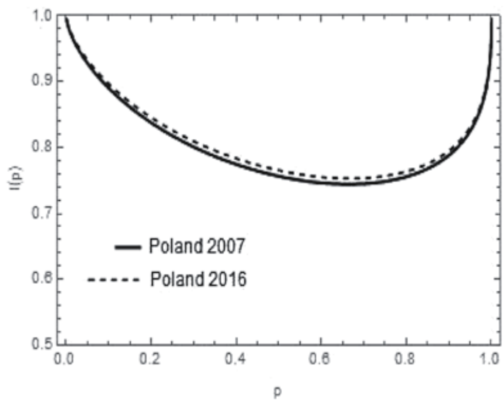
Source: Authors' calculation

Figure 10 Zenga curves *I*(*p*) for the Czech Republic in two periods 2007 and 2016



Source: Authors' calculation

Figure 11 Zenga curves *I*(*p*) for Poland in two periods 2007 and 2016



Source: Authors' calculation

Zenga's curve can be considered more explanatory and flexibile and its results possess more intuitive interpretation than Lorenz one (Polisicchio and Porro, 2009).

Comparing two populations of economic units we can also note that income inequality are slightly greater for both countries in 2016. The Gini and Zenga coefficients in two periods 2007 and 2016 for Poland do not differ significantly, we can see it in Figure 11. In Figures 8 and 9 we can discover that the Zenga inequality curves for the Czech Republic lies below the curve for Poland for the entire income range in two periods 2007 and 2016. It proves large income discrepancy between this country.

CONCLUSIONS

Income distributions in two countries (the Czech Republic and Poland) are studied for comparison. The Zenga distribution has not been used so far to analyze income distributions in the Czech Republic. The density function of the Zenga income model has a number of interesting statistical properties and thus easily adapts to various types of empirical income distributions. Zenga inome model has positive skewness, it has paretian right tail and it can be used to describe economic distributions by size.

The Zenga probability density function is characterized by a small number of parameters. The parameters of the Zenga distribution can be applied to evaluate various statistical characteristics of the distribution, in particular the point and synthetic measures of income inequality. Another worthy property of Zenga distribution is the equivalence of the parameter with the expected value, it provides the use of simple estimation methods, which is an additional advantage of this model. All these properties of the Zenga model confirm the validity of its application.

We have shown that Zenga distribution describes very well the distributions of individual incomes in both the Czech Republic and Poland. Obtained results show very interesting differences. The conducted analysis showed, using the Zenga distribution curve, how the incomes in the considered countries changed over the years. The results of the calculations concerning the level of distribution inequality, revealed differences between Czech Republic and Polish households.

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On What Really Matters: Evidence from Alternative Well-Being Indicator in EU-28 Countries

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Abstract

As the traditional approaches to measure economic growth have been lately a subject to several criticisms, there is an urge to find more suitable indicators covering the environmental and social aspects of progress. The aim of this paper is therefore to construct an alternative, country-specific indicator of subjective well-being, the so-called adjusted happy planet index (AHPI) for 28 EU member states in years 2012 and 2017. The ordinary least squares regression reveals a weak negative correlation between AHPI and gross domestic product per capita (GDPpc), but since we analyze countries, it is appropriate to use spatial econometric methods, which revealed the spatial relationship between EU-28 countries. Furthermore, the spillover effects are observed as well. This holds especially for natural resources, the reduction of which decreases a level of AHPI in EU-28 countries.

Keywords	***DOI***	***JEL code***
AHPI, GDP, environment, spatial econometric model, subjective well-being	*https://doi.org/10.54694/stat.2021.39*	*C21, E23, I31*

INTRODUCTION

In recent times, an increasing attention has been paid to the crises arising from macroeconomic imbalances, instability of the global economy (see, e.g., Xafa, 2007; Blanchard and Milesi-Ferretti, 2011; Jordà et al., 2011; Obstfeld, 2012), inequalities (e.g., Saint-Paul and Verdier, 1996; Ostry et al., 2014; Berg et al., 2018), and other current challenges, including climate change (e.g., Martens et al., 2009).

As previous evidence suggests (NEF, 2009; Endres, 2020), the causes of these crises might be associated with the persisting preference for economic growth as a focal government goal that goes beyond all other goals. Gross domestic product (GDP) presents most familiar measure of economic activity developed in the 1930–40s, primarily in response to the Great Depression with a goal to improve planning of war

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production. Even though economic growth measured by GDP implies a desired creation of wealth, this indicator arose at a time when environmental and social problems were behind economic problems (Stockhammer and Fellner, 2009). To this end, it does not take into account the environment and the living conditions of the population, whose worsening may result into stress and health issues (Pircher, 2019; Endres, 2020).

Some economists even believe that the pursuit of growth is incompatible with such social and environmental goals as economies operate on a system in which meeting the needs has been replaced by creating the needs themselves (NEF, 2009; Pircher, 2019). Progressive growth could be destructive to the environment, for which new ideas of static or shrinking economy have also appeared (Heinberg, 2011). In addition, the benefits and losses of economic growth have so far been unevenly distributed across different areas of the world (Victor, 2011) which contributes to increasing inequalities as well.

Due to the limits and shortcomings of GDP, alternative approaches to measuring economic growth have been emerging lately, which also respond to environmental and social factors. Among them, a concept of well-being which according to New Economics Foundation (2009: 20) represents: "*the dynamic process that gives people a sense of how their lives are going through the interaction between their circumstances, activities and psychological resources or 'mental capital'.*" While *the objective well-being* can be conceptualized in terms of material well-being, which is affected, *inter alia*, by a level and stability of income, educational opportunities, safety and security, *the subjective well-being* can only be understood as an inner subjective experience of each particular individual (Alatartseva and Barysheva, 2015). In this vein, life satisfaction formed by various socio-demographic factors can be considered as a key indicator of subjective well-being which should be increased (Eurostat, 2015) and combined with traditional measures of economic growth (Bleys, 2005).

The alternative indicators relying only on economic indicators, i.e., national accounts and GDP (such as the Index of Sustainable Economic Welfare, Genuine Progress Indicator, Green GDP, etc.) have certain limitations, including a lack of consensus on how to quantify the cost of depleting natural resources or which expenses are beneficial and should be added to the total amount and which are harmful and should be deducted. On the contrary, the other alternatives focused on measuring environmental or social aspects (e.g., Gross National Happiness, Ecological Footprint) miss the economic elements. To avoid such shortcomings, the alternative indicators in a form of the composite indicators (e.g., the Human Development Index, Happy Planet Index) should combine these aspects in order to offer the best prospects for policy making (Costanza et al., 2009). Moreover, since the previous studies have drawn the attention to the spatial aspects in determining economic growth (see, e.g., Abreu et al. 2005; Annoni et al. 2019), environmental issues (see, e.g., Anselin, 2001), and well-being (see, e.g., Brereton et al., 2006; Takeshi, 2020), the spatial dependences should not be omitted in the analyses of alternative indicators as well.

The aim of this paper is to calculate an alternative indicator, relying on previously mentioned factors – more specifically, subjective well-being, life expectancy, and ecological footprint reflecting the human impact on the environment, in particular on the productive area needed to secure the renewable resources used by mankind – and confront it with the traditional GDP measure. By doing so, we contribute to sparse evidence on exploring well-being at macroeconomic level. Besides that, in line with previous studies, in which only OLS is normally used and does not take into account spatial contexts, we estimate spatial econometric model to look at spatial dependences among considered countries.

The remainder of the paper is as follows; the next section provides a literature review of the existing alternative approaches to measure economic growth. In the second section, we describe data used to calculate our alternative indicator, so-called *adjusted happy planet index* (AHPI) and a methodology for spatial econometric analysis. The third section provides empirical results and discussion on the relationship between economic growth and AHPI, along with the discussion on the spatial dependences among considered 28 EU countries in the time period 2012–17. The final section concludes our findings. We also give recommendations for future research.

1 LITERATURE REVIEW

In the early 1970–1980s, intense discussions began on the environmental and social damages caused by the focus on economic growth. These discussions have resulted from the fact that GDP was not originally intended to measure well-being, however, it has become a normative and reference indicator of economic and social performance (Bleys, 2005). Gradually, it became clear that GDP does not represent an adequate indicator of prosperity since it systematically provides distorted information on the sustainable development of prosperity (Stockhammer and Fellner, 2009).

Schepelmann et al. (2010) agrees that GDP does not allow for social and environmental costs and benefits when measuring a country's economic prosperity. Moreover, it is difficult to make sustainable progress when growth is assessed from a purely financial point of view. To avoid this, Schepelmann et al. (2010) suggest supplementing GDP with environmental and social information. Adler (2009) also considers progress as more than economic growth measured through GDP; this category should reflect how the society has developed, but also individuals themselves. To achieve this, Adler (2009) proposes a discussion what progress means to inhabitants of particular country, based on which its indicators should be then created and implemented.

A more complex view is presented by Bleys (2005) who suggests that all alternative measures of welfare should be encouraged since each of them contains valuable information. According to this author, if economic, social, and subjective welfare indicators were combined, the best perspective would emerge.

The recent empirical literature does not provide consensus on the use of GDP as a good indicator of the prosperity of the country or other, suitable measure of progress or well-being. For instance, Patterson (2019) considers the Genuine Progress Indicator (GPI) to be more appropriate indicator of well-being than GDP, since GPI also implies a macro-scale analysis of costs and benefits of activities related to economic growth. Whereas consumption of goods and services can be viewed as a benefit, the social and environmental factors such as the income inequality or emission of greenhouse gases are treated as costs. For this reason, Patterson (2019) comes to conclusion that GPI reaches considerably lower values compared to traditional GDP.

Gallardo (2009) claims that the Human Development Index (HDI) presents a better way of measuring well-being than traditional GDP per capita and it has a potential to strengthen the paradigm of human development. According to Gallardo (2009), the analysis of three main components of HDI (long and healthy life, knowledge, and a decent standard of living) can identify areas that require political attention in considered economies.

In similar way, the Initiative "*Beyond GDP*" originated in 2007 encourages the creation of new, alternative indicators which compared to GDP should be clearly focused on the environmental and social aspects of progress, but more importantly, on the global challenges of the 21st century, such as climate change, battling poverty, resource depletion, health, and quality of life (European Commission, 2007).

On the other hand, Cohen (2018) states that GDP per capita in some way reflects welfare since it tends to correlate with well-being indices. The author argues that richer nations tend to be healthier, and the improving state of health is considered as a key indicator of increasing well-being. However, a high level of GDP does not necessarily lead to a high level of well-being or good health of the country's citizens. To accomplish this goal, Cohen (2018) emphasizes new technologies, equality of access to health, and preventive care which could have a positive effect on life expectancy and consequently, economic growth.

Similar opinion is provided by Norberg (2010) who does not support the view of full GDP replacement as it strongly correlates with economic security, education, health, life expectancy or poverty reduction. According to Norberg (2010), the amount of information available would be reduced if we replaced GDP with another indicator of well-being. Moreover, the unification of the term well-being would also be necessary, which would also tempt the governments to apply a one-size-fits-all approach with questionable results.

To avoid this, several authors suggest considering a combination of traditional and alternative aspects of prosperity. For instance, D'Acci (2011) proposes the idea of well-being and progress in balancing each other. The author creates a new index – the Well-being and Progress Index (WIP) which covers health well-being, economic well-being, happiness, human progress, and cultural progress. This indicator can thus provide global and balanced vision of prosperity because of a large number of variables considered in each category. In similar way, Drabsch (2012) agrees that focusing on GDP as the only measure of well-being is not the best solution and points out to its limitations such as the lack of a relationship between happiness and GDP per capita.

While the evidence at the microeconomic level suggests that the relationship between subjective well-being (SWB) and individual characteristics follows some homogenous patterns (Frey and Stutzer, 2002), the recent research of SWB stresses that there exists a substantial variation in the level of SWB across regions or countries (see, e.g., Aslam and Corrado, 2012; Takeshi, 2020; Hoogerbrugge et al., 2021). The rationale behind this matter comes from possible heterogeneities among regions/countries, but also from the psychological concept of *emotional contagion*. The emotional contagion can be defined as: "*the tendency to automatically mimic and synchronize expressions, vocalizations, postures, and movements with those of another person's and, consequently, to converge emotionally*" (Hatfield et al., 1992: 153–154). As the emotional states can be transferred (Fowler and Christakis, 2008), the person's SWB might determine the SWB of others. Thus, we can observe the spillover effects, whose identification requires spatial econometric approaches.

The contribution of the present study is threefold. Firstly, this paper proposes an alternative indicator of subjective well-being taking into account social and environmental aspects of growth, which we compare with the traditional GDP measure. Since majority of existing empirical studies is focused on the subjective well-being at the individual level (e.g., Helliwell, 2002; Grossi and Sacco, 2011; Kelley and Evans, 2017), we aim to address gaps in empirical literature and contribute to sparse evidence on exploring well-being at macroeconomic level. Secondly, we contribute to the literature on relationship between economic growth and subjective well-being. Our findings suggest that constant pressure to increase economic growth can lead to environmental problems, and later, to a deterioration in people's well-being. We therefore propose an indicator combining GDP with alternative sub-indicators, which we believe reflect domains neglected in existing empirical studies. Finally, an additional aim of this research is to examine whether the adjusted happy planet index (AHPI) proposed in this is spatially dependent; by doing this, we enlarge the empirical literature focusing on the spatial aspects in determining subjective well-being.

2 METHODOLOGY AND DATA

We build on the original *Happy Planet Index* (HPI) introduced by the New Economic Foundation (NEF) which measures the ecological efficiency that a country could maintain, while ensuring the well-being of the population. The basic formula of the index is as follows:

$$\text{HPI} \approx \frac{\text{SWB} \cdot \text{LE}}{\text{EF}}, \tag{1}$$

where *SWB* stands for a subjective well-being indicator,[3] *LE* stands for a life expectancy, and *EF* denotes ecological footprint. By including these variables, the index can be used to compare the countries' progress towards long-term prosperity with respect to the environment. However, the NEF does not provide an exact procedure on the variables transformation which is in this case necessary (such as data standardization, inequality adjustment, etc.). We created so-called *adjusted happy planet index* (AHPI), because the calculation of the initial HPI requires some adjustments in order to find out whether the constant pressure to increase GDP can result in a deterioration of subjective well-being.

Firstly, in line with the NEF, we calculate the Atkinson index to adjust subjective well-being and life expectancy for inequality. The Atkinson index *A(ε)* was firstly used to calculate income inequality (Atkinson, 1970). It represents a percentage of total income that a given society would have to give up, in order for citizens, to have a more equal share of income.

$$A(\varepsilon) = 1 - \frac{\prod_{i=1}^{N}\left(y_i^{\left(\frac{1}{N}\right)}\right)}{\bar{y}}, \varepsilon = 1, \tag{2}$$

where y_i represents individual indicator, $\bar{y}$ denotes average income, N denotes population size and ε is the inequality aversion parameter. In our research, we followed the NEF (2016) steps, and we adjust the Atkinson index as follows:

$$A(\varepsilon) = 1 - \left(\frac{\overline{x_g}}{\mu}\right), \tag{3}$$

where $\bar{x}_g$ represents geometric mean and μ represents simple arithmetic mean of measured values. In our case, we consider time period 2011–17.

The Atkinson index is then used to calculate the inequality-adjusted life expectancy (*IALE*) and inequality-adjusted subjective well-being (*IASWB*) for each country. The *IALE* and *IASWB* is the mean of *LE* and *SWB* of residents of a country, adjusted to reflect inequalities. The basic formulas are as follows:

$$\text{IALE} = (1 - \text{Atkinson index for LE}) * \text{Mean LE}, \tag{4}$$

$$\text{IASWB} = (1 - \text{Atkinson index for SWB}) * \text{Mean SWB}. \tag{5}$$

In order to compare IALE which is reported in years and IASWB which is expressed in points, we had to balance the data. We applied a Z-score, which is designed to convert data so that they are comparable. We applied the standard score method to both variables, where we focused on a standard deviation, which was much lower in the case of SWB than in the case of LE, so without this adjustment the variable on LE would have a more significant effect on the AHPI calculation than SWB. To adjust this, we include the median from converted SWB values (from Z-score of SWB) as constant (α) to the final formula.[4]

Not every country has the same biocapacity, so it would be incorrect to take into account only the net indicator of the ecological burden as the ecological footprint (EF) variable. We calculate EF as the share of a country's ecological burden on total biocapacity:

[3] Life satisfaction (subjective well-being) is given as an answer to the question: *„Please imagine a ladder with a number of steps from 0 to 10. The upper part of the ladder represents the best possible life for you and the lower part of the ladder the worst possible life. Which stairway would you say you are on?"*

[4] In our dataset, median value for SWB (α) presents –0.079.

$$EF = \frac{\text{Ecological burden}}{\text{Biocapacity}}. \quad (6)$$

The final *adjusted happy planet index* then can be expressed as:

$$AHPI = \left(\frac{IASWB - (\alpha * IALE)}{EF + \beta} \right). \quad (7)$$

As we mentioned above, unadjusted LE would significantly affect the whole result, so we multiplied IALE by α, and then we subtracted it from the well-being (IASWB), by which we ensure that each of these two variables contributes equally to the variance. Thus, the AHPI should be equally sensitive to changes in life expectancy as well as in subjective well-being, which would not be possible by only including IASWB*IALE. In denominator, we add the constant β. We take the constant β from the Global Footprint Network organization. Since we calculate AHPI only for the EU countries and not the world sample, we adjust the EF variable using constant β, which represents use of natural resources in Europe; the value 2.89 suggests that Europe uses resources for almost three planets. (Global Footprint Network, 2021).

For better visualization, we scale the results and provide target values from the interval 0 to 100. The performance, where the score of AHPI will be equal to 0 and 100, is obtained at min/max values of other variables, which correspond to the target values given by New Economics Foundation (2006) in their report. So, theoretically, the best performance of the AHPI is, when the indicator equals to 100 and can be reached when LE = 85, SWB = 10 and EF = 0. On the contrary, the worst performance of the AHPI (AHPI = 0) can occur when LE = 25, SWB = 0, and EF = 16.

Due to the fact that we work with spatial data, we supplement the common analyzes of the OLS type with analyzes developed for spatial data, namely the Moran's test and spatial models, through which we are also able to estimate the so-called, spatial spillovers. In spatial analysis, our goal is to determine whether the AHPI indicator is spatially dependent. Firstly, we calculate the spatial autocorrelation between values of AHPI in EU-28 countries. Spatial dependence reflects a situation where the values observed within one country depend on the values of the neighboring countries. To examine the existence of spatial relationships, we use Moran's I test for spatial autocorrelation. The aim of this test is to determine if the distribution of the observed variable (AHPI) is positively or negatively spatially correlated in the EU area, or if there is no spatial dependence between regions/countries.

Secondly, we analyze the spatial impacts of AHPI within the EU countries, by what we want to find out whether AHPI in a given country depends on the determinants of that country or also on the characteristics of neighboring countries. With spatial econometric models, our goal is to examine the extent to which the AHPI indicator is associated with economic growth, as well as other factors such as education (D'Acci, 2011), natural resources (Buhl et al., 2017), and CO_2 emission (DEFRA, 2011).

We start by estimating a simple OLS regression model to exploring the relationship between AHPI and GDP. In the next place, we estimate three spatial econometric models – Spatial Autoregressive Model (SAR), Spatial Error Model (SEM), and Spatial Lag of X Model (SLX). Subsequently, we extend the SLX model to create the Spatial Durbin Error Model (SDEM) and then, the most general Spatial Durbin Model (SDM). We consider the key model to be the one, which the tests indicate us the best, the results of this model are presented in the outputs. In the order we wrote about the models above, we express the following formulas for these models:

$$Y = \rho Wy + X\beta + \varepsilon, \quad (8)$$

$$Y = X\beta + \varepsilon; \varepsilon = \lambda W\varepsilon + u, \quad (9)$$

$$Y = X\beta + WX\theta + \varepsilon, \quad (10)$$

$$Y = X\beta + WX\theta + \varepsilon,\ \varepsilon = \lambda W\varepsilon + u\,, \quad (11)$$

$$Y = \rho Wy + X\beta + WX\theta + \varepsilon\,. \quad (12)$$

For all models, Y denotes the dependent variable, the parameter θ represents the autoregressive parameter, β represents the vector of regression coefficients, X is the matrix of explanatory variables, WX is spatially lagged explanatory variables and ε the error term. In all models, W presents the spatial weights matrix where we consider queen contiguity-base spatial weights. In this case, it does not matter on the length of the common border, since we consider countries to be neighboring when they have at least one common point. For SDEM (see Formula 11), λ expresses the spatial dependence, i.e., the spatial error coefficient and u is the error component. For SDM model (see Formula 12), ρ and θ represent spatial autoregressive coefficients and Wy spatially lagged dependent variable.

All model estimations in our research were performed using R and primary packages, e.g. "spData", "spatialreg", "sp". After estimating and comparing these models with each other, based on criteria as the highest Log Likelihood, the lowest AIC criterion and total p-value, we consider the optimal model, the SLX model, which we will work with in the main part of the article.

In Tables 1 and 2, we provide descriptive statistics for considered variables used as inputs for the calculation of AHPI for years 2012 and 2017. At the same time, we supplement table with GDP per capita, which we use in econometric analysis. We work with data that were available for the period from 2011 to 2017 for the 28 countries of the European Union.[5]

Table 1 Descriptive statistics for EU countries, 2012

	Min	Mean	Median	Max	S.D.	Target value
LE (years)	73.78	79.02	80.38	82.43	2.82	85.00
SWB (points)	4.22	6.19	6.12	7.56	0.93	10.00
GDPpc (PPS)	47.00	99.00	89.00	263.00	42.02	–
Biocapacity (gha)	0.33	3.17	2.28	12.97	3.11	–
EB (gha)	2.83	5.28	4.93	13.95	2.06	l.80
AHPI (points)	13.85	47.62	51.68	79.62	17.46	100.00

Note: Data for SWB are available for each 28 countries from year 2011. Data for ecological burden and biocapacity are available only till year 2017.
Source: Authors' calculations based on data from World Bank, Eurostat, Human Development Index, Global Footprint Network, and World Happiness Report

Table 2 Descriptive statistics for EU countries, 2017

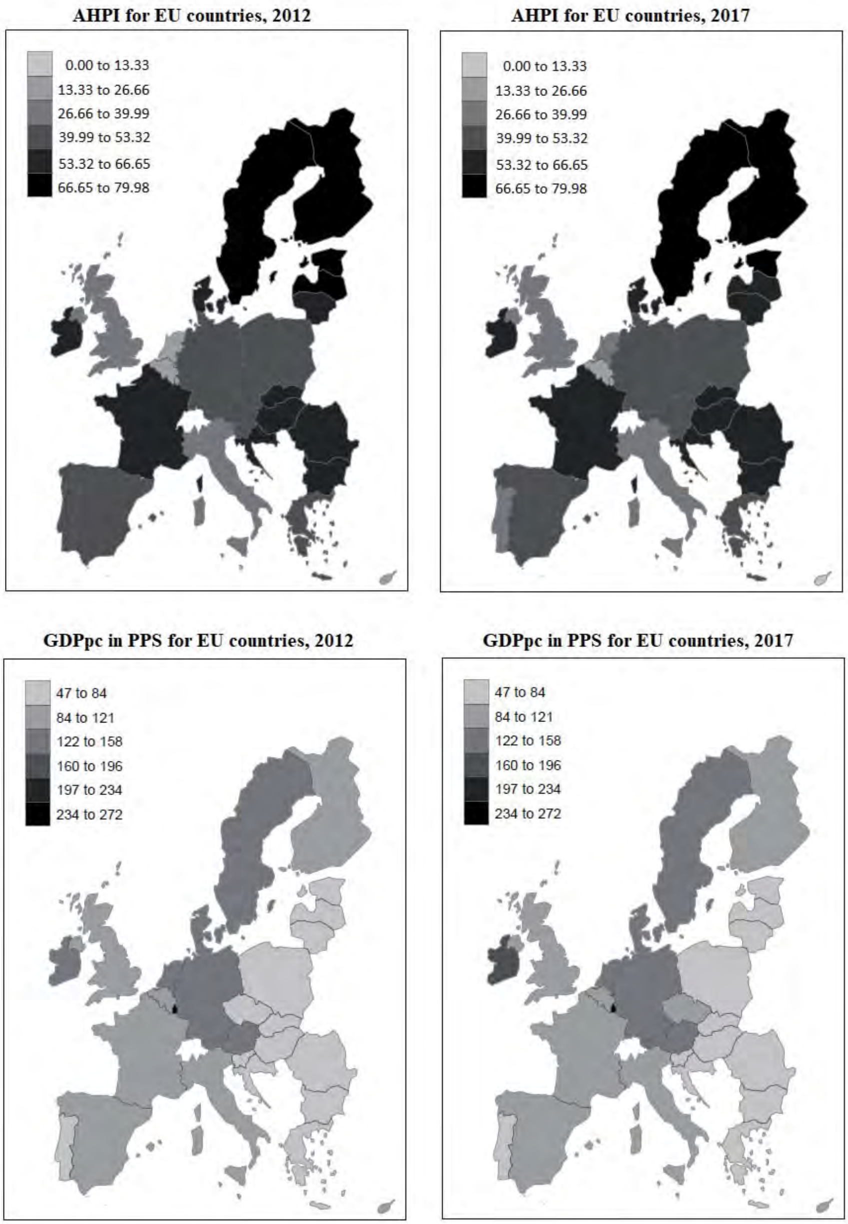
	Min	Mean	Median	Max	S.D.	Target value
LE (years)	63.29	79.88	81.14	83.28	2.80	85.00
SWB (points)	4.84	6.35	6.24	7.66	0.76	10.00
GDPpc (PPS)	50.00	101.00	92.00	263.00	42.87	–
Biocapacity (gha)	0.24	3.22	2.44	12.45	3.10	–
EB (gha)	3.40	5.26	4.81	12.79	1.81	1.80
AHPI (points)	10.15	47.63	50.38	79.80	17.76	100.00

Source: Authors' calculations based on data from World Bank, Eurostat, Human Development Index, Global Footprint Network, and World Happiness Report

[5] Due to the Atkinson index, where the arithmetic and geometric mean are used in the calculation, and due to the unavailability of ecological footprint data after 2017 and well-being data before 2011, the calculations of AHPI are only possible for years 2012–2017.

The data are selected from several sources, namely from the World Bank, where we use data on LE reported in years or from Eurostat where we use GDP per capita in Purchasing Power Standards (EU-28 = 100). Ecological burden and biocapacity data, which are reported in global hectares per person (gha), are taken from the Global Footprint Network. The subjective well-being data are taken from World Happiness Report database.

Figure 1 AHPI and GDP per capita for EU countries – 2012, 2017



Source: Authors' calculations based on data from World Bank, Eurostat, Global Footprint Network, and World Happiness Report

3 RESULTS AND DICUSSION

In Figure 1, we depict values for our alternative indicator AHPI and traditional measure, GDP per capita in EU-28 countries. To illustrate time dimension, we compare year 2012 with year 2017 for which we have last available observations. Overall, we can observe a decreasing trend of the AHPI indicator in time. The AHPI reached the maximum of 79.62 points in 2012, while the maximum for 2017 was 74.62 points, in. Decrease of AHPI occurred is in countries such as France, Austria, Cyprus, Malta, Bulgaria and also the Slovak Republic.

Whereas Luxembourg presents the country with the highest GDP per capita among the EU-28 group, this country gains the second lowest value for AHPI. This situation can be explained by the ecological footprint of Luxembourg which is up to 9 times higher than its biocapacity allows. We can therefore expect that persisting economic growth of Luxembourg may have a negative effect on the environment which may later adversely affect the level of SWB of the population. On the other hand, we can observe countries which are economically strong and at the same time, achieve high AHPI scores – e.g., Sweden, Finland, or Denmark.

To examine the relationship between the AHPI and GDP per capita more closely, we firstly calculate a simple Pearson correlation which is available in Table 2.

Table 3 Correlation between AHPI and GDP per capita – 2012, 2017

	2012	2017
Correlation	–0.341	–0.305
t-value	–1.847	–1.631
p-value	0.076*	0.115

Note: Level of significance 0.1*, 0.05**, 0.01***.
Source: Authors' calculations based on data from World Bank, Eurostat, Global Footprint Network, and World Happiness Report

In Table 3, the relationship between the variables is statistically significant and negative for year 2012, so in this case, if one variable tends to increase (GDPpc), the other should decrease (AHPI) and vice versa. In the case of 2017, the values are not statistically significant, but there is an indication of a negative relationship. Similar results are provided by Campus and Porcu (2010) who analyzed the composite indicator HPI, as an alternative measure to GDP in assessing the welfare of countries. The authors do not find substantial correlation for analyzed 178 countries since HPI does not reflect the same reality as GDP. We can see that the correlation between AHPI and GDPpc in our sample is modest, almost unproven, which however, does not mean that there is no relationship between these variables. We therefore continue with the regression analysis and examine this relationship in detail. As mentioned, the correlation between these two variables is very weak, so it's possible that the AHPI indicator is also affected by other factors than just by GDP. Similar to study by D'Acci (2011) and study by DEFRA (2011), we decided to include other aspects, i.e., control variables – in particular, education, natural resources, and CO_2 emissions, and estimate the OLS regression. By doing this, we eliminate potential omitted variables bias. The variable education is defined as % of 20–24 years old students in tertiary education, natural resources as total natural resources rents (% of GDP), and CO_2 emissions reported as metric tons per capita. At the same time, there may be a certain limit for the level of GDP after which the AHPI decreases. We will now look at how this relationship between AHPI and GDP behaves with the addition of the control variables mentioned above.

After estimating the OLS model, we can notice that in both years, 2012 and 2017, the p-value is lower than the level of significance, so we can claim that this model is statistically significant. Based on the estimated GDPpc coefficient for year 2012 and 2017 in Table 4, we can see that GDPpc has a positive effect on AHPI, but the results are not statistically significant.

Table 4 Relationship between AHPI and GDP per capita – 2012, 2017 (OLS)

	Dependent variable: AHPI	
	2012	**2017**
Constant	17.015	12.474
	(22.548)	(19.807)
GDPpc	0.096	0.152
	(0.149)	(0.117)
Natural resources	8.648	39.275***
	(5.325)	(10.496)
Education	0.793	0.610
	(0.468)	(0.426)
CO_2	–1.490	–1.958
	(1.579)	(1.476)
N of observation	28	28
R	0.163	0.369
p-value	0.088*	0.005***

Note: Level of significance 0.1*, 0.05**, 0.01***.
Source: Authors' calculations based on data from World Bank, Eurostat, Global Footprint Network, and World Happiness Report

In addition to OLS, we will look at the results, where we work with models designed specifically for spatial data. These models also allow us to explore spillover effects. We contribute to the existing literature by estimating spatial models, which unlike simple OLS are more appropriate to use because of the character of our data. The economic development of individual EU countries is different due to the impact of climate change, historical differences, different approaches of government, etc. While in some countries the situation in terms of both GDP and AHPI is significantly better, there are countries that may face economic and social problems. There are countries that suffer significantly not only in terms of economic strength, but also because of poverty in then reflected in the health and overall well-being of the population. If we try to find out whether the community of EU countries is influenced by each other or whether there are neighborhood influences to increase/decrease the indicators, it is possible to estimate this using spatial econometric models. When monitoring AHPI, countries that are more developed or achieve higher AHPI scores can positively or negatively affect neighboring countries. By ignoring this, our results could be skewed.

Table 5 Moran's I test of AHPI

Year	Moran's I	p-value
2012	0.397	0.035**
2017	0.393	0.035**

Note: Level of significance 0.1*, 0.05**, 0.01***.
Source: Authors' calculations based on data from World Bank, Eurostat, Global Footprint Network, and World Happiness Report

Based on the calculated p-values from Moran's I (see Table 5), we claim that a statistically significant spatial autocorrelation exists. At the same time, in both cases the Moran index (I) was positive, which indicates a positive spatial autocorrelation. This means that the level of AHPI in one country has a positive effect on the level of AHPI in a neighboring country, in other words, if one country shows certain properties (values) from the AHPI indicator, it is likely that neighboring countries will show similar characteristics.

Based on the results, we claim that the variables are spatially autocorrelated, so in the final, it makes sense to estimate spatial models. As mentioned above, in order to avoid possible bias of the results, when estimating spatial models, we add three other determinants of AHPI to the relationship – education, natural resources and CO_2. At the same time, it is important to look at the direct and indirect effects of AHPI determinants. Based on the estimation of all models and on criteria such as Log Likelihood, AIC criterion and LR tests, we came to the conclusion that the most suitable model for our sample is the SDM model for year the 2012 and SLX model for year the 2017.[6]

Table 6 Estimation results – the SDM and SLX model

	Dependent variable: AHPI	
	2012 SDM	**2017 SLX**
Constant	24.790	6.851
	(15.521)	(17.172)
GDPpc	0.050	0.158
	(0.123)	(0.106)
Natural resources	2.417	21.964**
	(3.784)	(10.211)
Education	0.051	0.431
	(0.381)	(0.372)
CO_2	–2.043*	–3.033**
	(1.154)	(1.309)
Lag. GDPpc	0.338**	0.349***
	(0.140)	(0.123)
Lag. natural resources	15.384***	35.521***
	(5.894)	(12.193)
Lag. education	0.001	0.270
	(0.345)	(0.416)
Lag.CO_2	–4.643**	–4.470**
	(1.938)	(2.223)
AIC	231.625	225.780
Log likelihood	–104.812	–102.890
p-value	0.041**	0.001***

Note: Level of significance 0.1*, 0.05**, 0.01***.
Source: Authors' calculations based on data from World Bank, Eurostat, Global Footprint Network, and World Happiness Report

Based on the results provided in Table 6, we confirm that the final score of AHPI in a particular country depends not only purely on the values that are produced within that country, but also on the values of production in neighboring countries. At the same time, we can see that some estimates of coefficients are statistically significant, and therefore we can say, that these variables affect the total AHPI (negative/positive) in one, monitored country, as well as the level of AHPI in its neighboring countries. The advantage of the SLX model is that direct and indirect effects are already included directly in the model output. Direct effects are estimates of coefficients (β) and indirect effects are those related to spatially delayed explanatory variables (θ).

[6] We do not report in our research the spillover effects of SDM model, because they are similar to the spillovers of the SLX model (available upon request).

The spillover effects are positive for GDPpc, natural resources and in year the 2017 also education, which means that if these variables increase in one country, it will have a positive effect on AHPI in that country as well as in neighboring countries. The loss of natural resources can be caused by the fact that large companies consume huge amounts of water for their production, or e.g., by interfering with nature through further construction of buildings. If we look at the variable CO_2, we see that this variable shows negative values and is statistically significant. In the case of indirect effects, this means that an increase in carbon dioxide in a country will lead not only to a reduction in AHPI itself in that country, but also to a reduction in AHPI in neighboring countries.

Based on all the tests performed, taking into account the spatial correlation in explaining AHPI within the EU countries ultimately seems necessary and correct. If we did not take space into account for this indicator, we would lose information about the interdependence of countries. In our case, based on LR tests, it would be the best choice to choose the SDM model for the year 2012, and because that in year the 2017 is Rho coefficient statistically insignificant, the most suitable model for this year is SLX model. Spatial econometrics models have allowed us to take into account the spatial relationships of the AHPI, and at the same time it has been possible to find out that there are clusters of countries in the EU community that influence each other.

CONCLUSION

GDP indicator is increasingly criticized for its shortcomings and for the fact that it does not actually measure what really matters. On this basis, many alternative indicators have been developed that either want to complement or replace GDP, focusing mainly on environmental and social aspects. The aim of this paper was to construct such alternative indicator, the so-called the adjusted happy planet index (AHPI), which combines the environmental factor in form of the ecological footprint, the social factor in form of the average life expectancy, and finally, the subjective well-being.

We confirm spatial dependence among the EU-28 countries with regard to the AHPI, which means that AHPI in one country is affected by neighboring countries, and also affects the situation in these neighboring countries. To consider spatial dependences, we estimate spatial econometric models. For the observed year 2012, the most suitable model for our data sample is SDM and for 2017 the SLX model. The AHPI is mainly negatively affected by CO_2, i.e., the more carbon dioxide is released into the atmosphere, the greater the global warming, which results in a decrease of AHPI. Natural resources have positive impact of the selected variables on AHPI, so if the extraction of these resources were reduced, the Earth would have more resources at its disposal, which would have a positive effect on AHPI.

Increasing GDP is not the only factor that can result in an environmental crisis. The cause of environmental problems is not only companies that produce significantly more than in the past, but also the population itself, which pollutes the environment through its own activities, and which is not yet aware of the problems caused by climate change. Combining GDP with such indicators could reveal useful relationships between economic activity, environmental impact, and quality of life. One solution could be for governments to target the public as well, to make their citizens aware of the need to move towards sustainable growth and sustainable future. Technologies that do not cause damage to the environment could be introduced, on the contrary, renewable resources would be drawn. There are many other factors that can have a major impact on the environment, subjective well-being, or AHPI itself, for which a more comprehensive analysis is needed that can be further investigated.

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Did Covid-19 Precautions and Lockdowns Cause Better Air Quality? Empirical Findings from Turkish Provinces

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Abstract

The Covid-19 pandemic have dramatically affected the socio-economic structure in the world since governments put into action considerable precautions including lockdowns to reduce the speed of the contagion. Focusing on this point, we empirically investigate the environmental outcomes of the Covid-19 precautions and lockdowns in Turkey. The empirical analysis through the data obtained from different measurement stations indicate that the air pollution in the selected Turkish cities decreased due to the implemented precautions. The findings suggest that the Covid-19 might be an opportunity to rethink some economic and behavioral practices, as demonstrated by the reduction in the emission of air pollutants.

Keywords	***DOI***	***JEL code***
Covid-19 pandemic, social interaction, greenhouse gas emission	*https://doi.org/10.54694/stat.2021.34*	*Q53, Q56, R19*

INTRODUCTION

The Covid-19 pandemic has been radically affecting the world economy since February 2020. The governments implemented different measures including lockdowns to reduce the spread of the disease. Many companies have switched then to remote-working system and many others have adjusted their production systems to the new pandemic order. Precautions that were efficient in reducing the contagion

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of the pandemic caused severe repercussions for economies across the world. The "Great Lockdown" has triggered the deepest global recession (–5.2%) since World War II and the highest synchronization of national recessions since 1870 according to the World Bank estimates (WB, 2020).

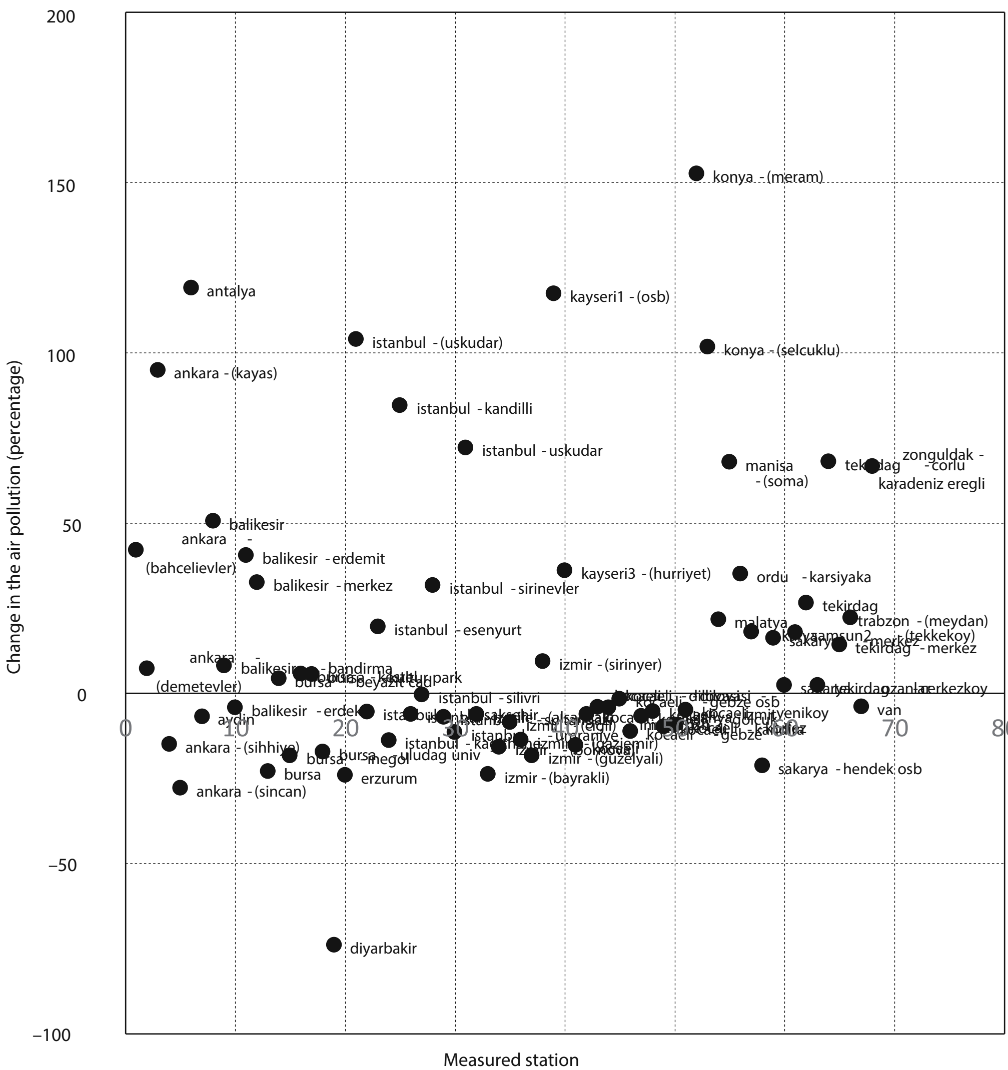
Although economic issues caused by the pandemic are undoubtedly important, the recession and social isolation had some positive environmental consequences. Lower production and reduced social interactions increased the air quality, especially in industrial zones, metropolitan areas, and city centers. At this point, a new literature in the environmental science has emerged. For instance, Sharma et al. (2020) analyzed whether the restricted population activities during the Covid-19 pandemic led to better air quality in 22 cities of India. Their findings showed that the air quality got better due to lockdown enforcements. Dantas et al. (2020) investigated the impact of Covid-19 lockdowns on air quality in Rio de Janeiro, Brazil. The findings indicated that the air polluting gas amount decreased by about 24%–43% compared to the past year. Similarly, Nakada and Urban (2020) did an analysis for São Paulo, Brazil and they found even higher rate of decrease in greenhouse gas emission (more than 50%). Berman and Ebisu (2020) compared the 2017–2019 mean air pollution level with the Covid-19 period for the US. Their findings showed that especially the nitrogen dioxide level decreased by 25% during the Covid-19 period. Xu et al. (2020) analyzed the impact of pandemic on air quality of the selected Chinese provinces. Their analysis showed that the harmful gas emissions decreased by almost 50% compared to the previous years. By analyzing the air pollution data of Korea, Ju et al. (2021) found that due to the decreasing social and traffic activities, the harmful particles in the air decreased during the Covid-19 pandemic. Muhammad et al. (2020) examined the same issue for some major epicenters of Covid-19 such as China, Italy, Spain, and the US. Their findings based on the data obtained from NASA (National Aeronautics and Space Administration) revealed that air pollution in these countries decreased up to 30%. Venter et al. (2020) investigated whether Covid-19 lockdowns caused a global air pollution decline and found that there were significant reductions in harmful gas emissions. Zambrano-Monserrate et al. (2020) focused on both positive and negative outcomes of the lockdowns during the Covid-19 pandemic in China, Italy, Spain, and the US. They emphasized that decreasing production activities positively influenced the environment by improving the air quality. However, millions of people staying at home adversely affected the environment due to the increasing amount of inorganic and organic domestic wastes.

Some other studies, on the other hand, dealt with the issue for the Turkish case. Aydin et al. (2020) found that the air quality in terms of 2.5μm particulate matter (PM2.5) improved in Turkey during the lockdown period. Yet another study considering the PM2.5 is Rodríguez-Urrego and Rodríguez-Urrego (2020) which focused on the air quality for the 50 capital cities around the world during the pandemic period. Despite some retrograding capitals, they found a significant air quality improvement after the lockdown enforcements for the overall sample. As for Ankara, the capital city of Turkey, their results showed a decrease in the PM2.5 emissions. Sahin (2020) investigated the changes in selected particulate matters during March 2020 in Istanbul which is the biggest city of Turkey. The findings of the study revealed notable reductions in emission levels during March.

The empirical evidence shows the air quality in many countries changed for the better during the pandemic period. Limited production capacity and minimized social activity led to lower greenhouse gas emission and higher air quality level. From this point of view, we aim to empirically analyze the same possible impact for Turkish provinces. To this end, we gather data about air quality from different measurement stations located in different parts of Turkey. As the first Covid-19 case in Turkey was observed on March 11, 2020 and the government decided to normalize the economic and social life starting from June 1, 2020, we consider this period in which many precautions and lockdowns were put into action.

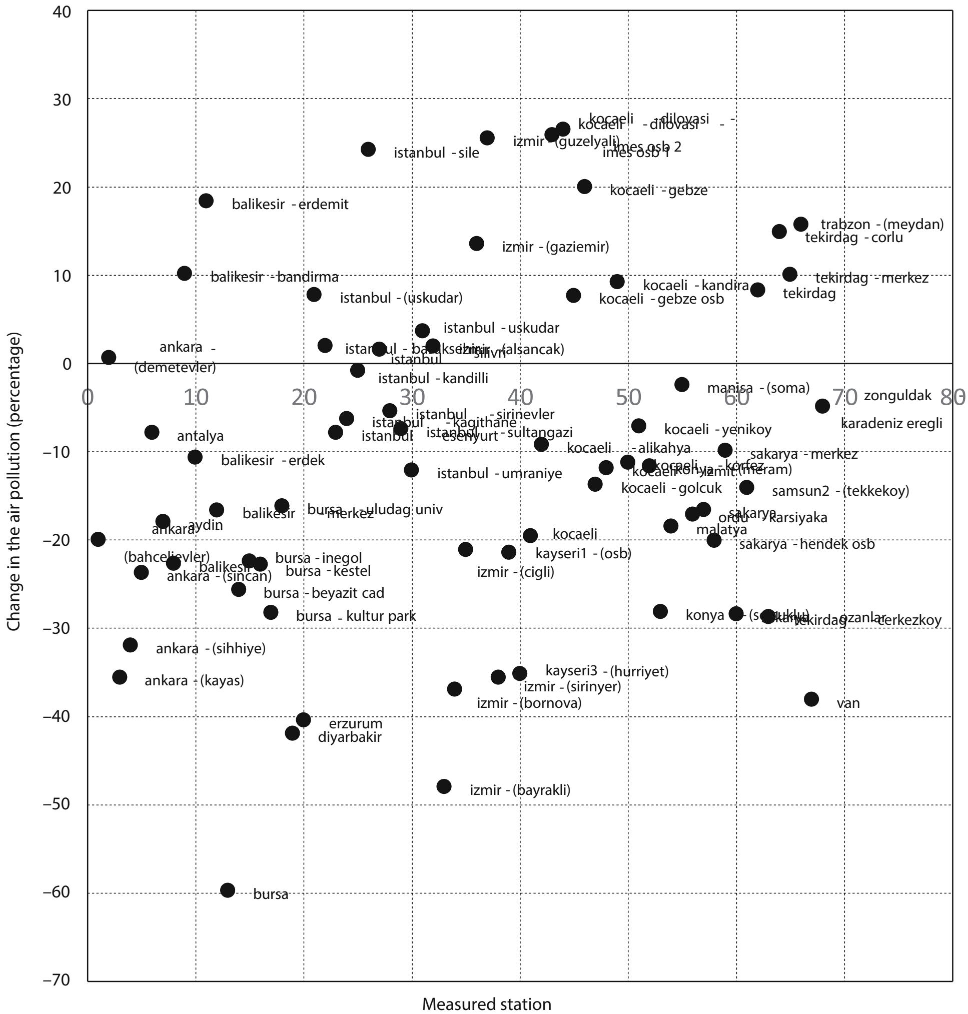
First, we compare both the air quality levels of March 11–May 28 of 2019 and December 31–March 10 of 2020 periods with the period of March 11–May 28 of 2020 to find evidence favoring an increase in air quality in some Turkish cities. The preliminary outlook is shown in Figures 1 and 2. The Air Quality index which will be explained in detail in the next section is an inverse index and lower values indicate better air quality. As observed in Figure 1, there are improvements in air quality of more than 50% of the cities when we compare the active Covid-19 period in Turkey with the same period of the last year (2019). In the first Figure, on the other hand, we also see that the air quality of some other stations worsens. However, since we have not associated the air quality data with any explanatory factors yet, one may only focus on the improvements. When we check out for the December 31 of 2019–March 10 of 2020 period (which corresponds to an interval starting with the first Covid-19 case in the world and ending with the day before the first case in Turkey), we observe an improvement in air quality in 78% of the stations.

Figure 1 Change in air pollution (from March–May 2019 to March–May 2020)



Source: World Air Quality Index (WAQI) project

Figure 2 Change in air pollution (from December 31, 2019–March 10, 2020 to March 11–May 28, 2020)



Source: World Air Quality Index (WAQI) project

Although these basic statistical findings are important, they only reflect a potential relationship between the time trend (covering pre- and post-Covid-19 periods) and air quality level. Here, we aim to observe whether the air quality increased due to the precautions implemented by the government. To our knowledge, although some of the previous studies investigated the air quality in Turkey during the Covid-19 pandemic, this is the first study statistically estimating the impact of Covid-19 precautions on the air quality in Turkey via a constructed precaution series. In other words, the present study tries to observe the impacts of changing precautions enforced by the government. This is a more comprehensive approach compared to the previous studies dealing with the issue only by comparing pre- and post-pandemic periods. Our empirical results indicate that the air quality got better due to the implemented precautions in more than half of the selected stations.

The paper is organized as follows. Section 1 describes data and methodology. Section 2 discusses the empirical findings. Last section concludes with some policy implications.

1 DATA AND METHODOLOGY

We analyze the impact of the precautions implemented against Covid-19 on air quality in Turkey. For this purpose, we use the air quality index values at 68 stations in 21 provinces for the December 31, 2019–May 28, 2020 period. We use air quality index data gathered from the World Air Quality Index (WAQI) project. The WAQI is a non-profit project launched in 2007. The WAQI provides transparent air quality information for more than 130 countries, covering over 30 000 stations in 2000 major cities.[4] The composite air quality index is calculated as follows by using the individual pollutant variables in the WAQI project:

$$AQI = \max(AQI_{PM_{2.5}} AQI_{PM_{10}}, AQI_{O_3}, AQI_{NO_2}, AQI_{SO_2}, AQI_{CO}), \quad (1)$$

where Air Quality Index (AQI) is calculated by using particulate matter ($PM_{2.5}$ and PM_{10}), Ozone (O_3), Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2), and Carbon Monoxide (CO) emissions. The Air Quality Index is valued as the highest value of these measurements. In other words, if all the other measurements are zero but only one of them has a value greater than zero, then the AQI value is determined as this only value.

We choose the stations depending on the availability of data for the analysis period. Note that as some provinces have more than one station, air quality index values may differ for the same province. We use two explanatory variables in the econometric analysis. The first one is the lockdown variable which is a dummy variable that takes a value of 1 for the days when there is a lockdown in that province and 0 for the other days. Our second explanatory variable is the 'strength of precautions'. This variable reflects the effects of any additional precaution taken against the Covid-19. The value of the strength of precautions variable is based on the timetable given in Table 1. The Table indicates that the Turkish government augmented the level of measures through March and April, then relaxed those measures starting mid-May. This variable takes a value between 0 and 12 according to the number of implemented precautions. While the variable takes the value 0 on the day when there is no precaution, it takes the value equal to the number of each implemented precaution on other days. To be more explicit, note that the variable takes the value 2 from March 13th to March 15th as the government took two precautions, while it takes the value 6 starting from March 16th as four more measures were implemented.

$$The\ strenght\ of\ precautions = (precautions1 + precautions1 + \ldots + precautions12). \quad (2)$$

The trends of the lockdowns and precautions series are shown in Figure 3. Even in this basic depiction, one may suggest that there is a negative relationship between Covid-19 precautions and air quality index. Note that, since the values show harmful particles in the air, lower values indicate better air quality. However, to make sure of our inferences, we need to employ further econometric techniques. Hence, we estimate two different models to analyze the effect of lockdowns and the strength of precautions on air quality. These models are as follows:

$$\text{Model 1: } AQI_t = \alpha_0 + \beta_1 LD_t + \varepsilon_{0t}, \quad (3)$$

$$\text{Model 2: } AQI_t = \alpha_1 + \beta_2 SP_t + \varepsilon_{1t}, \quad (4)$$

where α_0 and α_1 represent constant terms, *AQI* is air quality index, *LD* denotes lockdown, *SP* illustrates the strength of precautions, and ε_{0t} and ε_{1t} are error terms. The estimations are made via the ordinary least

[4] The AQI data can be reached through these two websites: *<http://www.aqicn.org> and <http://www.waqi.info>*.

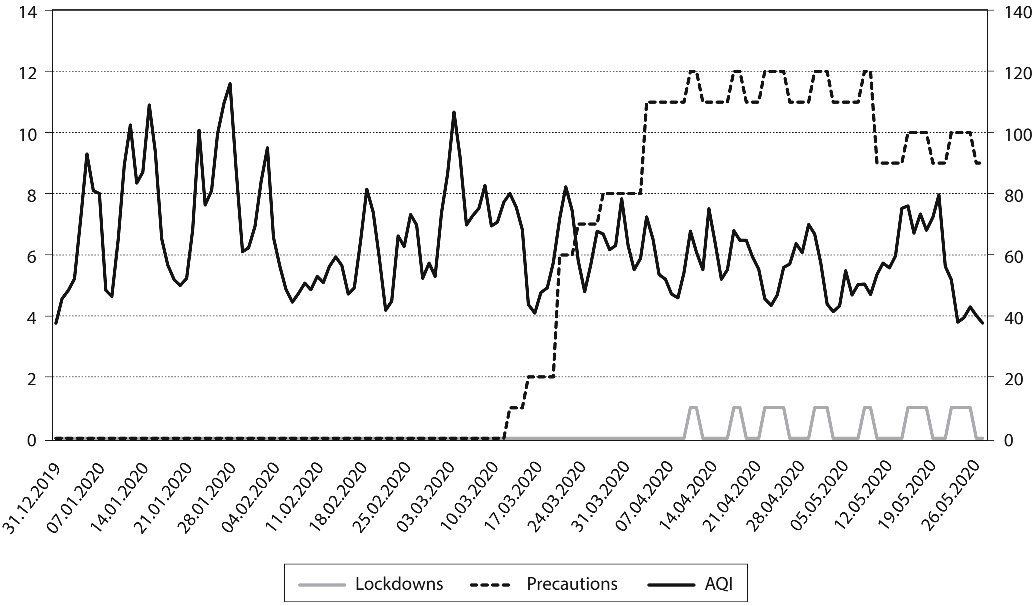
squares method (OLS). The General Linear Regression Model for k variable can be written as follows: $y = X\beta + u$. Where y is an $nx1$ vector of dependent variable, X is a nxk matrix of explanatory variables, β is a $kx1$ vector of the unknown parameters, and u is an vector of errors (Gujarati and Porter, 2009).

Table 1 The timeline of the first wave of Covid-19 in Turkey

Date	Precautions
March 11, 2020	• The first COVID-19 case observed in Turkey.
March 13, 2020	• Sports competitions without spectators. • Flights to some major European countries are stopped.
March 16, 2020	• Temporary break in education. (One week for primary and secondary schools; three weeks for colleges. After this break, the primary, secondary, and tertiary educations in the country have turned into distance-learning.) • Prayer gatherings are banned. • Gatherings for social and cultural activities (concerts, theaters, etc.) are banned. • More countries are added in the flight ban list.
March 21, 2020	• All the scientific, cultural, and artistic events are postponed. • A general lockdown is announced for people aged 65 and over. • 46 more countries are added in the flight ban list. Thus, the air transport with 68 countries is completely cut.
March 24, 2020	• The number of customers in groceries and shops is limited to 10% of their capacity. • The number of passengers in public transportation vehicles is limited to 50% of their capacity.
March 28, 2020	• All the international flights are stopped. • Domestic flights are limited to some major cities from Istanbul and Ankara. • All the intercity transport is subjected to the permission of the state governors.
April 3, 2020	• A general lockdown is announced for people aged under 20. • Wearing a facemask is made mandatory in shops and bazaars. • The entrance (and exit) ban is announced for 30 metropolitan cities and Zonguldak which is the main coal producing city in the country. • Turkish Airlines stops all the domestic flights.
April 11, 2020	• A general lockdown for the weekends is announced until June 1, 2020.
May 4, 2020	• People aged 65 and over on Saturdays; young people (15–20 years) on Fridays; children (under 14 years) on Wednesdays are allowed to go out for 4 hours. • The lockdown enforcement has been expanded for more cities.
May 11, 2020	• Shopping malls, barbershops, and beauty salons are reopened on condition with extra hygiene measures taken.
June 1, 2020	• The government decided to normalize the economic and social life.

Source: Compiled from different daily newspapers

Figure 3 The outlook of the lockdowns, precautions, and air quality in Turkey



Note: The air quality data is the mean of the AQI values of the selected 68 measurement stations. Since the values show harmful particles in the air, lower values indicate better air quality. The left axis is the scale for the lockdown and precautions while the right axis is the scale for the air quality index.
Source: World Air Quality Index (for AQI variable) and authors' own methodology described in this section (for lockdown and precautions variables)

2 EMPIRICAL FINDINGS

The empirical findings are presented in Table 2. Although the precautions were enforced for 31 metropolitan cities in Turkey, due to lack of data we can include only 21 cities into the analysis. The estimation results show that lockdowns lead to better air quality in 25 stations over 68, while for other stations there is no significant evidence. This result is explicable since lockdowns in Turkey were only enforced during the weekends and national holidays. On the other hand, our second explanatory variable yields significant evidence for more cities and stations (39 over 68). This result is also quite meaningful since the precautions were implemented over a longer period and the strength of precautions was augmented as the Covid-19 cases increased in Turkey. Overall, our results suggest that the air quality in the majority of provinces got better as the government took stronger precautions to cope with the Covid-19 pandemic.

The Table 2 also shows us some interesting results: despite increasing precautions during the Covid-19 period, the air quality worsened in some stations. These stations such as Kocaeli-Dilovası-imes (oiz 1), Kocaeli-dilovası-imes (oiz 2), and Kocaeli-Gebze (oiz) are located in the organized industrial zones (OIZ, briefly listed with the obs abbreviation in Turkish), or stations such as Istanbul-Esenyurt and Tekirdağ are located nearby OIZs. On the other hand, the estimated coefficients of Izmır-Çiğli (located nearby an OIZ) and Sakarya-Hendek (oiz) imply that the air quality in these zones thrived as the precautions tightened. Moreover, the models employed for Kayseri1 (oiz), Kocaeli-Gebze (oiz), Samsun2-Tekkeköy and Tekirdağ-Çorlu stations do not yield statistically significant results.

This intriguing result may be explained by the sectoral characteristics of OIZs. For instance, Dilovası OIZ mainly covers chemical, plastic, and pharmaceutical industries in which the production level increased with the Covid-19. Thus, one may clearly suggest the production level to be the key factor for air pollution.

Table 2 The impacts of lockdowns and precautions on air quality (OLS results)

Measurement station	Model I		Model II	
	Constant	Lockdown enforcement	Constant	Strength of precautions
Ankara-Bahçelievler	65.450***	–8.260	70.184***	–1.253***
Ankara-Demetevler	65.907***	29.998***	69.232***	0.186
Ankara-Kayas	95.070***	–39.070***	108.609***	–4.044***
Ankara-Sıhhiye	67.225***	–15.606***	75.712***	–2.271***
Ankara-Sincan	59.961***	–18.295***	65.076***	–1.633***
Antalya	64.480***	–3.719	65.978***	–0.445**
Aydin	43.163***	–4.353	45.940***	–0.747***
Balıkesir	74.062***	–9.967*	8.826***	–1.736***
Balıkesir-Bandirma	39.760***	3.669	38.796***	0.314
Balıkesir-Erdek	55.085***	–16.228**	60.021***	–1.534***
Balıkesir-Edremit	45.178***	12.679***	41.879***	1.080***
Balıkesir-Merkez	71.612***	–7.517	76.322***	–1.226***
Bursa	128.764***	–66.291**	162.884***	–9.234***
Bursa-Beyazit Cad.	85.093***	–21.284**	93.388***	–2.399***
Bursa-İnegol	48.372***	–11.515***	52.796***	–1.284***
Bursa-Kestel	82.651***	–19.413**	89.612***	–2.059***
Bursa-Kültür park	86.985***	–23.175**	96.416***	–2.697***
Bursa-Uludağ Üniv.	80.380***	–11.523*	85.766***	–1.490***
Diyarbakır	24.860***	–13.718***	29.564***	–1.446***
Erzurum	89.907***	–34.717***	106.247***	–4.677***
İstanbul-Üsküdar	53.814***	2.281	52.779***	0.288
İstanbul-Başakşehir	58.225***	0.680	58.872***	–0.117
İstanbul-Esenyurt	59.597***	–6.787	62.448***	0.809**
İstanbul-Kağıthane	79.682***	–11.635*	82.272***	–0.898*
İstanbul-Kandilli	58.651***	3.539	59.305***	–0.034
İstanbul-Şile	55.140***	0.003	51.261***	0.825***
İstanbul-Silivri	63.023***	0.834	62.862***	0.059
İstanbul-Şirinevler	62.612***	–6.374	64.449***	–0.581*
İstanbul-Sultangazi	63.116***	–6.116	65.693***	–0.730**
İstanbul-Ümraniye	59.589***	–8.494**	62.652***	–0.905***
İstanbul-Üsküdar2	54.868***	1.227	54.517***	0.111
İzmir-Alsancak	24.054***	–0.435	23.740***	0.054
İzmir-Bayrakli	43.256***	–17.875	52.416***	–2.481*
İzmir-Bornova	42.085***	–12.181	48.722***	–1.775
İzmir-Çiğli	29.163***	–7.829**	32.193***	–0.878***

Table 2 (continuation)

Dependent variable: air quality				
Measurement station	**Model I**		**Model II**	
	Constant	**Lockdown enforcement**	**Constant**	**Strength of precautions**
İzmir-Gaziemir	37.388***	0.708	36.007***	0.315
İzmir-Güzelyalı	21.512***	5.441	19.950***	0.494**
İzmir-Şirinyer	41.147***	–13.052	46.815***	–1.595
Kayseri1-OIZ	129.705***	–20.039	134.793***	–1.679
Kayseri3-Hürriyet	94.333***	–33.286***	107.424***	–3.777***
Kocaeli	71.496***	–10.687*	77.088***	–1.508***
Kocaeli-Alikahya	66.876***	–6.066	69.481***	–0.735*
Kocaeli-Dilovası-imes OIZ 1	53.891***	1.680	50.117***	0.853**
Kocaeli-Dilovası-imes OIZ 2	53.760***	1.907	49.836***	0.892***
Kocaeli-Gebze OIZ	59.465***	–0.037	58.019***	0.307
Kocaeli-Gebze	53.752***	–3.085	50.591***	0.581*
Kocaeli-Gölcük	68.395***	–7.348	72.611***	–1.116***
Kocaeli-İzmit	67.876***	–7.066	71.248***	–0.928**
Kocaeli-Kandıra	45.178***	–2.274	44.011***	0.181
Kocaeli-Körfez	65.821***	–5.584	69.167***	–0.878**
Kocaeli-Yeniköy	66.093***	–4.712	68.274***	–0.604
Konya-Meram	77.147***	–8.243	81.122***	–1.091**
Konya-Selçuklu	88.775***	–23.870***	98.940***	–2.874***
Malatya	49.504***	–8.171*	54.14***	–1.247***
Manisa-Soma	81.085***	–0.466	81.951***	–0.198
Ordu-Karşıyaka	72.155***	–12.298***	76.222***	–1.264***
Sakarya	81.248***	–14.486	85.65***	–1.368*
Sakarya-Hendek OIZ	84.147***	–11.814**	90.647***	–1.735***
Sakarya-Merkez	77.411***	–10.649	79.765***	–0.818
Sakarya-Ozanlar	78.574***	–20.812***	87.523***	–2.524***
Samsun-Tekkekoy	67.643***	–10.310	71.128***	–1.048
Tekirdağ	78.442***	6.653	73.734***	1.200*
Tekirdağ-Çerkezköy	76.558***	–16.606**	85.402***	–2.376***
Tekirdağ-Çorlu	59.023***	1.072	57.974***	0.262
Tekirdağ-Merkez	70.225***	5.347	66.714***	0.930***
Trabzon-Meydan	70.767***	–3.529	68.581***	0.369
Van	33.628***	–8.056**	40.650***	–1.734***
Zonguldak-Karadeniz Ereğli	76.403***	–8.260	80.167***	–1.047*

Note: ***, **, and * denote 1%, 5%, and 10% statistical significance, respectively.
Source: Authors' own estimations

Another interesting empirical result is that the air quality worsened in stations such as Balıkesir-Edremit, İstanbul-Şile, and Izmir-Güzelyalı. This is plausible because many people from big cities have their summer or secondary houses in those provinces. With the start of the disease, some people went away from big cities to reduce the risk of contamination.

There might also be other explanations for these results: although the measured AQI levels provide important information about the air quality of the cities, there might be misleading biases due to wind, climate, and any other factors that may blow the harmful particles from one location to another one. Therefore, the estimated coefficients for some stations may yield insignificant results or even an opposite (positive) impact.

CONCLUSION

In this study, we empirically examined whether the lockdowns and implemented precautions during the Covid-19 pandemic constitute a positive externality favoring the air quality in Turkey. To do so, we used daily data obtained from the WAQI project for the period of December 31, 2019 and May 28, 2020. Although the data obtained from selected measurement stations basically shows that there are significant improvements in air quality, we decided to move one step forward and estimated the potential impact of government precautions on air quality for each of the measurement stations. The empirical findings suggest that the air quality recovered itself due to the implemented precautions in more than half of the selected stations. This result based on the Turkish experience is consistent with the early literature measuring the impact of the Covid-19 on air quality for different countries.

Our results also show that there are some stations where the air quality worsened despite increasing precautions during the Covid-19 period. Most of these stations are located in OIZs where the production level did increase during the pandemic. The findings suggest that the Covid-19 might be an opportunity to rethink some economic and behavioral practices, as demonstrated by the reduction in the emission of air pollutants from the perspective of sustainable development.

Since the empirical analysis of the present study covers only the first wave of the Covid-19 pandemic and the precautions-air quality relationship within this period, the interaction between these two indicators has a potential to change in the next waves of the pandemic. The reactions of households, firms and governments were quite strict during the first months. Nowadays, after the first three waves, some countries decide to implement precautions to prevent the spread of the pandemic while some others bend the rules. No one can know whether there should be an absolute need for lockdown-type precautions during the following periods of the Covid-19 pandemic. However, in the following years, in case of some new pandemics these kinds of precautions might be implemented again. Further research might focus on the impact of the upcoming waves and pandemics; and even may conduct comparative analyses covering a longer period.

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Material Flows Mobilized by Motor Vehicles and Transport Equipment Manufacturing and Use in the Czech Republic: an Application of Economy-Wide Material System Analysis

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Abstract

Manufacturing of motor vehicles and transport equipment is a key industry in the Czech Republic – it contributes to the national GDP by about 4.6%. The article applies economy-wide material system analysis (EW-MSA) in order to quantify physical material flows mobilized by manufacturing and use of motor vehicles and transport equipment in the Czech Republic. The results show that the Czech Republic is not endowed with the resources needed for the manufacture of motor vehicles such as metals or crude oil for manufacturing of plastics and thus these resources have to be imported. The physical stock of motor vehicles is growing in the Czech Republic, which poses a need for expansion of transport infrastructures. Moreover, almost 70% of waste from motor vehicles manufacturing and use is exported or landfilled, which represent a loss of resources that could be recycled domestically and sent back to manufacturing.

Keywords	***DOI***	***JEL code***
Economy-wide material system analysis (EW-MSA), motor vehicles and transport equipment, dependency on foreign natural resources, physical stock of the economy, waste recycling, Czech Republic	*https://doi.org/10.54694/stat.2021.28*	*Q56, L62*

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INTRODUCTION

The manufacture of motor vehicles and transport equipment is one of the most significant global industries: it contributes to global GDP by 1.6% and to global manufacturing value added (MVA) by about 10% (UNIDO, 2021). At the same time the automotive industry mobilizes large volumes of resources and products. About half of the global consumption of oil and rubber, about $^1/_4$ of the glass output, and $^1/_6$ of the steel output is accounted for by the automotive industry. The industry is the second after aircraft construction in terms of the volume of consumed products of other industries (Saberi, 2018).

The Czech Republic is a medium-sized country in central Europe with 10.7 million inhabitants and has been a member of the European Union since 2004. The Czech economy depends to a large degree on the manufacturing industry: its share in GDP was almost 23% in 2018, which was the second highest value in the EU after Ireland. The most important part of the manufacturing industry is the manufacture of motor vehicles and transport equipment in the Czech Republic. Its share in MVA was 20% in 2018, which was the second highest value globally after Slovakia. In terms of the share of automotive industry in global GDP, the Czech Republic accounted for 4.6% in 2018, which was in fact the largest share in the world followed by Slovakia (4%), Republic of Korea (3.8), Hungary (3.5%), Germany (3.5%) and Japan (3.4%) (UNIDO, 2021). Motor vehicles and transport equipment manufacture was further an important employer in the Czech Republic, providing about 5% of total jobs and representing 16% of manufacturing industry jobs in 2018 (Czech Statistical Office, 2019c).

In spite of the crucial role manufacturing motor vehicles and transport equipment plays in the Czech economy, only fragmented and internally inconsistent information is available on the amount of resources and products from other industries needed for the Czech automotive industry and on the waste flows from car manufacturing and use. This can be considered a shortcoming because the viability of a particular industry for an economy is not determined by its economic performance only. Other factors such as whether resources and products needed for the industry are available domestically or have to be imported, or the ways in which waste from the industry is treated are also important and contribute to the long-term viability of the industry.

The aim of this article is to provide a comprehensive picture of all material flows mobilized by manufacturing and use of motor vehicles and transport equipment in the Czech Republic. These flows will be expressed in physical units, namely tonnes, and we will discuss whether they contribute to a long-term viability of the automotive industry in the country. The literature search showed that there are various approaches for monitoring material flows related to motor vehicles in physical terms. For instance, Ortego et al. (2020) developed a method to identify strategic elements for the automobile sector. This approach defined a variable called Strategic Metal Index (SMI), which was calculated for each metal. Andersson et al. (2017) analyzed to which extent strategic metals in end-of-life vehicles were recycled in Sweden. Carmona et al. (2021) identified how steel accumulation in vehicles contributed to passenger mobility between 1960 and 2015. Liu et al. (2020) carried out a dynamic material flow analysis in order to quantify the amount of end-of-life passenger cars in China in the future while Sharma and Pandey (2020) examined the recovery of resources from end-of-life passenger cars in the informal sector in India.

The above studies are focused on a selection of material flows related to motor vehicles and transport equipment such as strategic metals and/or end-of-life vehicles and their recycling. The approaches from these studies are therefore not designed to quantify all material flows mobilized by motor vehicles and transport equipment manufacturing and use. The above studies further claim that they apply a material flow analysis (MFA). This term comprises a family of methods which have some common features including the focus on physical flows or clear definition of the studied system and its boundaries, but otherwise they can significantly differ, which hampers the compatibility and comparability of resulting studies (OECD, 2008). So far there have been only a few methods quantifying material flows, which achieved a high level of standardization, one of them being economy-wide material flow analysis (EW-MFA) (Eurostat, 2001; Eurostat, 2018). EW-MFA has been widely applied both in developed and developing countries by various research studies (e.g. Adriaanse et al., 1997; Krausmann et al., 2009; West et al., 2014; Schandl and West, 2012; Giljum, 2004; Matthews, 2000), but also by international institutions like Eurostat (Eurostat, 2021), or the UN Environment Programme International Resource Panel (UN Environment Programme International Resource Panel, 2020).

EW-MFA regards the economy as a black box and is devoted exclusively to the monitoring of overall input and output material flows while physical flows within the economy are neglected. This is the reason why EW-MFA cannot be used to quantify how various product groups like motor vehicles and transport equipment are produced in the economy, what their demand on raw materials is, or how they contribute to waste production and waste recycling. There are, however, a few methods which can build on the standardized EW-MFA framework and open the black box of the economy. In that respect, material system analysis (MSA) is a promising candidate.

MSA is defined by the OECD (2008) as follows: "Material system analysis is based on material specific flow accounts. It focuses on selected raw materials or semi-finished and finished goods at various levels of detail and application (e.g. cement, paper, iron and steel, copper, plastics, timber, water) and considers life-cycle-wide inputs and outputs. It applies to materials that raise particular concerns as to the sustainability of their use, the security of their supply to the economy, and/or the environmental consequences of their production and consumption". The OECD definition of MSA is quite general which leaves space for further development of this method and it's tailoring to specific purposes. Recently, MSA has been extended by Kovanda (2021), who developed an economy-wide material system analysis (EW-MSA). EW-MSA covers all manufactured product groups as well as all extracted raw materials, imported and exported raw materials and products, and emission and waste flows and shows their physical flows through various phases of material processing and use. The method thus opens the black box of the economy and, on top of that, utilizes the system boundaries and major accounting principles typical for EW-MFA, thus ensuring the compatibility of these two approaches.

EW-MSA covers all raw materials and product groups which flow through the economy, and can be monitored and analyzed as a whole as shown by Kovanda (2021), or with the focus on selected raw materials and products. The approach can thus be used for monitoring of material flows mobilized by manufacturing and use of motor vehicles and transport equipment, which is the goal of this study. The rest of the article is structured as follows: Section 1 describes the conceptual framework of EW-MSA and its main components: EW-MSA indicators, EW-MSA database and EW-MSA flow charts. It further illustrates how data for the EW-MSA of motor vehicles and transport equipment can be collected and modelled for the Czech Republic. Section 2 provides results of the EW-MSA of motor vehicles and transport equipment for the Czech Republic while Section 3 shows how these results can be interpreted in order to assess long-term viability of motor vehicles and transport equipment manufacturing and use. Last section concludes on the EW-MSA applicability and results.

1 METHODS AND DATA

1.1 EW-MSA methodology

The EW-MSA methodology has been described in detail by Kovanda (2021). This section thus only repeats its key features needed to understand EW-MSA results for motor vehicles and transport equipment.

Unlike EW-MFA, EW-MSA further splits the system into sub-components by phases of material processing and use. These include extraction, manufacturing, use, waste treatment and waste treatment – recycling. The last sub-component was set aside from waste treatment, since recycling and reuse of resources are crucial for establishing circular economies. On the other hand, like EW-MFA, EW-MSA focuses on the physical flows at the current stage of its development. This means, for instance, that net additions to physical stock of the economy are quantified, but in-use physical stock as such is not.

The focus on physical flows is suitable for evaluation of environmental pressures, foreign resource dependency or the rate of recycling. The authors of the study are aware that even small physical flows can present significant monetary flows (e.g. in the case of electronics), but analysis of monetary flows would require a different methodological approach.

The major types of material flows include primary materials that can be identified as belonging to the category domestic extraction (DE) in EW-MFA. That said, the pilot EW-MSA for the Czech Republic does not include unused domestic extraction (UDE). Products include any manufactured commodities at various levels of processing either used for further manufacturing or for final consumption. Waste and water emissions are a result of product manufacturing and primary material and product use and are tackled by waste treatment. After that they are either transformed into secondary materials and input back into manufacturing or added to the physical stock of landfilled materials of the economy in the form of waste deposited in controlled landfills or released to the environment. Some residual waste is also produced in the process of recycling. Air emissions are emitted during product manufacturing, primary material and product use and waste treatment. Some products and collected waste such as fertilizers, manure or pesticides are applied intentionally to the environment (dissipative use of materials). Other products and infrastructures are added to the in-use physical stock of the economy. Finally, even though EW-MSA, like EW-MFA, does not account for bulk water and air flows in general, it includes some of them in input and output balancing items, which are needed for the transformation of material inputs into material outputs, but are usually not a part of resource extraction or emission statistics. Gases from ambient air (oxygen and nitrogen) that take part in oxidizing processes when burning fuels are examples of such balancing items on the input side, while water vapor generated from the water and hydrogen content of fuels in combustion constitute a balancing item on the output side. The introduction of input and output balancing items is necessary in order to establish a material balance. This balance must hold for the EW-MSA system as a whole as well as for manufacturing, use, waste treatment and waste treatment – recycling sub-components. This means, for instance, that the input of materials into the use phase (primary materials from extraction and imports, products from manufacturing and imports, input balancing items) is equal to the output of materials from the use phase (waste and water emissions from use, air emissions from use, dissipative use of products, output balancing items) plus net additions to stock.

The EW-MSA was designed to be compiled in an aggregated form and also broken down by major groups of primary materials and products. The above mentioned material balances also hold true for these major groups of primary materials and products. In order to be able to use official statistical figures as much as possible when populating the system with data, we decided to stick to official classification of products by activities (CPA). Table 1 shows the classification of EW-MSA primary material and product groups by CPA. The article is focused on motor vehicles and transport equipment, which are shown in bold in Table 1.

Table 1 Classification of EW-MSA primary material and product groups by CPA

Primary materials/ product	Group name	CPA
Primary materials	Plant biomass	CPA 01.1, CPA 01.2, CPA 01.3
	Forestry products	CPA 02
	Hard coal	CPA 05.1
	Brown coal and lignite	CPA 05.2
	Crude oil	CPA 06.1
	Natural gas	CPA 06.2
	Ores	CPA 07
	Industrial non-metallic minerals	CPA 08.9
	Construction non-metallic minerals	CPA 08.1

Table 1 (continuation)

Primary materials/ product	Group name	CPA
Products	Animal biomass	CPA 01.4, CPA 03
	Food and tobacco products	CPA 10, CPA 12
	Beverages	CPA 11
	Textiles	CPA 13
	Wearing apparel and leather products	CPA 14, CPA 15
	Wood and wood products	CPA 16
	Paper and paper products	CPA 17
	Coke and refined petroleum products	CPA 19
	Chemicals, chemical and pharmaceutical products	CPA 20, CPA 21
	Rubber and plastic products	CPA 22
	Other non-metallic mineral products	CPA 23
	Basic metals	CPA 24
	Fabricated metal products	CPA 25
	Computer, electronic and optical products	CPA 26
	Electrical equipment	CPA 27
	Machinery	CPA 28
	Motor vehicles and transport equipment	**CPA 29, CPA 30**
	Furniture	CPA 31
	Other manufacturing products	CPA 32
	Manufactured gaseous fuels	CPA 35.21
	Buildings and infrastructures	CPA 41, CPA 42
	Books and magazines	CPA 58

Source: Own construction

The quantification of material flows in EW-MSA is carried out by unambiguously defined EW-MSA indicators. A list of these indicators broken down by phases of material processing and use is shown in Table 2.

Table 2 EW-MSA indicators

Material processing and use phase	Indicator identifier and title
A. Extraction	A.1 Production of primary materials sent to further manufacturing
	A.2 Production of primary materials sent to use
	A.3 Exports of primary materials
B. Manufacturing	B.1 Domestic production of materials intended for manufacturing
	B.2 Imports of materials intended for manufacturing
	B.3 Production of products sent to further manufacturing
	B.4 Production of products sent to use
	B.5 Exports of products
	B.6 Manufacturing waste sent to treatment
	B.7 Manufacturing water emissions sent to treatment
	B.8 Manufacturing air emissions
	B.9 Manufacturing input balancing items
	B.10 Manufacturing output balancing items

Table 2	(continuation)
Material processing and use phase	**Indicator identifier and title**
C. Use	C.1 Domestic production of materials intended for use
	C.2 Imports of materials intended for use
	C.3 Net additions of primary materials and products to stock
	C.4 Dissipative use of primary materials and products
	C.5 Use waste sent to treatment
	C.6 Use water emissions sent to treatment
	C.7 Use air emissions
	C.8 Use input balancing items
	C.9 Use output balancing items
D. Waste treatment	D.1 Domestic waste intended for treatment
	D.2 Imports of waste
	D.3 Exports of waste
	D.4 Water emissions intended for treatment
	D.5 Net additions of waste to stock (waste controlled landfilling)
	D.6 Waste sent to uncontrolled landfilling
	D.7 Waste sent to recycling
	D.8 Incineration/waste water treatment air emissions
	D.9 Water emissions released to the environment
	D.10 Incineration/waste water treatment input balancing items
	D.11 Incineration/waste water treatment output balancing items
E. Waste treatment – recycling	E.1 Waste intended for recycling
	E.2 Production of secondary material for manufacturing
	E.3 Dissipative use of waste
	E.4 Net additions of recycling waste to stock (recycling waste controlled landfilling)
	E.5 Recycling waste sent to uncontrolled landfilling
	E.6 Recycling air emissions
	E.7 Recycling input balancing items

Source: Own construction

Net additions to stock (NAS) represent the amount of materials added yearly to the physical stock of the economy. According to the EW-MFA methodology (Eurostat, 2018), NAS includes not only primary materials and products like motor vehicles, but also waste deposited into controlled landfills, which are considered parts of the economy. NAS is therefore reported under three indicators in EW-MSA: C.3 Net additions of primary materials and products to stock, D.5 Net additions of waste to stock (waste controlled landfilling) and E.4 Net additions of recycling waste to stock (recycling waste controlled landfilling).

As mentioned above, material balances are held for the material processing and use phases (for the indicator identifiers see Table 2).

Manufacturing:

1) B.1 + B.2 + B.9 = B.3 + B.4 + B.5 + B.6 + B.7 + B.8 + B10.

Use:

2) C.1 + C.2 + C.8 = C.3 + C.4 + C.5 + C.6 + C.7 + C.9.

Waste treatment:

3) D.1 + D.2 + D.4 + D.9 = D.3 +D.5 + D.6 + D.7 + D.8 + D.10.

Waste treatment – recycling:

4) E.1 + E.6 = E.2 + E.3 + E.4 + E.5.

The data on EW-MSA indicators are organized in an EW-MSA database held in MS Excel. The database is split into worksheets by the material processing and use phases which are further broken down by particular primary material and product groups. The results of EW-MSA are presented by Sankey flow charts drawn with the use of e!sankey software: <*https://www.ifu.com/e-sankey*>.

1.2 Data collection and modelling for EW-MSA of motor vehicles and transport equipment

An EW-MSA of motor vehicles and transport equipment was carried out for the Czech Republic using 2017 data.

Domestic input-output tables (Czech Statistical Office, 2019a) were used for the attribution of domestically-produced products to manufacturing of motor vehicles and transport equipment and for the quantification of motor vehicles and transport equipment sent to the use phase while the data on total domestic production of these products came from the Czech Statistical Office (2018b). Use of monetary input-output tables for attribution of various physical flows to manufacturing and use of products is a common approach applied by practitioners from the field of environmentally extended input-output analysis (Tukker et al., 2013). It was also used in the Raw Material Equivalent Model published by Eurostat (Eurostat, 2019) and in our previous work (Kovanda, 2018). We assumed a direct proportion between monetary and mass flows for this attribution.

Imports of products for manufacturing and use of motor vehicles and transport equipment as well as exports of motor vehicles and transport equipment was taken from the database on foreign trade (Czech Statistical Office, 2019b). This data was corrected by the direct transit of goods which were not used for production and consumption purposes in the Czech Republic and therefore did not enter manufacturing and use phases of EW-MSA. The correction as well as the attribution of imported products to manufacturing and use of motor vehicles and transport equipment was made with the help of monetary input-output tables for imported commodities (Czech Statistical Office, 2019a).

The generation of waste by industries is reported by the Czech Statistical Office (2018a). Waste was attributed to motor vehicles and transport equipment with the help of monetary supply tables (Czech Statistical Office, 2019a), which provide information on product group supply by particular industries. Afterwards the generated waste was split between the manufacturing and use phases according to the amount of materials entering the respective phases.

The generation of emissions to water by industries is reported by the T. G. Masaryk Water Research Institute (Dlabal, 2019). This was attributed to motor vehicles and transport equipment in the same way as generation of waste. Data on air emissions from manufacturing and use phases were taken from reporting for the International Panel for Climate Change (Czech Hydrometeorological Institute, 2019). This reporting allows for distinguishing whether air emissions stem from the transformation of material inputs into products during manufacturing or from the use of products, as well as for identification which product groups are responsible for which air emissions.

Net additions to stock of motor vehicles and transport equipment was calculated as the difference between inputs and outputs into and from the use phase.

Imports and exports of waste and waste sent to recycling were taken from the Eurostat waste statistics (Eurostat, 2021). These are reported by waste categories, which can be attributed to motor vehicles and transport equipment in EW-MSA. Waste sent to landfill was calculated as the difference between inputs and outputs into and from the waste treatment phase. Incineration/waste water treatment air emissions were taken over from reporting for the International Panel for Climate Change (Czech Hydrometeorological Institute, 2019) and attributed to motor vehicles and transport equipment according to the amount of incinerated waste (Eurostat, 2021). Data concerning water emissions released to the environment were provided by T. G. Masaryk Water Research Institute (Dlabal, 2019) and attributed to motor vehicles and transport equipment in the same way as generation of emissions to water.

Recycling waste sent to landfill came from Eurostat (Eurostat, 2021), which reports recycling wastes by waste categories. Recycling air emissions were taken over from reporting for International Panel for Climate Change (Czech Hydrometeorological Institute, 2019). Production of secondary materials for manufacturing were calculated as a difference between inputs and outputs into and from the waste treatment – recycling phase.

After populating the EW-MSA database with the described data, the material balance was held for those phases, where one of the indicators was calculated as a balance of material inputs and outputs. In order to arrive at full material balance for all the phases, we applied a RAS-type approach, which reconciled inconsistencies in data that should match or sum up to the same amount. For details on the RAS approach see e.g. Lahr and de Mesnard (2004).

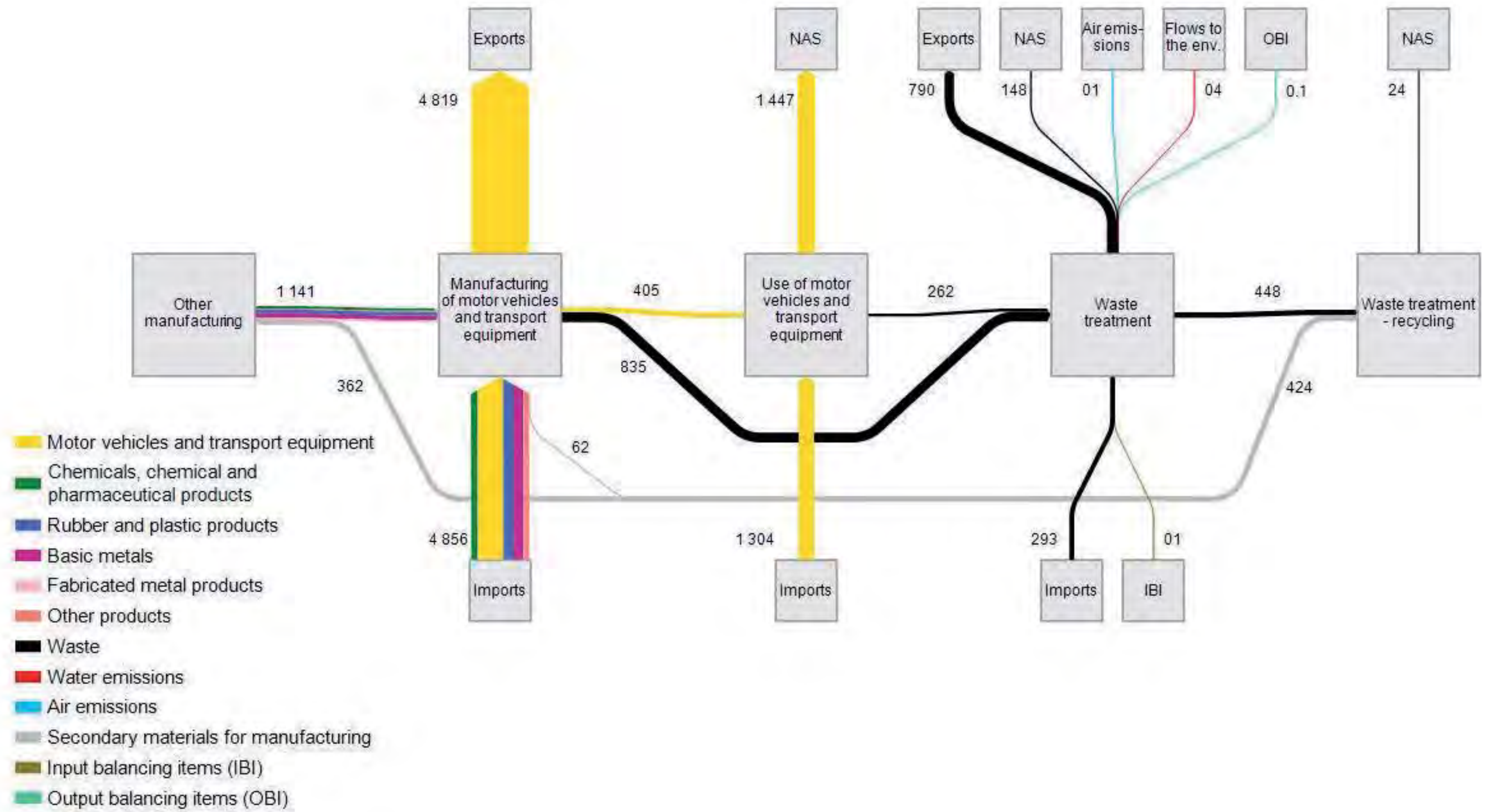
2 RESULTS

Figure 1 shows the overall EW-MSA of motor vehicles and transport equipment for the Czech Republic. Figure 2 depicts a more detailed flowchart for the manufacturing phase.

Manufacturing of motor vehicles and transport equipment did not receive any primary materials from the extraction phase. It only consumed manufactured products – 6 059 thousand tonnes in total in 2017. The largest part of them came from abroad (80%, 4 856 thousand tonnes). Imports consisted especially of various motor vehicles and transport equipment parts (45%, 2 170 thousand tonnes), followed by basic metals (18%, 853 thousand tonnes), rubber and plastic products (17%, 832 thousand tonnes) and chemicals, chemical and pharmaceutical products (11%, 528 thousand tonnes). Other domestic manufacturing supplied manufacturing of motor vehicles and transport equipment with 1 141 thousand tonnes of materials (19% of total material inputs). They were mostly composed of basic metals (30%, 366 thousand tonnes), rubber and plastic products (26%, 310 thousand tonnes), chemicals, chemical and pharmaceutical products (18%, 212 thousand tonnes) and fabricated metal products (13%, 157 thousand tonnes). Secondary materials contributed to material inputs into manufacturing of motor vehicles and transport equipment by only 1%. Regarding material outflows, the largest part was exported (79%, 4 819 thousand tonnes), 7% was sent to use (405 thousand tonnes) and 14% (835 thousand tonnes) was manufacturing waste and water emissions sent to waste treatment.

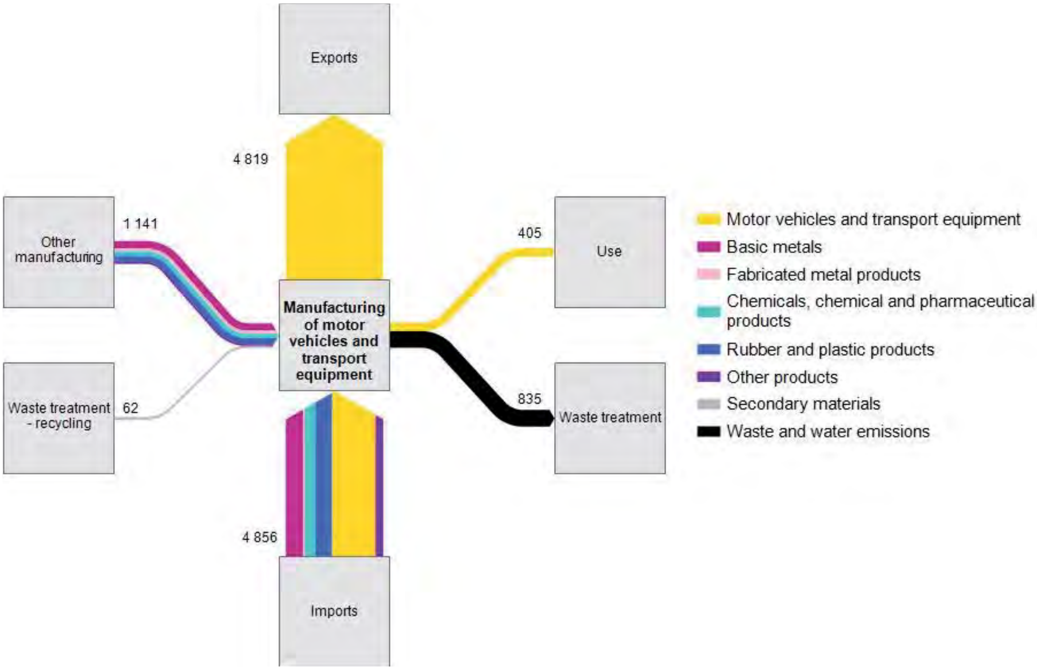
A total of 405 thousand tonnes of motor vehicles and transport equipment entered the use phase from domestic manufacturing (24% of material inputs) and 1 304 thousand tonnes from imports (76% of material inputs). Motor vehicles and transport equipment totaling 1 447 thousand tonnes was then added to physical stock while 262 thousand tonnes of vehicles currently in-use was discarded and sent to waste treatment. The total mass of waste and water emissions entering waste treatment amounted to 1 390 thousand tonnes, of which 60% came from manufacturing phase (835 thousand tonnes), 19% from use phase (262 thousand tonnes) and 21% was imported (293 thousand tonnes). The largest amount of this waste was exported (57%, 790 thousand tonnes), 448 thousand tonnes was sent to waste treatment

Figure 1 EW-MSA of motor vehicles and transport equipment (thousand tonnes), Czech Republic (2017)



Source: Own calculation

Figure 2 EW-MSA of motor vehicles and transport equipment – manufacturing phase (thousand tonnes), Czech Republic (2017)



Source: Own calculation

– recycling (32%) and 151 thousand tonnes of waste and water emissions was landfilled or released to the environment (11%). A minor amount of waste was further incinerated, which resulted in some negligible air emissions and input and output balancing items. In the waste treatment – recycling phase, 424 thousand tonnes was sent back to manufacturing in the form of secondary materials (95%) and 24 thousand tonnes was landfilled (5%). In the case of secondary materials, 62 thousand tonnes headed directly to manufacturing of motor vehicles and transport equipment while 362 thousand tonnes headed to manufacturing of other products.

3 DISCUSSION

As stressed in the Introduction, manufacturing of motor vehicles and transport equipment plays a crucial role in the Czech economy. This has been determined by historical development as well as more recent policies. Tatra produced the first ever passenger car in Central Europe on the area of the current Czech Republic in 1897 followed by the first lorry in 1898. Laurin & Klement was producing motorcycles from 1899 and passenger cars from 1905, but merged with Skoda in 1925, which was originally founded as an engineering company in 1866. Walter produced motorcycles, passenger cars, lorries and buses from 1901, while Praga produced them from 1907 and Sodomka produced coachwork from 1925. Liaz was founded after WWII and focused on the production of utility motor vehicles while Skoda became the largest producer of passenger cars in communist Czechoslovakia (Karaban, 2012). When the communist regime was overthrown in 1989, the previously state-owned companies mentioned above were privatized and Skoda became a part of the Volkswagen Group in 1991 (Volkswagen Group, 2021). In the 1990s several other motor vehicle-producing companies established themselves in the Czech Republic, because the country offered a stable political and economic environment, qualified workforce and good access to the European market. Moreover, there was a number of investment incentives available for these companies, such as tax rebates, subsidies for affected municipalities or workforce education and requalification (Junga, 2009). Two notable companies included Toyota Motor Manufacturing Czech Republic Ltd., which started producing cars in 2005, and Hyundai Motor Manufacturing Czech Ltd., which opened in 2006. Thanks to these investments and also because Skoda has flourished under the Volkswagen Group, almost 1.5 million motor vehicles were produced in the Czech Republic in 2019, which was the fourth highest number in Europe after Germany, Spain and France (The European Automobile Manufacturers' Association, 2021).

In spite of a strong focus on manufacturing motor vehicles and transport equipment, the EW-MSA showed that the Czech Republic is not endowed with the appropriate resources for their manufacture. It does not mine any ores apart from a small amount of uranium ore and it extracts only a negligible amount of crude oil (Czech Geological Survey, 2018). This is the reason why the vast majority of semi-manufactured products needed for motor vehicles and transport equipment manufacturing had to be imported (Figure 2) and even those supplied by the Czech economy such as some basic metals, fabricated metal products or rubber and plastic products were produced from imported raw materials. This means that the environmental pressure associated with the production of imported raw materials and products is overwhelmingly shifted abroad, which poses a question about fairness of such manufacturing in terms of and environmental justice. For further details on the shifts of environmental pressure due to foreign trade see Kovanda and Weinzettel (2013). High dependency on natural resources from abroad, however, is also an economic threats, because the required resources and semi-manufactured products might not necessarily always be available on international markets and/or their price can fluctuate. Moreover, the Raw Material Policy of the Czech Republic (Ministry of Industry and Trade, 2017) pleads for decreasing foreign resource dependency. Any potential further increase in the share of motor vehicle manufacture in the Czech economy is thus in contradiction with this policy.

Over 92% of manufactured motor vehicles and transport equipment were exported in 2017 and contributed by 7% to total exports in terms of mass, but by 25% in monetary terms. No other product group had such a high share in monetary exports (Czech Statistical Office, 2019a). Four hundred and five thousand tonnes of motor vehicles and transport equipment was sent to use and another 1 304 thousand tonnes was imported for use. Despite 262 thousand tonnes of motor vehicles and transport equipment were discarded in 2017, its physical stock increased by 1 447 thousand tonnes (Figure 1). The number of road motor vehicles per 1 000 inhabitants was thus growing in the Czech Republic – it was 625 in 2016, but 645 in 2017, which was a yearly increase of more than 3% (Ministry of Transport, 2018). According to some researchers (Bringezu and Bleischwitz, 2009) growing physical stock (i.e. a positive NAS indicator) is a sign of unsustainability, as it implies growing material inputs for stock maintenance as well as growing waste flows from these stock in the future. Even though the NAS of motor vehicles and transport equipment constituted less than 2% of total NAS in 2017, about 86% of total NAS was related to buildings and transport infrastructures that year. This means that an increase in NAS and of the numbers of motor vehicles also drove an expansion of transport infrastructures, which accumulated a significant amount of materials. Moreover, increase in road traffic is related to many well-known negative impacts on ecosystems and human health (e.g. World Health Organization, 2000).

Waste-related policies in the Czech Republic required an increase in waste recycling in order to support a transition to an economy based on circular use of resources (Ministry of Industry and Trade, 2018). From the 1 390 thousand tonnes of motor vehicles and transport equipment waste which was either imported or came from manufacturing and use phases, the largest share was exported – 57% (790 thousand tonnes), 31% (424 thousand tonnes) was recycled and sent back to manufacturing and the rest was mostly landfilled (NAS) or released to the environment from waste treatment and waste treatment – recycling phases (Figure 1). Exported waste was sent abroad either for final treatment/disposal or recycling, representing a significant loss of resources which could have been recycled domestically and sent back to manufacturing. This touches upon the tricky question of the scale at which material loop closing should be attempted. Not all countries have domestic metal processing industries which would be required for the proper recycling of metals. Material cycles can, therefore, not easily be established at national scale – and it is not even clear if this would even make sense from a sustainable resource use perspective. In the case of the Czech Republic, however, manufacturing of basic metals and fabricated metal products is a key industry – the share of MVA from this manufacturing in total MVA was 15% in 2017 (Czech Statistical Office, 2019a). Therefore, capacity for metal recycling should be increased.

CONCLUSIONS

Manufacture of motor vehicles and transport equipment is a key industry in the Czech Republic – it contributes to national GDP by about 4.6%, which is in fact the highest share globally. The prominent position of motor vehicle manufacturing in the Czech Republic has been partly determined by historical development, since the first company producing motor vehicles was founded on the area of what is now the Czech Republic at the end of 19th century, and partly because of qualified workforce, good access to the European market and various investment incentives, which attracted large international car producers like Toyota and Hyundai to open their factories in the country after the communist regime had been overthrown in 1989. The aim of this article was to study physical material flows mobilized by motor vehicles and transport equipment manufacturing in order to assess long-term viability of these flows from the perspective of resource self-sufficiency and waste management. We applied an economy-wide material system analysis (EW-MSA) for this purpose – a new method recently developed by Kovanda (2021) – which monitors material flows along production chains, connects manufacturing and use of various products with related waste flows and shows how waste is recycled.

EW-MSA revealed that the Czech Republic is not endowed with resources needed for manufacturing of motor vehicles such as metals or crude oil. These resources have to be imported, which is related to controversial shifts of environmental pressure abroad, but also some economic threats, because the needed resources do not have to be always available on international markets for reasonable prices. The stock of motor vehicles is growing in the Czech Republic, which is reflected by an increase in motorization rate, i.e. the number of vehicles per 1 000 inhabitants. More motor vehicles pose a need for an expansion of transport infrastructures, which constitute a major part of total physical stock of the economy. This is a sign of unsustainability according to some researchers, because larger physical stock implies growing material inputs for stock maintenance as well as growing waste flows from these stock in the future. Regarding waste from motor vehicles manufacturing and use, 57% was exported, 31% was recycled and sent back to manufacturing and the rest was mostly landfilled. Both exported and landfilled waste represent a loss of resources which could be recycled domestically. While exported waste can still be recycled abroad, it would be much more beneficial for the Czech Republic to recycle it at home, send it back to manufacturing and decreasing the need to import further primary resources.

Focus on the manufacturing of motor vehicles and transport equipment brings about economic benefits for the Czech Republic, but as highlighted above the perspective of related physical material flows points at various critical issues. A further increase in the share of motor vehicles manufacturing in the economy would even be in the contradiction with some other policies like Raw Material Policy of the Czech Republic (Ministry of Industry and Trade, 2017), which pleads for decreasing foreign resource dependency. Also treatment of waste from motor vehicles manufacturing and use is far from being in line with the principles of circular use of resources (Ministry of Industry and Trade, 2018). Last but not least, the strong focus of an economy on one manufacturing branch can be risky from economic point of view in a long-term perspective, since we live in a changing world and the dominance of motor vehicles manufacturing in the global economy could abruptly come to an end, e.g. due to potential technological breakthroughs in the field of goods and passenger transportation. All these factors should be taken into account when designing further economic, but also social and environmental policies, which calls for horizontal and vertical policy coordination, articulated e.g. in the Strategic Framework Czech Republic 2030 (Government of the Czech Republic, 2017).

EW-MSA is a new methodological approach. This is the reason why we could provide international comparison of some more general indicators like the share of automotive industry in GDP, but we were not able to show any international benchmarking of particular EW-MSA indicators. Still, EW-MSA is a promising tool, which can be applied for other product groups as well, including food, textiles or plastics. Major shortcoming of EW-MSA is the fact that it is a very data-demanding method. Only a fraction of needed data is directly accessible in the official statistics while the rest has to be estimated and modelled with the use of various proxies like monetary input-output tables. This would present a challenge for official statistics if the proposed method was applied more widely or was considered obligatory by institutions like Eurostat.

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A Demand-Supply Equilibrium Model – Study Case on the Electricity Market for Households from the Perspective of Prices Liberalization

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Abstract

Energy production and consumption exert considerable environmental pressure on climate change, deterioration of natural ecosystems and adverse health impacts. Our paper/scientific approach starts from the premise that in the near future the Romanian Electricity Market will be completely liberalized in order to be integrated in the Single Market Electricity. These profound changes will have a strong impact on the household behaviour. In this regard, we develop a dynamic model for the electricity market, based on the principle of supply and demand equilibrium. At the same time, by means of extrapolation methods we are deducing the expressions of demand and supply functions for electricity. These expressions are entered in a demand-supply model given by a dynamical system. The aim of this study is to investigate the equilibrium and the evolution of this system based on data sets from 1999 to 2021, in order to determine the evolution of electricity consumption and to establish competitive advantages for sustainable consumption.

Keywords	***DOI***	***JEL code***
Consumption, energy, environment, equilibrium model, prices liberalization, Romania	*https://doi.org/10.54694/stat.2021.30*	*C6, C62, D1, E21, H31, P18, P48*

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INTRODUCTION

Electricity is perceived as a public service to the population and, at the same time and equally, as a necessity for the economy. Citizens (consumers), when provided with this service, have not only the right to be served, but also an obligation to use energy rationally, under the conditions of energy efficiency. Distribution companies can be carriers of this message in a transparent way through appropriate price corrections.

Energy sources can have a major impact on the environment, on the atmosphere, such as acid rain and global warming. This is due to the widespread use of fossil fuels. The impact on water, soil and landscape must also be mentioned.

In recent years, the European Union has had to reach a balance between protecting the environment, and the political interests on the one hand, and meeting the energy needs of individual economies on the other hand. The European Union (EU) has identified the energy sector as one of its main policy priorities. Reliable and sustainable energy supplies at reasonable prices for businesses and consumers are crucial for the European economy. In the past, the energy industries were organized as vertically integrated monopolies and they were generally belonged to the state. The growing ideological and political disaffection with vertically integrated monopolies and the liberalization successes of other network industries have led to liberalization initiatives in the energy industries (Streimikiene, Bruneckiene and Cibinskiene, 2013).

The liberalization of the energy market became obligatory in Romania, once the country joined the European Union. The liberalization of energy prices in our country was a difficult process. The leaders of the Union have imposed a schedule for the liberalization of prices on the government, mentioning that the failure to comply with it would result in certain penalties to be paid. At European level, the liberalization of the energy market was set up in July 2009 with the adoption of the third legislative package on domestic electricity and gas markets, which was to be completed in 2011 (Eberlein, 2008). Romania did not comply with the European deadlines; the new energy law was adopted with delay by the Chamber of Deputies and promulgated by the President of Romania in the first half of July 2012. Although this liberalization was to be applied from 2012, it seems that for last year, 2021, it would only be applied to household consumers, because so far there are no implementation rules. At the same time, this year, very few competitors entered the market, therefore the change is not significant.

The major distortions (subsidies/cross-subsidies) present on the Romanian electricity and natural gas markets stem from the fact that energy prices have been artificially maintained at very low levels and used as a short-term fix for pervasive social problems. Therefore, in contrast to other European countries where timely deregulation has led to bigger competition, resulting in lower prices (both in wholesale and retail markets), in Romania the expectation is that deregulation will result in higher prices, particularly because the measure is long overdue and has, in the meantime, created series of other problems: mainly, the low energy prices have de-capitalized the energy companies that were thus unable to invest in energy efficiency measures and other modernization projects – all this driving further up the real costs of energy supply. The social problem is composed of the renewable support scheme and the cogeneration bonus. District heating is an energy sub sector with its own set of problems producing a significant social impact. All these different problems accrue in the energy bill (Leca et al., 2014).

However, the liberalization of the energy prices is conducted amidst a grossly unsustainable energy sector which incurs huge losses. Due to its great delay, price deregulation will put a significant strain on all the consumers. Measures aimed to soften this shock will have to target a reduction of both energy consumption (through energy efficiency) and energy loss (through modernization of the antiquated infrastructure). Studies show that energy efficiency can be improved by 16–24% (Leca, 2012).

Before and after Romania's accession, the privatization process in the energy sector unfolded haphazardly, no investments were made to modernize the thermal power plants and the district heating system that is now in a very precarious situation, threatening the heat supply in 32 cities. Before 1989, Romania had and continues to have a very high-energy intensity, which results in a wasteful use of resources (Leca et al., 2014).

Leaving aside the big negative effect of liberalization of the energy market in our country – increasing the mass of vulnerable consumers – theoretically, liberalization should have beneficial effects on energy efficiency, so the impact on the environment should decrease. But the increase in energy consumption will lead to extra pressure on the environment, by over-exploitation of natural, non-renewable deposits. This involves new investments in the field of natural gas exploitation, in the development, rehabilitation and dispatching of natural gas pipelines, in the increase of the natural gas storage capacity. Furthermore, this involves additional costs for a country already not rich enough.

A report of the National Regulatory Authority in the Field of Energy shows that the power prices in Romania went up by nearly 20% in 2017 compared to 2016, while there is also an increase of over 3% in domestic electric energy consumption compared to 2016, which strengthens the result of our analysis. One of the reasons for the rise in prices is the liberalization of electricity prices. On the other hand, suppliers are still obliged to buy a certain amount of import and a certain amount of domestic production by 2021. And last but not least, energy bills are higher than they need be because homes are energy inefficient.

In the first part of the article, we made a brief introduction to what energy means in economics, in the life of today's man. In the first part, we have shown the impact on the environment of the production of energy from renewable sources and we have made a foray into the legislation of Europe and Romania related to green energy and the liberalization of energy prices. In the second part, we described the mathematical model itself, and then, some conclusions about what we were looking for.

The purpose of the article is to make an analysis of the influence of price liberalization on the energy market for household consumers in Romania. To this end, we have considered a mathematical model and realized the graphic interpretation of the results obtained using the considered model.

1 THE ELECTRICITY MARKET AND THE IMPACT OF THE ENERGY SECTOR ON THE ENVIRONMENT

One of the major challenges for the European Union is how to ensure energy security with competitive and "clean" energy, taking into account the limitation of climate change, the escalation of global energy demand and the uncertain future of access to energy resources. The energy sector comprises the following activities: the extraction and preparation of coal; oil and natural gas extraction; the extraction and preparation of radioactive ores; oil processing industry; the production, transport and distribution of electric and thermal energy, gas and hot water.

The production units in Romania are thermal power plants, hydropower plants and the Cernavoda nuclear power plant.

A country traditionally rich in energy resources, Romania has a very poor understanding of the concept of energy saving and no culture in this respect at all. Energy efficiency was recognized as a priority only in 2000, through Law 199/2000, itself adopted with great delay. While the discussions about price are endless, there is little to no focus on the other component of the energy bill: quantity. Thus, energy efficiency should become the government's number one priority over the next period, more so since Romania's potential in this respect is quite untapped (Leca et al., 2014).

But burning solid fuel is not only unsustainable (in the case of peat and coal), but it also generates a wide spectrum of particulate and gaseous air pollutants such as respirable particles (PM10) and non-respirable particles, carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), and polycyclic aromatic hydrocarbons 210 (PAH) (Guo, Lewis and Mclaughlin, 2008).

Industrial competitiveness is at the forefront of the EU's energy policies, along with the following aspects: liberalization of energy markets, energy security, environmental protection and climate change.

In consensus with the Kyoto commitments of the European Union, the liberalization of the electricity markets has been announced to reduce prices, increase efficiency, guarantee security of supply and develop renewable energy sources (National Regulatory Authority in the Field of Energy, 2017). Some solutions, of course in agreement with other researchers, would be the use of bio-energy, for the generation of electricity, and heat using modern conversion technologies (Al Asfar et al., 2018).Thus, biomass may be used as an alternative fuel which may save 40% of fuel cost (Demirbas and Demirbas, 2016).

The 2009/28/EC Directive on renewable energy, implemented by Member States by December 2010, sets ambitious targets for all Member States, such as that the EU will reach a 20% share of energy resulted from renewable sources by 2020 and a 10% share of renewable energy specifically in the transport sector.

The 2009/28/EC Directive was approved for the regulation and the promotion of renewable energy, and established a mandatory methodology to assess the sustainability of biofuels in terms of greenhouse gas emissions (Lapuerta, Ruiz and Lechon, 2014).

In order to reduce the impact of the energy sector on the environment, Romania has transposed into Romanian legislation, in 2003, the 2001/80/EC Directive on the limitation of air emissions of certain pollutants by large combustion plants. This legislative act aims at limiting emissions of sulphur dioxide, nitrogen oxides and dust from large combustion plants, i.e. plants with a thermal output of more than 50 MW thermal (The energy strategy of Romania for the period 2007–2020 updated for the period 2011–2020).

2 DYNAMIC MODELING OF SUPPLY–DEMAND MODELS, METHODS – RESULTS – DISCUSSION

The market price of goods is determined by both the supply and demand. In 1890, English economist Alfred Marshall published his work, Principles of Economics (Marshall, 1890) which was one of the earliest writings on how both supply and demand interacted to determine price. Today, the suply – demand model is one of the fundamental concepts of economics. The point at which the quantity supplied equals the quantity demanded essentially determines the price level of a product.

This is a model studied by Beckmann and Ryder (Beckmann and Ryder, 1969) and Mas-Collel (Mas-Collel, 1986).

A demand supply model in which price (p) reacts to quantity (q) and vice versa was given in (Tu, 1992) by adding constants k and μ to Beckmann and Ryder model:

$$\begin{cases} \dot{p} = k\left[F(p) - q\right] \\ \dot{q} = \mu\left[p - C(q)\right] \end{cases}. \tag{1}$$

In the model, (p) represents the price and (q) represents the quantity. $F(p)$ represents the quantity demanded at price (p) and $C(q)$ represents the marginal cost. Price rises in response to the excess demand $F(p)$ over supply (q) and the quantity increases in response to the excess of price over cost $C(q)$.

In the considered demand supply model $\dot{p}$ and $\dot{q}$ denotes the derivates of price and quantity with respect to time.

Let us take $k = 1$ and concentrate on the speed of adjustment $\mu > 0$ treated as a single parameter on the model. The system becomes:

$$\begin{cases} \dot{p} = F(p) - q \\ \dot{q} = \mu\left[p - C(q)\right] \end{cases}.$$

We note: $f_1(p,q) = F(p) - q$; $f_2(p,q) = \mu\left[p - C(q)\right]$.

In order to solve the system, first we need to compute de Jacobian matrix:

$$\frac{\partial f_1}{\partial p} = \frac{\partial F}{\partial p} \; ; \; \frac{\partial f_1}{\partial q} = -1$$

$$\frac{\partial f_2}{\partial p} = \mu * 1 = \mu \; ; \frac{\partial f_2}{\partial q} = -\mu * \frac{\partial C}{\partial q} \cdot$$

Let us consider:

$a = \frac{dF}{dp}$ and $c = \frac{dC}{dq} > 0 \cdot$

The Jacobian matrix is:

$$A(\mu) = \begin{pmatrix} \frac{\partial f_1}{\partial p} & \frac{\partial f_1}{\partial q} \\ \frac{\partial f_2}{\partial p} & \frac{\partial f_2}{\partial q} \end{pmatrix} = \begin{pmatrix} a & -1 \\ \mu & -\mu c \end{pmatrix}. \tag{2}$$

We study the eigen values, determined from the Jacobian matrix, in order to determine the type of equilibrium. The eigen values λ_1 and λ_2 are the solutions of the characteristic equation:

$$\lambda^2 - tr(A)\lambda + \det A = 0 .$$

So, the eigen values satisfy the following relations (Viète relations):

$$\lambda_1 + \lambda_2 = tr(A) = a - \mu c ,$$

$$\lambda_1 * \lambda_2 = det(A) = \mu(1 - ac) .$$

The sign of the eigen values influences the equilibrium point of the system and we analyze the relations between the sign of the eigen values of the system matrix and the equilibrium point.

If $Re\lambda_1 > 0$ and $Re\lambda_2 > 0$, then the system solution is getting closer to the point of unstable equilibrium.

The characteristic equation is obtained by replacing $tr(A)$ and $det(A)$ in the characteristic equation:

$$\lambda^2 + (\mu c - a)\lambda - \mu - \mu ac = 0 .$$

We consider the following notation:

$$r(\mu) = tr(A) = a - \mu c ,$$

and so, if an equilibrium point exists, we have:

$$r(\mu_0) = a - \mu_0 c .$$

A complete analyse of the model stability was made by to Beckmann and Ryder in their paper (Beckmann and Ryder, 1969). We used their complete evaluation and adapted it to this particular model. We can comment the behaviour of the systems as follows:

- If $a < 0$, $r < 0$, the model is instable.
- If $a > 0$, r > 0, we have:
  - For $\mu < \mu_0$ and $r(\mu_0) < 0$ the model is stable.
  - For $\mu > \mu_0$ and $r(\mu_0) = 0$ for $\mu_0 = \frac{a}{c}$ and det $A > 0$ we obtain the equilibrium point.

The bifurcation takes place when the determinant of the Jacobian matrix is different to zero or when the eigen values of the matrix are both different to zero.

In order to analyse the demand-supply equilibrium model we consider the available data from the Eurostat. Eurostat is the Commission's department responsible for publishing comparable statistics across the EU. For our study, we consider the consumption and the price for householders' energy. All data from the Eurostat database are included in Table 1 and we further use them to determinate and to visual represent the relation between price and consumption.

Table 1 Numerical application, Romania case (the data corresponds to each year)

Year	Consumption (TWh)	Price (EUR/kwh)
2000	7.652	0.0541
2001	7.724	0.0561
2002	7.771	0.0419
2003	8.243	0.067
2004	8.043	0.0921
2005	9.234	0.0655
2006	9.999	0.0792
2007	10.389	0.0855
2008	10.400	0.0885
2009	11.021	0.0814
2010	11.329	0.0856
2011	11.577	0.0848
2012	12.035	0.0795
2013	11.896	0.089
2014	11.910	0.091
2015	12.095	0.0927
2016	12.067	0.0914
2017	12.596	0.0871
2018	12.779	0.099
2019	12.984	0.0983
2020	data not yet available	0.1045
2021	data not yet available	0.1115

Source: Eurostat

For the evolution of the price we initially obtained a linear trend, but since 2015, it has reached a maximum, after which the price lowered slightly.

To apply the proposed demand supply in the study about electricity prices liberalization we consider the reference year 2008. We note $t = 0$ for the year 2008, and this parameter increases or decreases in concordance with the considered year.

In terms of price evolution, calculations were made both for a linear function of function and for a parabolic function.

Thus, for the price, we will stop at the second degree expression of:

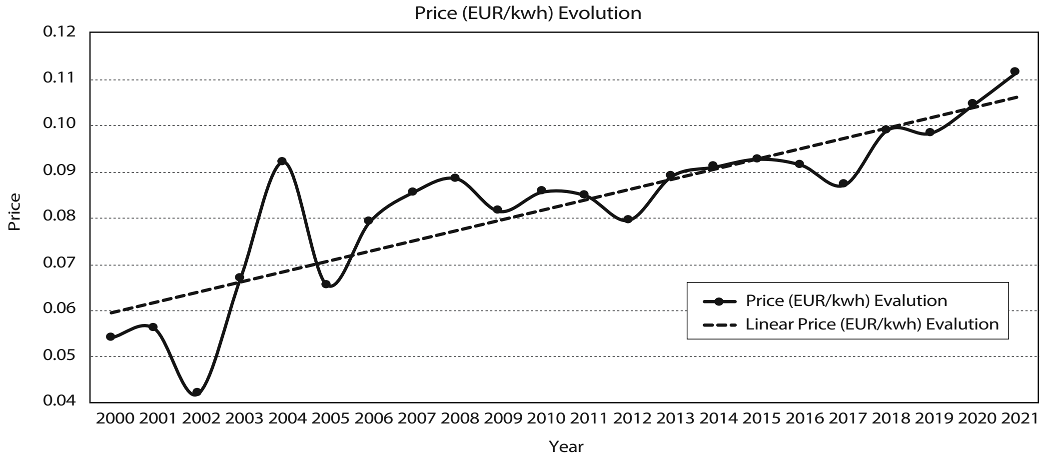
$$P_t = -0.0002t^2 + 0.6434t - 649.57.$$

If we take into account a linear trend, that is, a continuous price increase, it will have the expression:

$P_t = 0.0037t - 7.3637.$

Graphical representations of the linear expression for the price evolution in time are given in Figure 1.

Figure 1 Study of price evolution using a linear expression



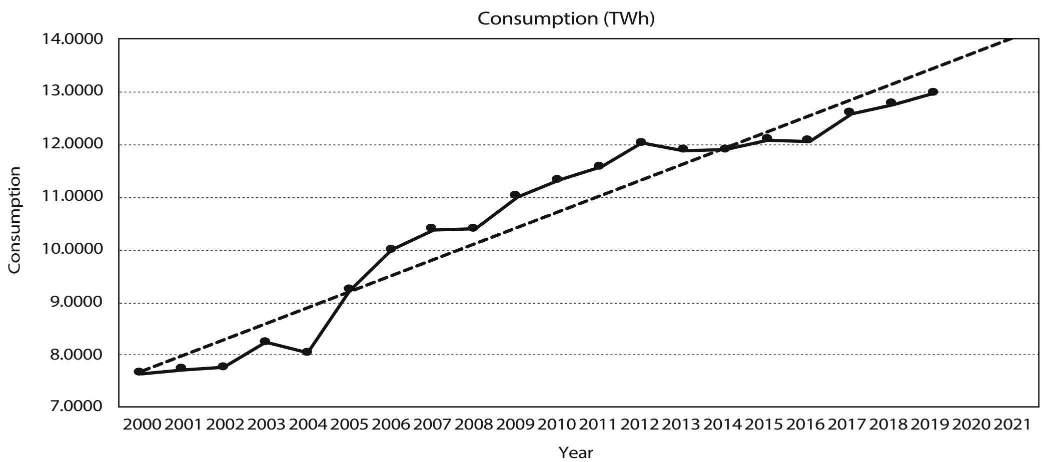
Source: Eurostat

Further, using the same program, we find a linear evolution of consumption, given by expression:

$C_t = 0.0037t + 10.15$.

Graphical representation of the linear expression for the consumption evolution in time is given in Figure 2.

Figure 2 Graphical representation of the linear evolution of consumption



Source: Eurostat

Figure 3 Price – consumption relationship

Source: Eurostat

In Figures 1–3, the blue line represents the actual value of price or consumption and the red line represents the linear trending of the dependency between price, consumption and time.

Analyzing the actual data on consumption and price data for households during the period 2000–2021, using the graphical representation, we determined, using the method of extrapolation and using the least squares method, both the evolution of the consumption and the price in time and the functional relationship between the two variables (consumption and price).

Thus, for the evolution of consumption, we determined a linear relation obtained from the relations between the consumption values and their evolutions in time, whose expression is:

$C_t = 0.0037t + 10.15.$

At the same time, the dependence of the consumer price is given by:

$P(q) = 0.0037q + 0.0507.$

By replacing these functions in the initial system and considering that $\dot{q} = 0$, we deduce that:

$C(q) = -1/\mu+0.0037q + 0.0507.$

If we consider that $\dot{p} = 0$ we obtain the following relation:

$F(p) = p/0.0037 + 0.0470.$

Returning to the system in (1) we find as:

$$\begin{cases} \dot{p} = k\left[F(p) - q\right] \\ \dot{q} = \mu\left[p - C(q)\right], \end{cases}$$

$$a = \frac{dF}{dp} = \frac{1}{0.0037} = 270.270 > 0,$$

$$c = \frac{dC}{dq} = 0.0037 > 0,$$

$$r(\mu) = a - \mu c = \frac{1}{0.0037} - 0.0037\mu = 270.270 - 0.0037\mu .$$

Therefore,

$$\mu_0 = \frac{a}{c} = \frac{270.270}{0.0037} = 73045.95.$$

The bifurcation takes place because the determinant of the Jacobian matrix is different than zero.

Replacing the values computed above in the system we obtain a dynamic system that is conducting to an unstable system.

$$\begin{cases} \dot{p} = 270.270p - q + 0.0470 \\ \dot{q} = \mu(p - 0.0037q) - 0.9493. \end{cases}$$

The equilibrium point of the system is determined by solving the system and considering that $\dot{q} = 0$ and $\dot{p} = 0$:

$$\begin{cases} 270.270p - q + 0.0470 = 0 \\ \mu(p - 0.0037q) - 0.9493 = 0. \end{cases}$$

This system admits a single equilibrium point ($p \cong 1.00463$, $q \cong 272.47$) and this is an unstable equilibrium point, a repulsive node. The value of this point depends on the parameter μ.

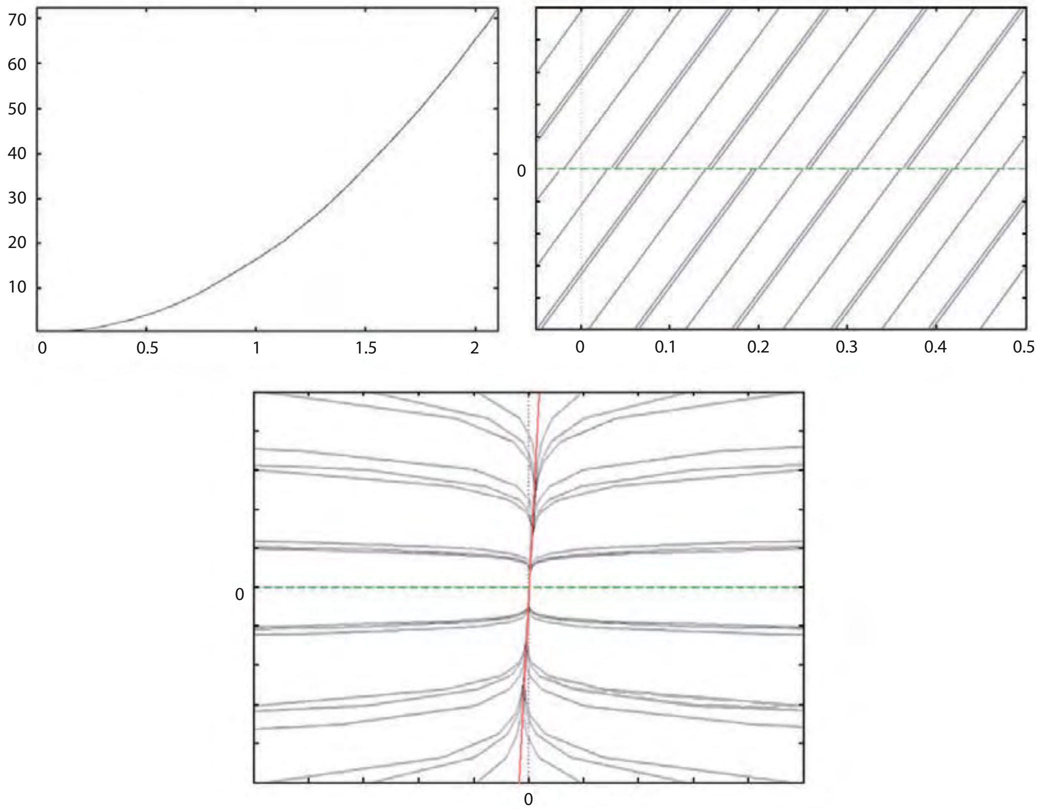
By computing the determinant of the Jacobian matrix, we observe that, for the value $\mu = 73045.95$, a bifurcation appears. We have illustrated the evolution of the system according to some parameter values in the following figures. The equilibrium point of the system is a repulsive and unstable node.

The following figure gives a visual representation of the described model for the data considered in Table 1. In the first part of the figure the axes are time (year) and price (a similar representation is if we represent consumption). Second part of the figure represents the relation between price and consumption in time (axes are price and consumption). And the last part of the figure represents the visual interpretation of the equilibrium point.

In a free market such the one considered in this article, energy market, the demand and supply tend to achieve an equilibrium. If the consumption tends to increase more than the availability then the price will go up. If the consumption decreases then the price will do down. Based on the relation between price and consumption, the model will determine an equilibrium between these two components. If we analyse the graphical representations in Figure 4, we can observe that in all cases the system tends to find its own equilibrium point (to balance the price and consumption).

While the price rises, the consumption decreases, but as we can observe from the considered example, these changes are not proportional. The same observation can be done when the price decreases and the consumption increases. As we can observe in the Figure 4, the equilibrium point is obtained but the lines that represent the price and the consumption are not symmetrical. This equilibrium point is obtained based on the interaction of the supply and demand.

Figure 4 Visual representation for the model: price/consumption evolution over time, the evolution of consumption by price, the equilibrium point (repulsive node)



Source: Own construction

CONCLUSION

Romania is the European country with the largest rural population. Slowly but surely certain areas start growing; people buy computers, television sets, home appliances. Consumption increases from one year to another, and the trend will continue in the coming period.

Bucharest is the European capital where the price paid by the household consumers was, in February 2021, 18% higher than the price paid one year ago. It is, by far, the biggest increase from all European capitals analysed in the latest statistics of the European Commission. In the second and third positions there are Kiev with a 16% increase and Belgrade with about 9% increase. Within the European Union states, 13 out of 27 capitals maintained the same prices or lowered them, while the increase of prices in all the other European capitals was moderate, generally by 5%, with the exception of Stockholm and Warsaw, but here the increase is much lower in comparison with Bucharest (Vaasaett, 2021).

From the forecasted model, it can be concluded that the liberalization of energy prices in Romania will lead to higher prices. The analysis was extended until 2021. Both the model and the tables show that, in order to maintain a balance (called equilibrium point in the model), as consumption increases, the prices must also increase.

The mathematical model allows us to study and to analyze the equilibrium point in the electrical market considering aspects like price and consumption. Using this model, we can analyze the evolution of the relation between the price and the consumption. The results obtained using the mathematical model are in accordance with the electrical market evolution.

We can notice that the bigger the price has become, the lower the consumption has dropper. The demand supply model allows us to sum up, when the demand is higher than the supply, the price will rise, and, when the demand decreases below the value of supply, the price will go down.

During the pandemic and as a result of rising prices or because a number of raw materials were not found, a large part of the Romanian industry was shut down. As a result, the energy required by the industry has decreased. In contrast, energy consumption has increased in household consumers. When the industry restarts, Romania will need more energy. For now, the production of energy is sufficient, even part of it is distributed abroad. It is expected that at the level of 2030, the Cernavoda Power Plant will start reactors 3 and 4. Until then, Romania must stimulate the production of energy from renewable sources, in the southeast, the production of energy from wind sources, due to the fact that the winds are stronger, then throughout the country the production of energy from photovoltaic cells and other renewable sources and non-polluting will be supported.

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