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THE IMPACT OF SOCIAL FEATURES ON THE FINANCIAL SUSTAINABILITY OF PENSION SYSTEMS IN CENTRAL AND EASTERN EUROPE AND BALTIC STATES

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Abstract. This paper analyses the financial sustainability of pension systems from the perspectives of labour supply, population aging, and demographic changes. The time period chosen was 1995 to 2022 and it takes into account nine countries from Central and Eastern Europe and the Baltic States. The econometric modelling techniques used are traditional linear regression, ridge and lasso regression, cross-validated glmnet models, and xboost flexible model used for the whole nine countries and also for country groups. The empirical results show that government expenditures and revenues in terms of social security funds are influenced by the demographic changes of the population that we face nowadays, are bound to the population aging phenomenon, and are dependent upon the elderly labour supply movements. The conclusions of this article reveal the practical need to reshape the financial sustainability of pension systems in all nine countries by developing a sustainable pension scheme that needs to be adjusted to the new social, demographic, and behavioural patterns of labour supply.

Keywords: pension systems, labour supply, elderly people, financial sustainability, aging society.

JEL Classification: H55, H62, H75, I32, J14, J11, G18.

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1. Introduction

1.1. Purpose of the study

The research agenda starts with the pension systems analysis over time and the long and systematic schemes that were used for attaining and maintaining a high level of social benefits for elderly people. However, in the last decades in can be observed some interesting social aspects which influenced the pension system policies. These aspects are generated by globalization, the digital economy, labour force movements, migration, artificial intelligence and computing mechanisms, and complex algorithms.

The research purpose reveals the necessity of recalibrating the pension system's sustainability, especially the financial aspects concerning a more suitable and stable pension scheme for the elderly people in the context of social security and standard of living. Moreover, the research highlights the necessity of an important mix of elements in granting a sustainable pension system structure.

The main added value of the paper consists of creating a framework for the pension systems by taking into account aspects such as demographic trends that manifest in several countries, the aging problem and the future challenges ahead, and the labour supply paths in terms of flexibility and accountability. These aspects will impact upon financial sustainability of pension systems in determining a comprehensible pension scheme for elderly people. The study takes into account both countries from Central and Eastern Europe and the Baltic States, countries with communist pasts and similar institutional, legal, economic, and social problems for gathering some patterns regarding the solutions that need to be enacted by the national authorities in reshaping the pension systems sustainability.

1.2. Research hypothesis

Analysing the financial, economic, social, and behavioural literature, has led to the development of the empirical study research hypotheses which are the following:

H1: *The total general social expenditures that generate high pressure on the pension system budget can be reduced by establishing and strengthening, ceteris paribus, the average tenure of elderly people who activate on the labour market giving stimulus to people who work better and longer consolidating the labour supply and enhancing financial sustainability of pension systems.*

H2: *The total general government revenue can be increased, ceteris paribus, through a sustainable social policy that will consolidate the labour force and also the elderly one, having measures of counteracting the demographic unbalances and population aging encouraging elderly people to continue to gain incomes and strengthening the financial sustainability of pension systems in the long run.*

1.3. Objectives of the study

The initial aim of the paper is to determine the influences of demographic changes, population aging, and labour force on the financial sustainability of pension systems in Central and Eastern Europe and the Baltic States. The specific aims which will be investigated in this study are the following:

- **i.** The impact of demographic changes on the pension systems scheme and policies in terms of soundness and sustainable paths.
- **ii.** The correlation between population aging and the necessary reforms needed to reshape and recalibrate the pension systems.
- **iii.** The *nexus* manifested between the total general government expenditure and total general government revenue for an equilibrated pension systems policy.
- **iv.** The actual trends and paths of the labour force and their impact on the financial sustainability of pension systems.

1.4. Research gap

Regarding the research gap, the theoretical literature does not correctly identify the *quid pro quo* arguments for establishing the social and behavioural features that influence the sustainability of pension systems. Although several underlying studies evaluate and assess some social features and characteristics, the gap remains due to the volatility in terms of social factors, demographic trends, and patterns and several important insights regarding labour supply behaviour.

From the practical point of view, governments and state authorities are primarily concerned with formulating a coherent pension systems agenda *vis-á-vis* of a balanced policy of pension income for elderly people which will grant an increasing trend in the standard of living and also in the happiness of elderly people. This fact regards also the technical features of pension systems which are currently analysed and studied in each country for conferring a sustainable pension system environment and higher financial equity.

In light of the aspects mentioned above, this research contributes to encapsulating empirical results which can be seen as a benchmark regarding the financial sustainability of pension systems. In light of these arguments, this research will analyse and assess the most important features of population aging problems, demographic trends, and labour supply patterns to evaluate the impact of these important aspects, on the pension system scheme, *lato sensu*, and the financial and economic aspects of pension systems, *stricto sensu*.

2. Literature review, theoretical and empirical background, and the current state of the art

The economic and financial literature regarding the sustainability of pension systems and their impact on population aging, demographic changes, and elderly labour supply has an extensive trend nowadays. Stanovnik et al. (2015) make a comprehensive review of pension systems in Croatia, Poland, and Slovenia by presenting the similarities and differences between these three pension systems by using a coverage wage bill indicator regarding contribution compliance. The author has concluded that the trend of this indicator has been decreasing since 2000 and affects the public pension financial sustainability in all three countries. Other authors such as Dorofeev and Tamashiro (2023) deal with the problem of pension systems deter during the 2008 recension and 2020 COVID crisis and suggest that due to especially aging problem, it needs to be implemented several reforms which need to be in light with the contemporary challenges of the global economy.

Gutierrez et al. (2023) connect the healthcare system in Spain with the public pension scheme before and after the Great Recession, highlighting some interesting factors such as intergenerational consensus, sufficient public spending, and the willingness to increase the amount of this spending and the balance of payments-benefits. Dumiter and Jimon (2022) also analyse the public pension systems' sustainability with a special focus oriented on a more financially soundness of public pension schemes; the authors have concluded that in former socialist countries from Central and Eastern Europe, it needs to be implemented structural changes in order to enhance the soundness of the pension reforms.

Other studies, such as Al-Hassan and Devolder (2022) developed stochastic models in the Belgian case for determining the demographic risks of PAYG pension plans, especially in terms of introducing a dependence demographic ratio for the evolution of contributions and benefits in terms of risk-sharing strategies. Safaralievich (2022) examines the efficiency of pension systems and makes recommendations regarding a decent retirement based on changes in the replacement rate, monthly wages, and pensions and the factors that influence the size of pensions. Aubry (2022) suggests the need for alternatives in public pension investment policies; the authors have made an empirical study investigating the performances of pension funds with the conclusion that the volatility increased due to alternative investments and actuarial expectations.

Romp and Beetsma (2023) connect the business cycle and demographic trends with pension reform in OECD countries revealing that their empirical study shows the timing and measures of pension reforms are not connected with the demographic shock but with business cycle shocks. Hoang and Maher (2022) study the problem of public pension contributions from the fiscal implications suggesting the importance of expenditures allocation of a sound public finance policy; the authors conclude that there is an inverse correlation between state expenditures, fund balances, budgetary balances, and employer contributions. Wolf (2021) made an interesting study connecting political pressure with risks in the pension systems using a binary path; the study highlights the need for a convergence process with inter and intragenerational components of a funded pension design.

Kanabar and Kalwij (2023) connect retirement behaviour with the eligibility age of state pensions and conclude that the whole retirement planning needs to be improved to rebalance the disproportion of the state pension and raise the retirement age upwards. Brunello et al. (2023) analyse the need for pension reforms connecting the absence of middle-aged workers with the increasing trends of working horizons and pension reforms agenda; the author concludes that females register smaller wage payments, but their work agenda registers higher flexibility. Jimon et al. (2020) developed an interesting study that connects health features, the free movement of people, and the labour market aspects to pension systems; the authors conclude that the pension systems need to be reshaped due to some factors as changes in the labour force structure, higher levels of death rate combined with lower levels of birth rate, demographic transition, aging and migration.

Analyzing sustainable pension systems starts with Clements et al. (2014) which focuses on the challenges and perspectives on more sustainable pension systems highlighting some interesting insights as the gender gap and intergenerational equity, poverty aspects, the role of family, and several risks. This approach was tackled also by Castanheira and Galasso (2011) which underline the main reforms for a sustainable pension system by two approaches: notional accounts systems and a fully funded system. Nomura (2023) studies the interconnections between public pension schemes and the macroeconomic slide in Japan concerning population aging and pension replacement rate. Other authors as Sorsa and van der Zwan (2022) make a comparative study regarding Finland vs. Netherlands' political sustainability of pension systems suggesting a direct connection between pension scheme parameters and governance culture.

The European Union pension system's financial sustainability was analysed by Bayar (2013) dealing with a triangle agenda: population aging, pension expenditures, and sovereign debt crises of the Eurozone. The interconnections between sustainable investments and pension systems were debated by Hammond et al. (2023) revealing the need for a sustainable and proper investment policy in the agenda of the retirement funds. Abdessalem and Chekki-Cherni (2016) present the multidimensional reforms of sustainable pension systems oriented towards financing sources outside labour income and diversifying other financial sources. Orban and Palotai (2005) suggest the need to introduce several reforms in the pension system which need to start with legal aspects, public liabilities, some important policy measures and budgetary adjustments, and strengthening the private pension funds system.

Table 1 presents several interesting empirical findings regarding the correlation between pension systems, population aging, and demographic changes. As can be seen, there are identified studies that use panel data for a large number of countries to test the connections between the financial sustainability of pension systems, retirement age, fertility rate, and replacement rate (Verbik & Spruk, 2014). In the aftermath, Jimon et al. (2021) reveal that in five Central and Eastern European Countries the connections between the financial sustainability of pension systems and the new social, judicial, medical, and economic conditions.

Other empirical studies deal with some mathematical models of pension systems and their impact on the sustainability of pension systems. This is the case for Ramaswamy (2012) constructed an actuarial model for determining the unit credit method for pension liability, Zhao and Mi (2019) focused on stochastic projection models and Cohort-component population projections, Sole et al. (2019) developing a study that relies on DyPeS behavioral microsimulation model, Gannon et al. (2020) constructing a smooth automatic balancing mechanism, Kulinskaya et al. (2020) with a mathematic model for effective age, life expectancy, and period life improving the Cox – Gompertz model, and Romp and Beetsma (2020) suggesting the need for overlapping generations model.

The mathematical approach to the sustainability of pension systems was developed further by Huang et al. (2020) by developing a mathematic model for the Netherlands using an STLT model – smoothed threshold life table, Bravo et al. (2021) using a Bayesian Model Ensemble of heterogenous parametric with novel adaptive technique using large time-periods and a significant country sample, and Fratoni et al. (2022) which deal with the deterministic shock on public pension systems due to the COVID 19 effects in Italy.

There can be identified also other interesting empirical studies dealing with the sustainability of pension systems, such as Amaglobeli et al. (2019) which analyze a large sample of 80 developed and emerging countries using demographic trends and developments, and private savings panel regressions. Moreover, Krpan et al. (2022) analyzed 11 members of the EU in terms of pension system sustainability and using the slack-based measure (SBM) and DEA methodology. Gomez-Deniz et al. (2022) studied the robustness of pension systems in Spain using a statistical model with total payments, meanwhile, Tomassetti (2023) developed an EU model of pension funds regarding the enactment of sustainable finance.

The economic literature reveals another part of interesting studies which need to be taken into consideration. First, Boj et al. (2024) developed an interesting study by including several clusters to analyze the effect on the lifetime of a family with household finances by using reverse mortgage loans. Dumiter (2023) expresses the importance of judicial and financial aspects of taxation with a direct effect on pension systems to strengthen the financial sustainability of pension systems and recalibration at the OECD level of the social system structure.

Table 1. Previous studies regarding the sustainability of pension systems, demographic changes, population aging, and elderly labour supply

Author	Research method	Sample	Results and main conclusion	Research Gap
Ramaswamy (2012)	▪ Actuarial model using the projected unit credit method for determining the service cost and pension liabilities.	▪ Canada, Germany, France, Italy, Japan, Netherlands, Sweden, United States.	▪ Occupational schemes need to comply with the accounting standards. ▪ Lower returns of pension assets are provided by poor financial market returns and low real interest rates.	▪ Reshaping the sustainability of pay-as-you-go pension schemes throughout pension risk exposure. ▪ Rising fiscal deficits and lower payroll tax revenues impact of pension schemes.
Verbic and Spruk (2014)	▪ Panel with fixed-effects and random effects.	▪ 33 countries in the period 1998–2008.	▪ The fiscal sustainability of pension systems can be improved by higher net replacement rate, increase retirement age and total fertility rate.	▪ Pressure on expenditures of pension systems due to the aging population. ▪ Improvement of life expectancy in line with the decrease in the fertility rate.
Amaglobeli et al. (2019)	▪ Demographic and pension system trends. ▪ Impact of demographic developments on savings. ▪ Private savings panel regressions.	▪ Advanced, emerging and developed economies. ▪ 80 countries.	▪ Aging challenges and savings rates – institutional settings for reshaping the pensions systems. ▪ The imperial need for reforms of public pensions. ▪ The need of measures to counteracting the aging effects on labour supply.	▪ Reshaping the design of retirement system scheme. ▪ Population age distribution movements due to the declining fertility and increasing longevity.
Zhao and Mi (2019)	▪ Stochastic projection models and Cohort-component population projections.	▪ Time period 2001–2016 and projections for the next 60 years for China.	▪ Pension system problems in China: insufficient collection, differential contribution rates and dual employment structure. ▪ The need to adopt other systems with redistributive basic old-age and multi pillar pension systems.	▪ Distortion of public systems and under the economic downturn and population aging. ▪ Pensions gap developments by using population projections and stochastic projection models.
Sole et al. (2019)	▪ Extension of the DyPeS behavioural microsimulation model.	▪ Period sample between 2008 and 2015 for Spain.	▪ Reforms to reduce pension expenditures due to demographic ageing consequences. ▪ The need of several indicators for intra and intergenerational distribution.	▪ Reforms of pension system for reducing the demographic ageing consequences. ▪ The balance between economic position of pensioners and average pension to average wage.

Continue of Table 1

Author	Research method	Sample	Results and main conclusion	Research Gap
Gannon et al. (2020)	▪ Smooth automatic balancing mechanism (S-ABM).	▪ US Social Security System.	▪ Financial sustainability pf pension system is prevailed by financial balance, social time preference rate, lower expenditures.	▪ The need for balancing expenditures of pension schemes with increasing receipts. ▪ Trade-off between social costs and social time preference.
Kulinskaya et al. (2020)	▪ Cox – Gompertz model for effective age, life expectancy and period life.	▪ Mathematical model.	▪ Among groups of people can have impact health interventions and medical advances. ▪ The composition of population can have impact upon life expectancy.	▪ Forecasting mortality projections and ageing population. ▪ Health interventions and medical advances affect life expectancy and have impact on pension systems.
Romp and Beetsma (2020)	▪ Overlapping generations model with (1) exogenous endowment income and (2) the consume of their savings and benefit from pensions.	▪ Mathematical model.	▪ Problems in the relaxed policy regarding the participation in existing pensions arrangements. ▪ The important need and willingness of young people to contribute to the pension systems. ▪ The impact of uncertainty and risk aversion impact upon social welfare of pension schemes.	▪ Reshaping intergenerational risk-sharing benefits. ▪ Uncertainty and risk aversion connected with social welfare maximizing.
Huang et al. (2020)	▪ STLT model – smoothed threshold life table.	▪ Mathematic model for Netherlands.	▪ Advanced life mortality acceleration and late life mortality deceleration.	▪ Advance ages with life table for extreme and non-extreme ages with smooth mortality transition.
Jimon et al. (2021)	▪ OLS, 2SLS; GMM; VAR.	▪ 5 Central and Eastern European Countries: Czech Republic, Hungary, Poland, Slovakia, and Romania.	▪ Financial sustainability of pension systems is preserved by the new social and economic conditions in CEE countries.	▪ Special reforms needed for former CEE countries due to the communist systems. ▪ Changing the legal environment of pension systems and strengthening the judicial features. ▪ Economic and financial reforms needed in order to exceed the catching up process from the developed countries.

End of Table 1

Author	Research method	Sample	Results and main conclusion	Research Gap
Bravo et al. (2021)	▪ Bayesian Model Ensemble of heterogenous parametric with novel adaptive technique.	▪ Period sample between 1960 and 2018 and projections through 2050 for the 42-nation population.	▪ For all countries life expectancy gap is positive and significant. ▪ It must be annually a indexation rate of pensions due to the magnitude of subsidy rates between generations.	▪ The revaluation of demographic projection between retirement income products and life expectancy cohort. ▪ Life expectancy gap of all ages modelling and mortality rate forecasting models.
Fratoni et al. (2022)	▪ Deterministic shock on public pension systems due to the COVID 19 effects.	▪ Period sample between 1983 and 2017 for Italy.	▪ Contributions incomes were lowered by economic restrictive measures and reduced wages and employment. ▪ There can be identified a dependence ration between unemployment rate and mortality on pensioners.	▪ COVID 19 effects upon the sustainability of pension systems. ▪ Stochastic framework using unemployment rate, wage growth, inflation rate, and mortality rate.
Krpan et al. (2022)	▪ Sustainability on pension systems using the slack based measure (SBM) and DEA methodology.	▪ 11 new members of the EU: Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.	▪ The funding level of pension systems if essential. ▪ Private pension system is important regarding the economic part. ▪ The older population participation in the labour force rate.	▪ Multipillar pension systems on new EU Member States. ▪ Future benefits of current pension systems by using Global Pension Index methodology (CFA Institute). ▪ Cross-country comparison needed between EU member states.
Gomez-Deniz et al. (2022)	▪ Statistical model for pension systems using total payments.	▪ Period sample between 2000 and 2019 for Spain.	▪ Addressing the unsustainability and system deficit with actuarial statistics and probability computing. ▪ Pension systems sustainability must be tackled also by the key element: the level of reserve funds.	▪ Creation and enhancing reserve funds for macroeconomic stability. ▪ The calculation and forecasting of these reserve funds in pension systems for mitigation of demographic, economic and social conditions.
Tomassetti (2023)	▪ EU model for pension funds regarding the enactment for a sustainable finance.	▪ EU Member States.	▪ The critical need for economic sustainability; the duality between workers as shareholders and workers as stakeholders; rebalancing pension funds.	▪ EU legislation improvement needed in terms of Directives and Regulations. ▪ Taxonomy regulation and pension fund governance need to enhance transparency rules.

Figuerola-Wischke and Gil-Lafuente (2024) make on the US case study regarding the benefits of real retirement average by using forecasting techniques; the authors conclude that the operator of a real average pension could be taken into account by the US authorities for a successful social security benefits policy implemented with good empirical results. Dumiter et al. (2023) evaluate and assess the sustainable aspects of pension systems in Central and Eastern Europe by taking into account the social, economic, and financial features and characteristics of pension systems.

3. Research methodology

3.1. Model specification and construction

In this research, we analysed the financial sustainability of pension systems by having two independent variables, pension expenditures and pension revenues. The pension funds data set contains N = 252 cases with m = 8 features (independent variables) each and two targets (dependent variables). Data are grouped by nine countries with 28 consecutive yearly entries (group cases) 9 × 28 = N. Subsequently, it will be used to evaluate the structure and dependence relations in the entire data set (disregarding the country groups). The first following subsections report on data analysis regarding this entire data set.

Expenditure and revenue targets: the linear base model

Given date input matrix $X \in \mathbb{R}^{N\times m}$ and a target $y_i \in \mathbb{R}^N$, $i \in \{1,2\}$, where the index $i$stands for expenditures or revenue as a percentage of GDP, respectively, the linear base model is obtained by solving:

$$\min_w \; ||y_i - ew_0 - Xw||^2. \tag{1}$$

The parameter vector $(w_0, w) \in \mathbb{R}^{m+1}$ is found by minimizing the squared error of hitting the target y_i by linearly combining the features (columns) from X. Parameter $w_0 \in \mathbb{R}$ is the intercept and e is the N-dimensional unity vector.

Setup of data analysis

In the sequel, and as a first step the entire data set will be analysed separately for both targets. Notwithstanding the data degeneracy of the entire data set, the aim is to specify and illustrate a strategy for model-based data assessment. To this end, a series of models with increasing representational and mapping capabilities are used. Because the number of cases is quite limited it is mandatory to use linear models first. The objective of the analysis is twofold: (i) testing for variable selection or input variable relevance, and (ii) reporting on the data reproduction quality of the models. Models to be used are:

(a) traditional **Linear** regression;

(b) **Ridge**- and **Lasso**-regression to check for input variable importance (sometimes referred to as for ARD – automatic relevance detection) with different regularization objectives,

(c) cross-validated **glmnet** models to find good combinations of Ridge- and Lasso-regression: an effective regularization for eliminating input variables from (linear) models;

(d) Xboost as a very flexible model class capable of building rather universal non-linear models (with much less effort compared to training and validating neural networks).

For small data sets, models of high mapping power equivalent to (d) like for instance **Xboost** cannot be sensibly used for data reproduction as they will almost always find ways to accurately reproduce the given data! However, if such reproduction succeeds with a reduction in the number of active inputs, this is still worthwhile reporting. Implicitly, such powerful models also map possible combined effects of variables, hence more informative approaches like Shapley's method can be used to assess variable importance.

Ridge- and Lasso-regression for assessing the variable importance

This is an extended linear modelling class that highlights variable importance by the use of regularized linear models. This extension calls for solving the following problem:

$$\min_{w} \left\| y_i - ew_0 - Xw \right\|^2 + \alpha\lambda \left\| w \right\| + (1-\alpha)\lambda \left\| w \right\|^2, \quad (2)$$
for $i \in \{1.2\}$, i.e., for both targets,

with λ ≥ 0 and 0 ≤ α ≤ 1. The meaning of all other variables is the same as that from the base model stated above. For λ = 0 there is no regularization, and for λ > 0 model truncation can be combined between soft regularization, for α = 0, and hard regularization, for α = 1, and anything in between.

3.2. Data and variables

The empirical study conducted in this article analyses the impact of demographic changes, population aging, and elderly labour supply in nine CEE and BS: Bulgaria, Czech Republic, Poland, Romania, Slovakia, Hungary, Estonia, Latvia, and Lithuania. Table 2 presents the empirical database constructed as well as the variables code, description, and unit scale. The time – period for the database is 1995–2022. The following dependent variables are total general government expenditures and total general government revenue, meanwhile, the independent variables are average population, population change, crude death rate, natural change of population, the median age of the population, old-age dependency ratio, proportion of population aged 60 years and more, proportion of population aged 65 years and more. The construction of the database was developed by using the data from Eurostat. The data analysis, the econometric modelling and the graphical outputs all use tools from the R software.

Table 2. Variables, data sources, description, unit scale, and construction mechanisms

Variables code	Variables description	Construction mechanism and Unit/Scale	Sources
Dependent variables			
soc_exp (yexp)	Total general government expenditure, Social security funds	Percentage of gross domestic product (% of GDP)	Eurostat database
soc_rev (yrev)	Total general government revenue, Social security funds	Percentage of gross domestic product (% of GDP)	Eurostat database

End of Table 2

Variables code	Variables description	Construction mechanism and Unit/Scale	Sources
Independent variables			
av_pop (avp)	Average population – total	The population average is calculated as the arithmetic mean of the population on 1st January of two consecutive years. The average population is further used in the calculation of demographic indicators, like the crude rates per 1000 persons.	Eurostat database
pop_ch (pch)	Population change – demographic balance and crude rates at national level	The difference between the size of the population and the end and the beginning of the period specifically, it is the difference in population size on 1st January of two consecutive years.	Eurostat database
dr (cdr)	Crude death rate	The ratio of the number of deaths during the year to the average population in that year. The value is expressed per 1000 population.	Eurostat database
n_ch_pop (ntch)	Natural change of population	The difference between the number of live births and the number of deaths during the year.	Eurostat database
mage_pop (mage)	Median age of population	The age that divides a population into two numerically equal groups, meaning half the people are younger than median age and half are older.	Eurostat database
oadr	Old-age dependency ratio 1st variant (population 65 years or over to population 15 to 64 years)	Is the number of persons of an age when they are conventionally considered economically inactive (aged 65 years and over 1st variant, to the number of persons conventionally considered of working aged 15–64 1st variant).	Eurostat database
pop60 (p60)	Proportion of population aged 60 years and more	% of total population	Eurostat database
pop65 (p65)	Proportion of population aged 65 years and more	% of total population	Eurostat database

4. Empirical results

This entire data set has the (linear) correlation structure depicted in Figure 1, which by visual inspection already points at a series of degeneracies (collinearity, etc.). For instance, note that both targets are highly positively correlated. High positive correlations appear also between input variables, for instance, the inside the block {***oadr***, ***p60***, ***p65***} and with the variable ***mage***.

Plotting both target values (Figure 2) against each other – irrespective of their order in the database – gives a fast and precise view of their similarity. The more they are aligned to the diagonal the more similar they are. Such scatterplots will also be used in the sequel. Both target variables are highly correlated but also have some dissimilarities. They seem somewhat redundant. Only very limited useful dissimilarity information is therefore to be expected from the overall data view. However, more detailed, country-wise analysis will finally assess their modelling value.

The population levels and the revenue target depicted in Figure 3 (sufficient due to the high correlation between both targets) seem to indicate a spuriously positive correlation. This seems at first surprising, but it may mainly be due to considering the entire data set (which contains contiguous country subgroups). Later analysis of country groups in parallel may present a more differentiated picture. However, using country-specific models implies a much-reduced number of cases (28 each), and hence, fewer degrees of freedom or more modelling uncertainty!

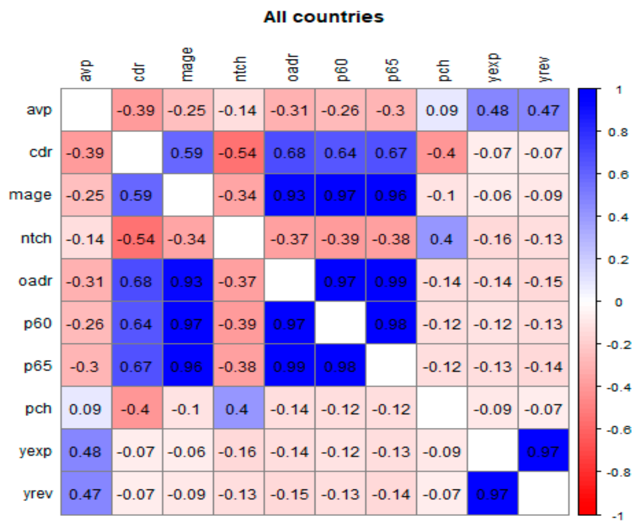

Figure 1. Linear correlations between all variables for the entire data set (all countries) (source: own processing using R software)

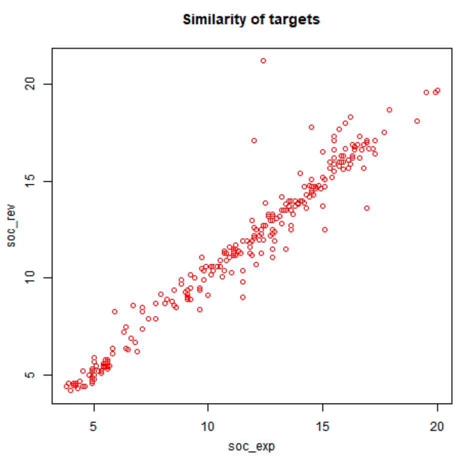

Figure 2. Plotting target variables expenditures targetagainst revenues (source: own processing using R software)

Figure 3. Comparing population levels and the revenue (source: own processing using R software)

4.1. Expenditure and revenue targets: the linear base model

In Figure 4 there is a slight change in position and importance of some variables. Variables with low or very low relative importance may be excluded from the data model. In general, if some input variables are effectively excluded the accuracy of the target reproduction is expected to be less or at most equal to that of the full model. Figure 5 depicts the reproduction accuracy of the full models for both targets.

Both target reproduction scatterplots of Figure 5 are more accurate the more the point distribution approaches the diagonal (the 45-degree line; can be seen also in Figure 2, which seems to be much better in comparison).

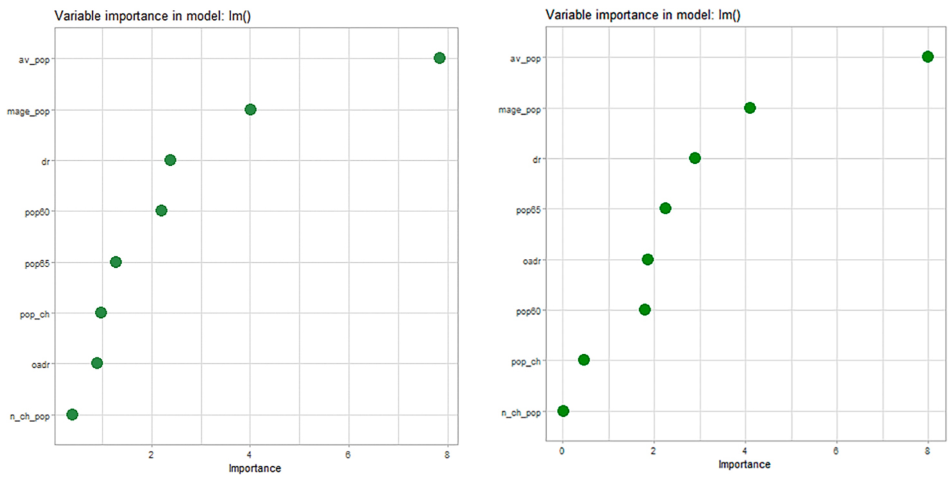

Figure 4. The importance of the feature variables for (approximately) reproducing both targets. Left panel: expenditures target, Right panel: revenue target (source: own processing using R software)

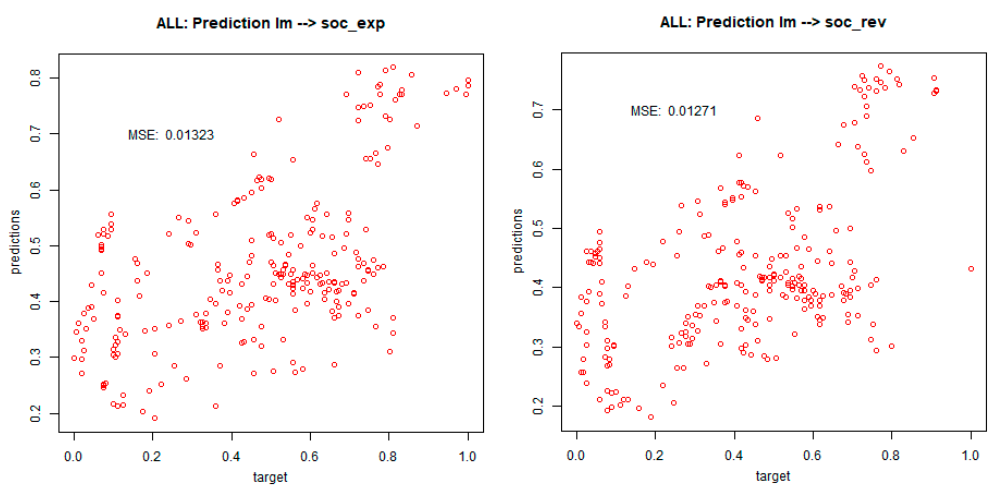

Figure 5. The target predictions of the linear model using all variables. Panels same as in Figure 4 (source: own processing using R software)

4.2. Variable importance: the ridge and lasso models for expenditure target

In Figure 6 model coefficients $w_j(\lambda)$, for $i \in \{1, 2, \ldots, m\}$, i.e., the different curves depicted, lead to acceptable model errors for $\log(\lambda)$-values between the respective vertical dashed lines. The upper line plots from Figure 6 indicate, however, that the overall error variation is quite limited.

4.3. Variable importance: the ridge and lasso models for revenue target

Figures 6 and 7 suggest that one may drop feature variables without a dramatic error penalty. Due to the high positive correlation between both targets, they are quite similar. Strong parameter fluctuation for lower λ indicates co-linearity problems in the data. The rather broad intervals surrounding the average curves in the upper line plots indicate strong fluctuations of error penalty caused by cross-validation as compared to average error variation.

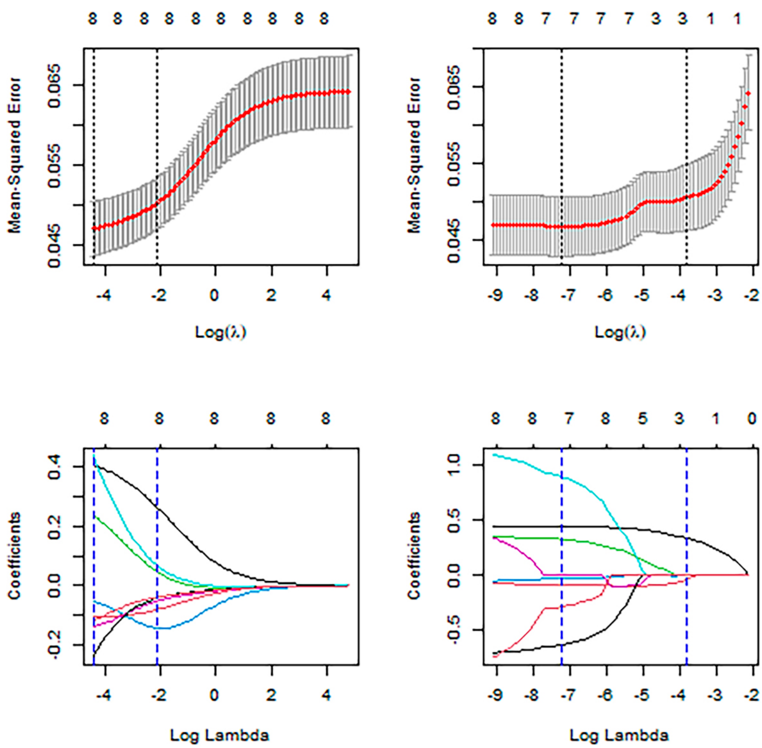

Figure 6. The ridge model (α = 0, left column plots) and the lasso model (α = 1, right column plots). Upper line plots: error penalty for regularization. Lower line plots: change of coefficients $w_j(\lambda)$ due to progressive regularization λ > 0. The shaded corridors in the upper line plots are error bars due 10-leave out to cross-validation. The upper horizontal numbers in the lower line plot represent the number of active variables for progressing Log-lambda (source: own processing using R software)

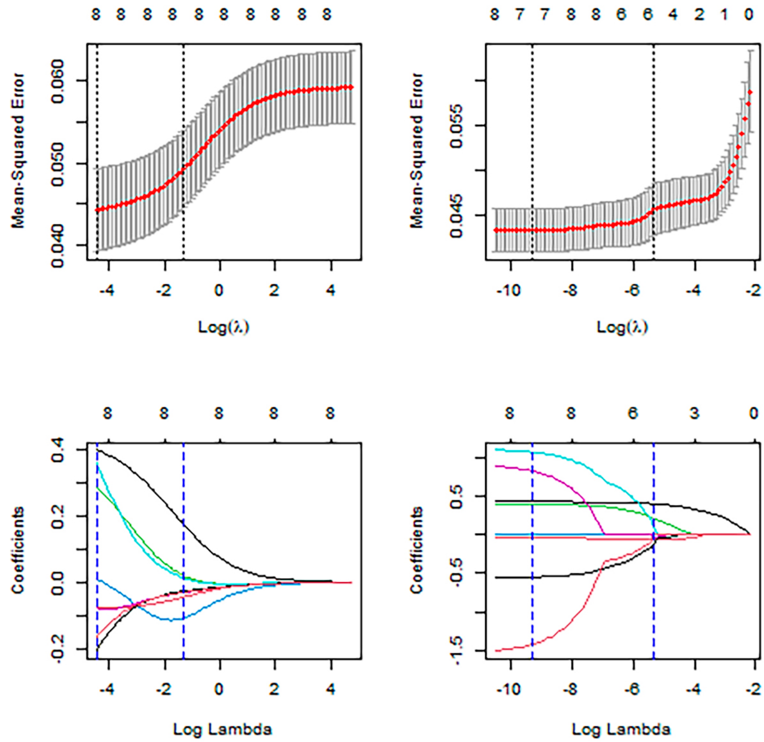

Figure 7. Same as Figure 6 but for the revenue target (source: own processing using R software)

4.4. Expenditure and revenue targets: the cross-validated glmnet model

The glmnet model produces the results depicted in Figure 8 and Figure 9. This model refers to a cross-validation-guided approach, which is used to combine different models acting on the same data. Here, the aim is to optimally combine the contribution of the Ridge-regression and that of the Lasso-regression model by varying parameters $0 \le \alpha \le 1$ and $\lambda > 0$ respectively. The model combination obtained is "optimal" in the sense of (statistical) robustness. Hence, the central role of (repeated 10-leave out) cross-validation. The relative contribution of both models (in our case Ridge and Lasso) to the final model (the glmnet) depends on the nature of the data and it cannot be guessed beforehand. For the given data, the outcome turns out to be strongly in favour of the Lasso, that is, $\alpha \approx 1$.

4.5. Expenditure and revenue targets: the cross-validated xboost model

The **xboost** model class uses a very powerful, ultra-flexible adaptation mechanism (similar in power to that of neural networks), which needs strong regularization (e.g. by cross-validation). If used for data analysis, one may run into difficulties if searching for explanations concerning a single isolated variable contribution (!) While prediction error is negligible in data reproduction, one may find information of variable relevance – here evaluated by the

Shapley method, which implicitly accounts for any types of (non-separable) interactions, by counting variable co-occurrences as different "coalitions" of input variables. There is a total of $\sum_{k=0}^{m}\binom{m}{k}$ such coalitions, with m the number of input variables. Hence, the number of coalitions is growing fast in the number of model input variables making Shapley evaluation potentially expensive as it can be seen from Figure 10 and Figure 11.

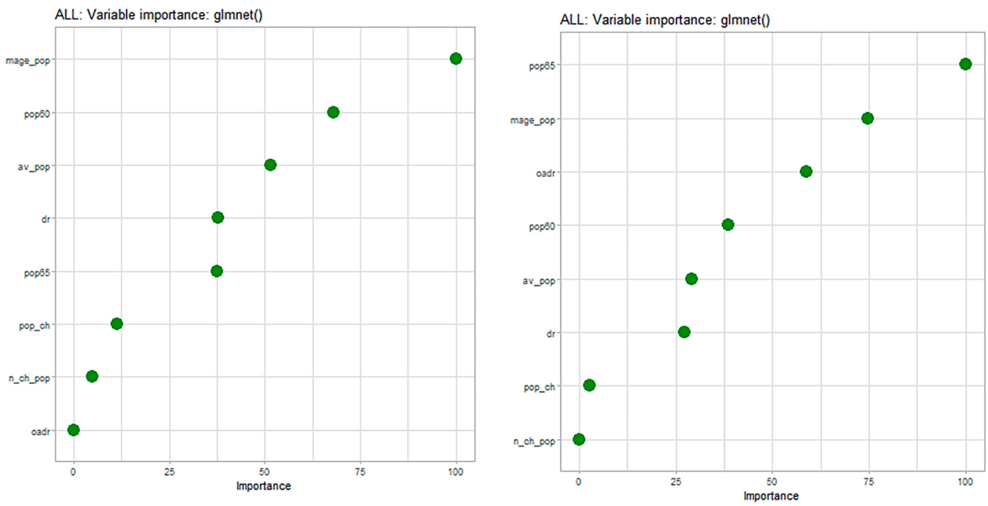

Figure 8. Variable importance for both targets (compared to Figure 4 with the same layout) (source: own processing using R software)

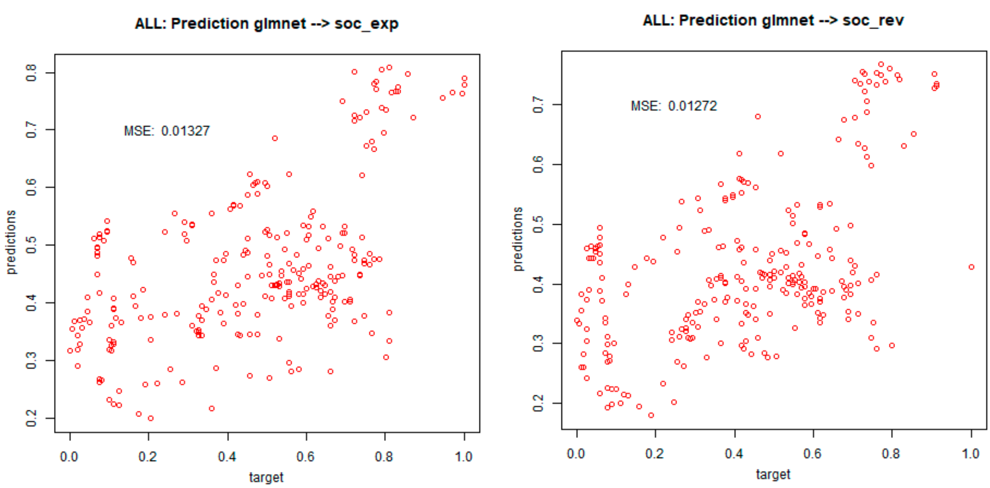

Figure 9. Target prediction of regularized models (compared to Figure 5 with the same layout) (source: own processing using R software)

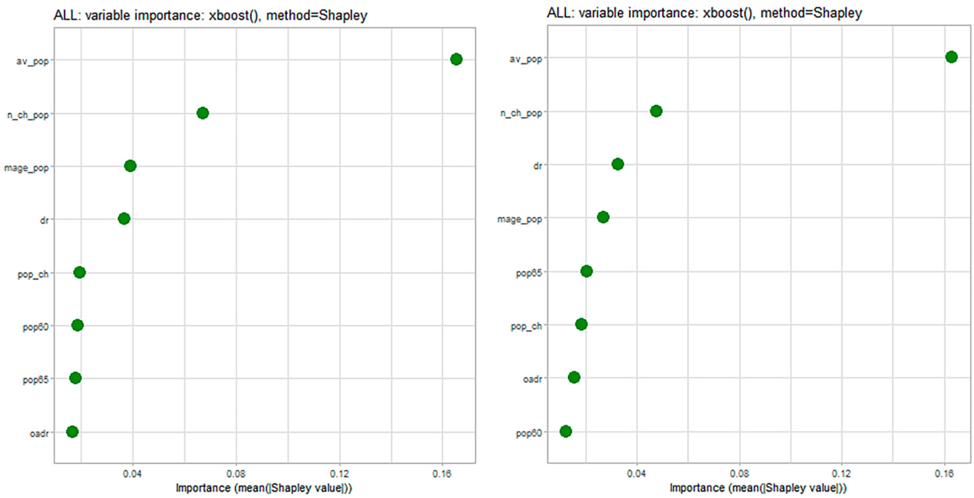

Figure 10. Variable importance for both targets (compared to Figure 4 and Figure 8 with the same layout) (source: own processing using R software)

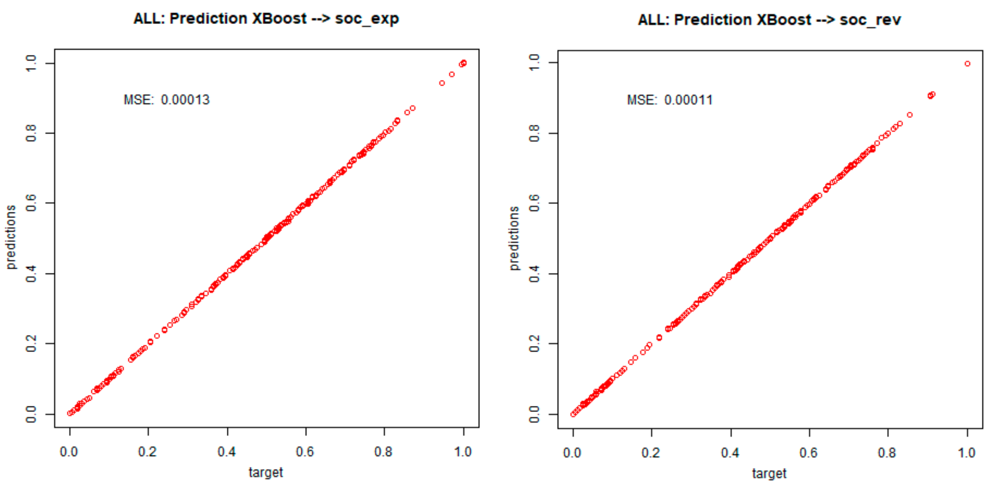

Figure 11. Target prediction of regularized models (compared to Figure 5 and Figure 9 with the same layout) (source: own processing using R software)

4.6. Empirical findings conducted on country groups

The data analysis methods detailed in the previous sections used all available country data in a contiguous manner. This amounts to glue blocks of country data into an essentially random sequence. We suspect that this artifact may be responsible for some of the degeneracies described so far.

Note that, owing to partial similarities in the structures of the country correlation matrices the aggregate correlation structure from Figure 12 contains weak and stronger positive correlation only. Furthermore, the correlation structure from Figure 12 is obtained by reordering

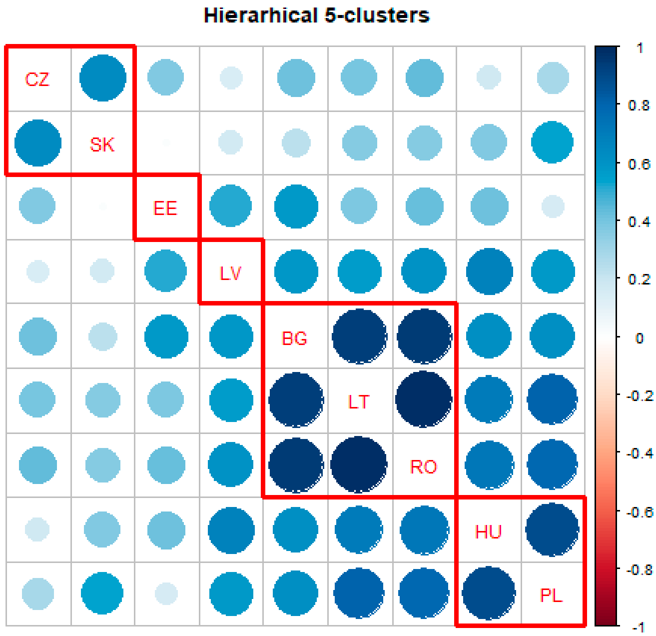

Figure 12. The correlation of the nine-country correlation matrices (source: own processing using R software)

(and grouping) the countries according to hierarchical clustering. For the depicted situation of five formal clusters of countries related by correlation structures, we have four effective country groups, namely (1) a strong cluster containing the Czech Republic (CZ) and Slovakia (SK), (2) a weaker cluster containing Estonia (EE) and Latvia (LV), (3) a strong cluster containing Bulgaria (BG), Lithuania (LT), and Romania (RO), as well as (4) a strong cluster containing Hungary (HU) and Poland (PL). Upon varying the number of clusters and restarting the hierarchical cluster algorithm, countries may be reordered anew but they largely stay within the same group compositions (not shown here). HU, PL, and BG may change subgroup membership somewhat but stay within the larger supergroup of {BG, LT, RO, HU, PL}. The targets expenditure and revenues tend to produce different outcomes in the entries between (and less so within) the groups.

4.7. Regression outcomes and research hypothesis testing results

Appendix presents the tabular results of the country–wise data models, including the model on all data. As it can be seen, Appendix shows that in all countries there can be identified significant linear coefficients in 2–3 variables, acceptable residual error, acceptable R-squared, and good F – statistic.

For Bulgaria, the results show significant linear coefficients in different 2–3 variables, small residual error strong R – squared and F – statistic. For the Czech Republic, there can be observed less significant linear coefficients, small residual error, strong R-squared explanation, and strong F-statistic.

Estonia's results show weakly significant linear coefficients, small residual error, medium R-squared explanation, and strong F-statistic. Regarding Latvia's results, it can be observed barely significant linear coefficients, small residual error, weak R-squared explanation, and strong F-statistic, meanwhile for Lithuania's results, there are significant linear coefficients, small residual error, rather weak R-squared explanations, strong F-statistic.

For Hungary, it can be observed that there are no significant linear coefficients, small residual error, medium R-squared explanation, and strong F-statistic, meanwhile, Poland registers partially significant linear coefficients, small residual errors, medium R-squared explanation, and strong F-statistic.

Romanian's case shows the weak significance of linear coefficients, small residual errors, weak R-squared explanation, and strong F-statistic, meanwhile Slovakia's results dome the significance of linear coefficients, small residual errors, medium R-squared explanations, and strong F-statistic.

Overall, it seems to be justified to complement the linear models with some other approaches as many countries display rather weak to moderate degrees of significance of their linear coefficients (which stand for separable effects). Nevertheless, linear models seem to be often sufficient for prediction purposes (residual errors, F-statistics), and owing to data sparsity they should not be discarded.

Table 3. Derived signs of the independent variables and validation by the empirical results for the total government social expenditures dependent variable (source: own processing)

Variable	Denominations	Acronyms	Sign	Empirical Results
Dependent variables	Total government social expenditures, social security funds	*soc_exp*(*yexp*)		
Independent variables	Average population – Total	*av_pop*(*avp*)	+	Support
	Population change	*pop_ch*(*pch*)	–	Support
	Crude death rate	*dr*(*cdr*)	+	Support
	Natural change of population	*n_ch_pop*(*ntch*)	–	Support
	Median age of population	*mage_pop*(*mage*)	+	Rejected
	Old age dependency ration	*oadr*	+	Support
	Proportion of population aged 60 years and more	*pop60*(*p60*)	–	Support
	Proportion of population aged 65 years and more	*pop65*(*p65*)	–	Support

Table 3 presents the results of testing the hypothesis regarding the total government social expenditures dependent variable. As can be seen, hypothesis 1 is confirmed mostly, because social expenditures of government are correlated with the average population and crude death rate and also with the median age of population. Population change is a difficult variable that must be developed in further studies, meanwhile, the old age dependent ratio has a significant impact on expenditures policy. Finally, the level of social expenditures has a direct impact on the financial sustainability of pension systems, and giving elderly people stimulus to work after 60 and 65 years can be a quid pro quo in balancing the pension schemes in all countries.

Table 4. Derived signs of the independent variables and validation by the empirical results for the total government revenue dependent variable (source: own processing)

Variable	Denominations	Acronyms	Sign	Empirical Results
Dependent variables	Total general government revenue, social security funds	*soc_rev* (*yrev*)		
Independent variables	Average population – Total	*av_pop*(*avp*)	+	Support
	Population change	*pop_ch*(*pch*)	–	Support
	Crude death rate	*dr*(*cdr*)	+	Support
	Natural change of population	*n_ch_pop*(*ntch*)	–	Support
	Median age of population	*mage_pop*(*mage*)	+	Support
	Old age dependency ration	*oadr*	+	Support
	Proportion of population aged 60 years and more	*pop60*(*p60*)	–	Rejected
	Proportion of population aged 65 years and more	*pop65*(*p65*)	–	Rejected

Table 4 presents the results of testing the hypothesis regarding the total government revenue-dependent variable. The results show that Hypothesis 2 is mainly confirmed, revealing that the total government revenue is influenced by the total population and crude death rate, meanwhile, there is a more complex relationship in practice with the natural change of population and old age dependent ratio. Finally, there is also a complex relationship manifested between other social and demographic unbalances and elderly people who continue their social and professional activity. In the long run, the financial sustainability of pension systems can be strengthened by increasing the age of retirement and giving fiscal advantages and stimulus to elderly people in order to continue their activities for longer periods.

5. Discussion and recommendations

Analysing and interpreting the empirical results resulting from the statistical model filter of this study one observes that the input variable relevance (importance) analysis conducted country by country reveals (see also Supplementary material):

- Different regularization paths for the Ridge / Lasso generalized linear modelling approach, which are observed between countries from the first lines of the four-in-one plots.
- Slightly different and in some cases markedly partially different magnitudes and orders of the variables when comparing the expenditure columns(s) with the revenue columns(s) for the countries.
- Overall, quite different variable relevance structures between (Lasso-based**) glmnet** models (2nd lines in the plots) and the related models generated by **xboost** (3rd lines in the plots). As xboost is exploiting all or most of the nonlinear relations (interactions, etc.) present in the data one may conclude that linear models are at best partially adequate for modelling the data.
- However, given the sparseness of the data, it remains uncertain if the data contain genuine (systematic) nonlinear relations or interactions or if xboost is merely adapting to “noise” caused by random historical events over time in the respective countries.

The empirical results encountered in this study show that there are similitudes and also differences between the nine countries analysed in this study. The similitudes are enacted by the communist past and also the long and hard transition period starting from the 1990s which contains also demographical challenges and population aging problems due to the migration of population in Western European countries and also in other highly industrialized countries from North America and Asia. The differences between countries shown in the empirical study findings suggest that the state authorities have adopted also some particular reforms and measures in each country that enabled the reshaping the pension schemes, especially aspects such as law and legislation reforms, pension points calculation mechanism adjustments and social policies for strengthening the labor supply giving several benefits for elderly people that continue their activity also at old ages.

Given these aspects, Balteș et al. (2018) highlight the most important features and trends of the Romanian pension system by providing both a quantitative and qualitative overview; the authors have concluded that in Romania there must be enacted legal, economic, and social aspects of pension system to face the future challenges. Later on, Dumiter et al. (2021) reveal several interesting insights regarding the Central and Eastern European Countries' private pension schemes and their connections with the macroeconomic environment; the authors suggest that the investment strategy of private pension funds is directly connected with the deposits interest rate having at the background a stable macroeconomic environment.

Danan and Dupre (2021) encompass a comprehensive study regarding the connections manifested between population aging and gerontology for the understanding of population dynamics and human aging trends; the authors propose multidisciplinary approaches to deal with the complex phenomenon of aging, longevity, and gerontology processes. Chlon-Dominczak (2021) analyses the demographically old problem in Southeast and Central-Eastern Europe revealing the economic transition of these countries in the context of international convergence with the EU policies and outlining the main challenges ahead. Nullmeier et al. (2022) highlight the importance of social policy and the need for its dynamics by enhancing the importance of domestic factors and transnational relations.

Kabasinskas et al. (2017) analyse the Lithuania risk-return profile of private pension schemes and conclude that there must be a correlation between a certain risk category and the pension funds low risk reference. Garvey et al. (2020) analyse the problem of minimum pension benefits with the NDC scheme and suggest that must be taken into account social aspects regarding the appliance of public pensions, especially in countries such as Norway, Poland, Latvia, and Italy.

Other authors as Boj et al. (2022) connect the financial sustainability framework with reverse mortgage contracts and conclude that for Spain family evidence, family composition influences initial income and increases the probability of future problems regarding liquidity issues. Frassi et al. (2019) propose an interesting intergenerational redistribution system enriched in the pension system with a fully funded and novel fully funded system which are capable of reducing the redistribution on the future intergeneration trends, increasing social welfare, and strengthening physical capital accumulation.

The problem of disability pensions connected with optimal retirement was studied by Fehr and Frohlich (2023) for the Germany case; the authors present several reforms that were taken in Germany and conclude in an aging society, the rehabilitation and activation of sick elderly in the workforce can be a path to secure the public pension systems financial stability. Costrell and McGee (2023) suggest the need for reshaping the funding of public pension schemes with an economic reformulation conferring theoretical insights regarding the risk-return relationship and new terms of contribution policy guidelines. In the aftermath, Sanchez-Romero et al. (2024) make a comprehensive analysis regarding the winners and losers of the pension systems' redistributive effects suggesting a multidimensional approach to dealing with reforms that need to take into account heterogeneous socioeconomic groups and behavioural feedback models. Innocenti et al. (2024) analyse a multicounty study regarding the connection manifested between planning, retirement concerns, and financial challenges of pension systems concluding that the persons unable to accumulate savings must invest in supplementary pension funds.

6. Conclusions

All CEE and BS countries face demographic challenges and threats to the financial sustainability of public pension systems. Demographic data shows that the median age of the population exceeded 44 years in Lithuania, Latvia, and Bulgaria, and the natural population change is negative in all CEE and BS countries. Bulgaria, Estonia, Latvia, Lithuania, and Hungary have an old-dependency ratio of over 30%, and the population aged over 65 represents over 20% of the total population in these countries. Life expectancy at age 65 reaches over 81 years in the Czech Republic, Estonia, Latvia, and Poland. Poland, Hungary, Slovakia, and Lithuania have the largest pension expenditures as a percentage of GDP.

Possible solutions for enhancing the financial sustainability of public pension systems in CEE and BS countries came in a wider framework, considering all social, economic, and political factors. In our opinion, the sustainability of public pension systems could increase by developing the economic competitiveness and social attractiveness of these countries by improving the business environment, growing labour accessibility and productivity, raising the quality of public and private services, and keeping safe and strong communities.

The empirical results obtained in this paper show that the financial sustainability of pension systems both in CEE and BS is dependent in terms of expenditures and revenues *vis-á-vis* of the demographic changes that nowadays countries need to deal with in terms of migration, free movement of people, and flexibility. Moreover, the empirical study shows that the population aging phenomenon which manifests also in CEE and BS has a direct impact on the sustainability of pension systems and the reforms must be oriented towards reshaping the pension systems and reconfiguring the pension schemes. Labour supply structure, developments, and evolution are the key features because the globalization phenomenon opened the door for stronger competition between the economies and the material and social needs of the people.

The main added value of the paper is represented by gathering together a group of nine countries from CEE and BS with a common past and with similar institutional requirements in terms of the sustainability of pension systems. The geographic area and location of these countries are confirmed also by similar demographical trends and patterns and also by the movements of the labor force. In the second place, we wanted to reveal some important characteristics of pension systems that are directly connected with social security, the labour force, and demographic challenges in order to highlight some interesting features convergent and divergent in these countries. In the end, the statistical model analysis reveals that there are several similarities in structural features in the social characteristics of pension systems which can be used by the state authorities in these countries for cooperation and best practice for solving the inequities regarding the pension systems schemes.

The disadvantages and the weak points of the study regard the limited time period for the indicators taken into account in this study. This is because there is a limited amount of data regarding pension systems and pension characteristics at both national and international levels. In the aftermath, this study has encountered the most comprehensive indicators for assuring the impact of population aging, demographic changes, and labour supply for elderly people in order to evaluate their impact on the financial sustainability of pension systems. However, it cannot take into account all social, demographic, and behavioural indicators that manifest themselves on national and international levels. The most important issue here is representing the constant change of pension schemes and systems promoted by these countries to enhance the financial sustainability of pension systems, the element which was very difficult to measure and highlight.

Future developments of this study regard, at first, the enlargement of the number of countries included in the sample. This is because there are also other states from the European Union with similar patterns and trends regarding the structure of pension systems. In the second place, it can be included also other interesting institutional features and quality indicators concerning pension laws, social insurance mechanisms, demographic indicators, and behavioural indices. Finally, the model for pension systems and financial sustainability schemes can be improved by using several econometrical or other mathematical techniques to recalibrate the pension systems for the social, economic, legal, and demographic challenges ahead.

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Competing interests

We declare no personal interest in the matters addressed in this research paper.

Data availability

The database was constructed by extracting the values on the Eurostat website.

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APPENDIX

Tabular results of country–wise data models including the model for all data

ALL COUNTRIES

```
Countries:   ALL     Target var:    soc_exp


Residuals:
 Min       1Q        Median    3Q        Max
-0.46353 -0.15724  0.02426  0.15468  0.49264


Coefficients:
             Estimate    Std. Error  t value  Pr(>|t|)
(Intercept)  0.34081     0.14636      2.329   0.0207 *
av_pop       0.43532     0.05553      7.839   1.42e-13 ***
pop_ch      -0.08047     0.08166     -0.985   0.3254
dr           0.34170     0.14270      2.395   0.0174 *
n_ch_pop    -0.06342     0.15811     -0.401   0.6887
mage_pop     1.14292     0.28478      4.013   7.98e-05 ***
oadr         0.47444     0.52825      0.898   0.3700
pop60       -0.71598     0.32319     -2.215   0.0277 *
pop65       -0.94167     0.72985     -1.290   0.1982
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.2139 on 243 degrees of freedom
Multiple R-squared:  0.3095,  Adjusted R-squared:  0.2868
F-statistic: 13.62 on 8 and 243 DF,  p-value: 2.803e-16
```

```
Countries:   ALL     Target var:    soc_rev


Residuals:
 Min       1Q        Median    3Q        Max
-0.43817 -0.14820  0.01198  0.14457  0.56766


Coefficients:
             Estimate   Std. Error  t value  Pr(>|t|)
(Intercept)  0.27160    0.14064      1.931   0.05463 .
av_pop       0.42591    0.05336      7.982   5.73e-14 ***
pop_ch      -0.03728    0.07847     -0.475   0.63516
dr           0.39701    0.13713      2.895   0.00413 **
n_ch_pop    -0.00358    0.15193     -0.024   0.98122
mage_pop     1.12079    0.27365      4.096   5.74e-05 ***
oadr         0.94505    0.50761      1.862   0.06384 .
pop60       -0.55758    0.31057     -1.795   0.07383 .
pop65       -1.58410    0.70133     -2.259   0.02479 *
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.2055 on 243 degrees of freedom
Multiple R-squared:  0.3057,  Adjusted R-squared:  0.2828
F-statistic: 13.37 on 8 and 243 DF,  p-value: 5.316e-16
```

BULGARIA

```
Countries:   BG     Target var:    soc_exp


Residuals:
 Min       1Q        Median    3Q        Max
-0.08236 -0.03607 -0.00975  0.03023  0.11076


Coefficients:
            Estimate   Std. Error  t value  Pr(>|t|)
(Intercept)  -5.2191    6.4522     -0.809   0.42860
av_pop       -0.2532   10.5378     -0.024   0.98108
pop_ch       -1.1552    0.9664     -1.195   0.24667
dr            3.1836    2.2424      1.420   0.17190
n_ch_pop      7.5025    6.3752      1.177   0.25380
mage_pop     -5.1065    1.3268     -3.849   0.00108 **
oadr         -6.6560    1.0807     -6.159   6.42e-06 ***
pop60         0.4039    0.4220      0.957   0.35046
pop65        11.2581    1.6905      6.660   2.28e-06 ***
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.05355 on 19 degrees of freedom
Multiple R-squared:  0.9178,  Adjusted R-squared:  0.8832
F-statistic: 26.51 on 8 and 19 DF,  p-value: 9.832e-09
```

```
Countries:   BG     Target var:    soc_rev


Residuals:
 Min       1Q        Median    3Q        Max
-0.07620 -0.03164 -0.01034  0.03682  0.08661


Coefficients:
             Estimate  Std. Error  t value  Pr(>|t|)
(Intercept)  -8.5762    6.4202     -1.336   0.19739
av_pop        7.0097   10.4854      0.669   0.51185
pop_ch       -1.4738    0.9616     -1.533   0.14185
dr            4.1401    2.2313      1.855   0.07911 .
n_ch_pop     10.1929    6.3436      1.607   0.12459
mage_pop     -4.9240    1.3202     -3.730   0.00142 **
oadr         -6.2439    1.0753     -5.806   1.36e-05 ***
pop60         0.3359    0.4199      0.800   0.43352
pop65        10.9607    1.6821      6.516   3.05e-06 ***
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.05328 on 19 degrees of freedom
Multiple R-squared:  0.8991,  Adjusted R-squared:  0.8565
F-statistic: 21.15 on 8 and 19 DF,  p-value: 6.53e-08
```

CZECH REPUBLIC

```
Countries:   CZ     Target var:   soc_exp


Residuals:
 Min       1Q        Median    3Q        Max
-0.012495 -0.005106 -0.001887  0.005770  0.013960


Coefficients:
            Estimate    Std. Error t value Pr(>|t|)
(Intercept) -2.16945    1.28273   -1.691   0.10712
av_pop       6.22384    1.80650    3.445   0.00271 **
pop_ch      -0.24207    0.32046   -0.755   0.45928
dr           0.89779    0.88445    1.015   0.32282
n_ch_pop     0.85183    1.61632    0.527   0.60428
mage_pop     0.25862    0.08922    2.899   0.00920 **
oadr        -0.64643    0.24621   -2.626   0.01665 *
pop60       -0.03895    0.11417   -0.341   0.73676
pop65        0.56655    0.37445    1.513   0.14673
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.009251 on 19 degrees of freedom
Multiple R-squared:  0.9381,  Adjusted R-squared:  0.9121
F-statistic: 36.02 on 8 and 19 DF,  p-value: 6.988e-10
```

```
Countries:   CZ     Target var:   soc_rev


Residuals:
 Min        1Q         Median     3Q         Max
-0.0091335  -0.0027509  0.0008805  0.0028677  0.0062048


Coefficients:
            Estimate    Std. Error t value Pr(>|t|)
(Intercept) -1.69954    0.65568   -2.592   0.017887 *
av_pop       2.74973    0.92341    2.978   0.007732 **
pop_ch      -0.27479    0.16381   -1.678   0.109815
dr           0.93439    0.45210    2.067   0.052657 .
n_ch_pop     1.34253    0.82620    1.625   0.120647
mage_pop     0.21068    0.04560    4.620   0.000187 ***
oadr        -0.39737    0.12585   -3.157   0.005185 **
pop60       -0.15005    0.05836   -2.571   0.018702 *
pop65        0.49491    0.19140    2.586   0.018130 *
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.004729 on 19 degrees of freedom
Multiple R-squared:  0.9815,  Adjusted R-squared:  0.9737
F-statistic:   126 on 8 and 19 DF,  p-value: 8.262e-15
```

ESTONIA

```
Countries:   EE     Target var:   soc_exp


Residuals:
 Min       1Q       Median    3Q        Max
-0.056111 -0.021995 0.000595  0.009681  0.089655


Coefficients:
            Estimate    Std. Error t value Pr(>|t|)
(Intercept) -74.9748    28.2409   -2.655   0.0156 *
av_pop       87.3179    41.0816    2.125   0.0469 *
pop_ch       -2.1682     0.8747   -2.479   0.0227 *
dr            6.6395     2.5336    2.621   0.0168 *
n_ch_pop     94.7273    35.7627    2.649   0.0158 *
mage_pop     -0.6122     1.4790   -0.414   0.6836
oadr          1.5907     0.8024    1.982   0.0621 .
pop60         0.9091     0.9497    0.957   0.3505
pop65        -1.6547     1.2241   -1.352   0.1923
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.04089 on 19 degrees of freedom
Multiple R-squared:  0.8542,  Adjusted R-squared:  0.7928
F-statistic: 13.91 on 8 and 19 DF,  p-value: 1.874e-06
```

```
Countries:   EE     Target var:   soc_rev


Residuals:
 Min        1Q          Median     3Q         Max
-0.039436  -0.014388  -0.002339  0.013009  0.036074


Coefficients:
            Estimate    Std. Error t value Pr(>|t|)
(Intercept) -50.16876   17.82621  -2.814   0.01107 *
av_pop       81.85674   25.93156   3.157   0.00519 **
pop_ch       -1.36891    0.55214  -2.479   0.02271 *
dr            4.59750    1.59924   2.875   0.00970 **
n_ch_pop     62.96638   22.57414   2.789   0.01169 *
mage_pop      1.21806    0.93359   1.305   0.20758
oadr          1.78484    0.50648   3.524   0.00227 **
pop60         0.06347    0.59946   0.106   0.91679
pop65        -2.45298    0.77270  -3.175   0.00499 **
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.02581 on 19 degrees of freedom
Multiple R-squared:  0.9191,  Adjusted R-squared:  0.885
F-statistic: 26.97 on 8 and 19 DF,  p-value: 8.489e-09
```

LATVIA

```
Countries:   LV     Target var:   soc_exp


Residuals:
 Min       1Q        Median    3Q        Max
-0.103377 -0.035334 -0.006562  0.024819  0.141519


Coefficients:
            Estimate    Std. Error t value Pr(>|t|)
(Intercept) -18.7585    18.8310   -0.996   0.3317
av_pop      -81.5753    75.4520   -1.081   0.2932
pop_ch       -1.3620     0.8846   -1.540   0.1401
dr            2.7950     2.5155    1.111   0.2804
n_ch_pop     29.3500    24.1019    1.218   0.2382
mage_pop      0.1991     2.5123    0.079   0.9377
oadr          1.7271     0.8139    2.122   0.0472 *
pop60        -1.9751     1.3311   -1.484   0.1543
pop65        -2.6877     1.2801   -2.100   0.0494 *
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.06567 on 19 degrees of freedom
Multiple R-squared:  0.6171,  Adjusted R-squared:  0.4559
F-statistic: 3.828 on 8 and 19 DF,  p-value: 0.007751
```

```
Countries:   LV     Target var:   soc_rev


Residuals:
 Min       1Q        Median    3Q        Max
-0.026023 -0.016306 -0.005075  0.012075  0.043952


Coefficients:
            Estimate    Std. Error t value  Pr(>|t|)
(Intercept)  -6.24278    6.35368   -0.983   0.33818
av_pop      -15.10949   25.45794   -0.594   0.55984
pop_ch       -0.41214    0.29846   -1.381   0.18334
dr            0.96937    0.84876    1.142   0.26760
n_ch_pop      9.52030    8.13212    1.171   0.25619
mage_pop     -0.04068    0.84767   -0.048   0.96223
oadr          1.44367    0.27462    5.257   4.49e-05 ***
pop60        -0.61445    0.44913   -1.368   0.18725
pop65        -1.49459    0.43190   -3.460   0.00262 **
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.02216 on 19 degrees of freedom
Multiple R-squared:  0.8488,  Adjusted R-squared:  0.7851
F-statistic: 13.33 on 8 and 19 DF,  p-value: 2.601e-06
```

LITHUANIA

```
Countries:   LT     Target var:   soc_exp


Residuals:
 Min        1Q        Median    3Q        Max
-0.107545 -0.034076 -0.004181  0.036620  0.140206


Coefficients:
            Estimate     Std. Error t value  Pr(>|t|)
(Intercept) -54.3175     13.9318    -3.899    0.000965 ***
av_pop       50.4545     51.9628     0.971    0.343761
pop_ch       -4.3076      0.9618    -4.479    0.000257 ***
dr           10.0121      2.3976     4.176    0.000513 ***
n_ch_pop     67.3996     15.1358     4.453    0.000273 ***
mage_pop      2.0857      2.7663     0.754    0.460098
oadr         -1.5043      1.7610    -0.854    0.403622
pop60        -3.7997      1.7232    -2.205    0.039976 *
pop65         3.8645      1.7220     2.244    0.036924 *
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.06487 on 19 degrees of freedom
Multiple R-squared:  0.7311,  Adjusted R-squared:  0.6178
F-statistic: 6.456 on 8 and 19 DF,  p-value: 0.0004171
```

```
Countries:   LT     Target var:   soc_rev


Residuals:
 Min        1Q        Median    3Q       Max
-0.13641 -0.03380 -0.01055  0.02681  0.25441


Coefficients:
             Estimate     Std. Error t value Pr(>|t|)
(Intercept)  -28.420      17.778     -1.599   0.12641
av_pop        77.377      66.309      1.167   0.25768
pop_ch        -2.107       1.227     -1.717   0.10226
dr             4.685       3.060      1.531   0.14222
n_ch_pop      31.413      19.315      1.626   0.12035
mage_pop       4.307       3.530      1.220   0.23740
oadr           8.585       2.247      3.820   0.00115 **
pop60         -5.539       2.199     -2.519   0.02089 *
pop65         -5.210       2.197     -2.371   0.02846 *
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.08277 on 19 degrees of freedom
Multiple R-squared:  0.6947,  Adjusted R-squared:  0.5662
F-statistic: 5.405 on 8 and 19 DF,  p-value: 0.001218
```

HUNGARY

```
Countries:   HU     Target var:   soc_exp


Residuals:
 Min        1Q        Median    3Q        Max
-0.042010 -0.023524 -0.006131  0.023901  0.062643


Coefficients:
            Estimate    Std. Error t value Pr(>|t|)
(Intercept)   4.6656    5.5188      0.845   0.4084
av_pop      -31.1745   15.7387     -1.981   0.0623 .
pop_ch       -0.8140    0.7812     -1.042   0.3105
dr            2.9389    2.0854      1.409   0.1749
n_ch_pop      4.8324    4.0142      1.204   0.2434
mage_pop      0.0552    0.7720      0.071   0.9438
oadr         -2.4468    1.0106     -2.421   0.0256 *
pop60        -0.1507    0.3857     -0.391   0.7004
pop65         1.4687    1.2654      1.161   0.2601
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.03585 on 19 degrees of freedom
Multiple R-squared:  0.8029,  Adjusted R-squared:  0.72
F-statistic: 9.677 on 8 and 19 DF,  p-value: 2.781e-05
```

```
Countries:   HU     Target var:   soc_rev


Residuals:
 Min        1Q        Median    3Q        Max
-0.096257 -0.026546 -0.002976  0.020117  0.070769


Coefficients:
            Estimate     Std. Error t value Pr(>|t|)
(Intercept)  10.25038    7.24702     1.414   0.1734
av_pop      -52.52325   20.66710    -2.541   0.0199 *
pop_ch       -0.64887    1.02588    -0.633   0.5346
dr            2.79263    2.73837     1.020   0.3206
n_ch_pop      4.42445    5.27121     0.839   0.4117
mage_pop     -0.06616    1.01377    -0.065   0.9486
oadr         -1.55390    1.32699    -1.171   0.2561
pop60        -0.20691    0.50654    -0.408   0.6875
pop65         0.07926    1.66163     0.048   0.9625
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.04708 on 19 degrees of freedom
Multiple R-squared:  0.7179,  Adjusted R-squared:  0.5991
F-statistic: 6.044 on 8 and 19 DF,  p-value: 0.0006263
```

POLAND

```
Countries:   PL     Target var:   soc_exp


Residuals:
 Min      1Q       Median   3Q       Max
-0.10069 -0.03467 -0.00801  0.04234  0.08468


Coefficients:
            Estimate  Std. Error t value Pr(>|t|)
(Intercept)  11.8462  4.1470      2.857   0.010096 *
av_pop       -8.6770  3.7153     -2.336   0.030634 *
pop_ch        1.9410  1.3826      1.404   0.176486
dr           -5.1222  3.8082     -1.345   0.194445
n_ch_pop     -3.1738  1.9556     -1.623   0.121076
mage_pop     -6.7411  1.6077     -4.193   0.000493 ***
oadr         -9.0393  2.0569     -4.395   0.000311 ***
pop60         2.6465  0.6742      3.925   0.000909 ***
pop65        10.7164  2.5233      4.247   0.000436 ***
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.05613 on 19 degrees of freedom
Multiple R-squared:  0.7183,  Adjusted R-squared:  0.5996
F-statistic: 6.055 on 8 and 19 DF,  p-value: 0.0006196
```

```
Countries:   PL     Target var:   soc_rev


Residuals:
 Min        1Q        Median    3Q        Max
-0.077981 -0.022847 -0.004656  0.033123  0.102775


Coefficients:
             Estimate  Std. Error t value Pr(>|t|)
(Intercept)   4.7176   3.8783      1.216   0.2387
av_pop       -2.2544   3.4745     -0.649   0.5242
pop_ch        1.6166   1.2930      1.250   0.2264
dr           -4.3576   3.5615     -1.224   0.2361
n_ch_pop     -2.4330   1.8289     -1.330   0.1992
mage_pop     -3.9791   1.5036     -2.646   0.0159 *
oadr         -4.5020   1.9236     -2.340   0.0303 *
pop60         1.3311   0.6305      2.111   0.0482 *
pop65         5.9300   2.3598      2.513   0.0212 *
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.0525 on 19 degrees of freedom
Multiple R-squared:  0.6123,  Adjusted R-squared:  0.449
F-statistic: 3.751 on 8 and 19 DF,  p-value: 0.008555
```

ROMANIA

```
Countries:   RO     Target var:   soc_exp


Residuals:
 Min        1Q        Median    3Q        Max
-0.092617 -0.028261 -0.002499  0.034569  0.080182


Coefficients:
            Estimate  Std. Error  t value Pr(>|t|)
(Intercept) -8.31536  2.28103    -3.645   0.00172 **
av_pop      10.42552  3.45380     3.019   0.00707 **
pop_ch      -1.72069  0.85801    -2.005   0.05937 .
dr           4.32945  2.45699     1.762   0.09413 .
n_ch_pop     3.93464  2.34606     1.677   0.10989
mage_pop     0.35557  0.40653     0.875   0.39268
oadr        -4.30144  1.11508    -3.858   0.00106 **
pop60       -0.05555  0.71742    -0.077   0.93909
pop65        5.43181  1.50478     3.610   0.00187 **
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.05373 on 19 degrees of freedom
Multiple R-squared:  0.6507,  Adjusted R-squared:  0.5037
F-statistic: 4.425 on 8 and 19 DF,  p-value: 0.003702
```

```
Countries:   RO     Target var:   soc_rev


Residuals:
 Min        1Q        Median    3Q        Max
-0.066193 -0.017698 -0.004362  0.010894  0.083540


Coefficients:
            Estimate  Std. Error  t value Pr(>|t|)
(Intercept) -5.86283  1.72639    -3.396   0.00303 **
av_pop       7.05098  2.61400     2.697   0.01427 *
pop_ch      -1.50235  0.64938    -2.314   0.03205 *
dr           3.53601  1.85956     1.902   0.07251 .
n_ch_pop     3.24120  1.77560     1.825   0.08370 .
mage_pop     0.02086  0.30768     0.068   0.94664
oadr        -3.05815  0.84395    -3.624   0.00181 **
pop60        0.45130  0.54298     0.831   0.41621
pop65        3.59290  1.13889     3.155   0.00522 **
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.04066 on 19 degrees of freedom
Multiple R-squared:  0.6953,  Adjusted R-squared:  0.567
F-statistic:  5.42 on 8 and 19 DF,  p-value: 0.001199
```

SLOVAKIA

```
Countries:   SK     Target var:   soc_exp


Residuals:
 Min        1Q        Median    3Q        Max
-0.078596 -0.019658 -0.001375  0.016922  0.099301


Coefficients:
            Estimate  Std. Error t value Pr(>|t|)
(Intercept) -17.9124  10.4610    -1.712   0.10311
av_pop      270.5563  42.1065     6.426   3.68e-06 ***
pop_ch        1.3639   1.4029     0.972   0.34317
dr           -3.8502   4.0727    -0.945   0.35634
n_ch_pop    -14.2278  14.2126    -1.001   0.32937
mage_pop      1.9937   0.8768     2.274   0.03476 *
oadr          4.5473   1.7465     2.604   0.01745 *
pop60        -1.9526   0.6785    -2.878   0.00964 **
pop65        -5.2748   2.2835    -2.310   0.03229 *
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.04615 on 19 degrees of freedom
Multiple R-squared:  0.7866,  Adjusted R-squared:  0.6967
F-statistic: 8.754 on 8 and 19 DF,  p-value: 5.613e-05
```

```
Countries:   SK     Target var:   soc_rev


Residuals:
 Min        1Q        Median    3Q        Max
-0.056800 -0.018047  0.004157  0.018538  0.042249


Coefficients:
            Estimate    Std. Error  t value Pr(>|t|)
(Intercept)  10.56169    6.25310    1.689   0.10756
av_pop      114.95937   25.16941    4.567   0.00021 ***
pop_ch        2.85532    0.83860    3.405   0.00297 **
dr           -8.11625    2.43449   -3.334   0.00349 **
n_ch_pop    -29.27814    8.49568   -3.446   0.00271 **
mage_pop      0.53337    0.52409    1.018   0.32161
oadr          3.93384    1.04400    3.768   0.00130 **
pop60        -0.07853    0.40560   -0.194   0.84853
pop65        -4.74993    1.36498   -3.480   0.00251 **
---
Signif. codes:  0  0.001  0.01  0.05  0.1  1


Residual standard error: 0.02759 on 19 degrees of freedom
Multiple R-squared:  0.9342,  Adjusted R-squared:  0.9065
F-statistic: 33.72 on 8 and 19 DF,  p-value: 1.24e-09
```