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Pension Benefits Adequacy and Social Security Budget Sustainability - What Influences the Resilience of Public Pension Systems in Central and Eastern European Countries?

Abstract. *This research examines the key factors contributing to the resilience of public pension systems in Central and Eastern European countries, focusing on strengthening pension benefit adequacy and the sustainability of social security budgets. The paper delves into how maintaining a balance between these two crucial aspects can enhance the long-term stability and resilience of public pension systems in the region. Using the Vector Autoregression (VAR) method, the influence of some demographic factors, labour market characteristics, financial and taxation features, financial education, technical development, and government effectiveness on the social security budget sustainability and pension benefits adequacy was investigated. The empirical results reflect the specific modus operandi of contributory public pension systems and enhance the broader understanding of how policy decisions can strengthen the resilience of public pension systems amid demographic and economic challenges.*

Keywords: *PAYG pension system, replacement rate, labour market, pension benefit, financial sustainability.*

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1. Introduction

This paper aims to investigate the pension benefits adequacy and the sustainability of public pension systems implemented by five countries from Central and Eastern Europe (CEE): the Czech Republic, Hungary, Poland, Romania, and Slovakia. The main tool for the financial protection of retirees in these countries is the public pension system, formed on the Bismarckian principles.

The parametric and structural reforms adopted in the CEE countries were intended to make public pension systems more resilient to demographic and economic challenges. Mitchel and Harris (2012) conceptualise resilience as the capacity to mitigate setbacks in development while enabling systems, regions, or individuals to recover rapidly from disruptions. In the case of public pension systems, resilience expresses the ability to provide adequate pension benefits and maintain the financial sustainability and solvency of the pension system budget. These two dimensions of public pension systems are "two sides of the same coin", only together reaching to effectively fulfil the purpose of providing pension benefits that can satisfy the needs of the elderly. However, Pascuzzo (2015) noticed that not always pension systems succeed in providing adequate pension benefits and maintaining budget sustainability. Usually, pension systems perform at one at the expense of the other.

This paper seeks new evidence on the factors that affect the long-term stability and resilience of public pension systems in CEE countries. Therefore, the influence of demographic trends, labour market characteristics, financial and taxation features, financial education, technical development, and government effectiveness on the social security budget sustainability and pension benefits adequacy was researched. The findings of this paper extend the research on public pension systems in CEE countries and provide some insights on how the socioeconomic policies may improve the social security budget sustainability and pension benefits adequacy.

The paper is structured in several sections, starting with the introduction of the research topic, followed by the literature review and research hypothesis development. The third section presents the research methodology and data series. The fourth section discusses the empirical results obtained, and the last section is dedicated to the conclusion of the papers and some policy recommendations.

2. Theoretical Background and Research Hypothesis Development

Ramlall (2018) highlighted a common response to public pension budget deficits in CEE countries: increasing the retirement age. By increasing the working life and the period in which social contributions are paid, governments seek to enhance the solvability of public pension systems. According to Hyndman et al. (2021), increasing the retirement age will smooth the old-age dependency ratio, with

a direct influence on reducing the pension benefit burden. Although increasing the retirement age and extending working life is often justified on the grounds of sustainability and might ease fiscal pressures, it raises concerns, particularly for lower-income groups who may not experience the same health benefits from extended working lives (Barschkett et al., 2022).

Demographic trends are also critical in determining the sustainability of public PAYG pension systems. Hoang (2022) found that migration plays an important role in the sustainability of the pension system, and Pânzaru (2015) stated that the Romanian public pension system can improve its solvency only through a positive migration inflow. These researches highlight that without addressing demographic shifts, reforms may not succeed in ensuring the long-term sustainability of public pension systems.

Fiscal policy, especially taxation, also plays a crucial role in the sustainability of pension systems. The results of Yasuoka (2021) showed the direct influence of tax policy and the social contribution rate on the financial sustainability of pension systems. Golpe et al. (2023) found that the public finance sustainability of euro-area countries is conditioned by the tax policy but, at the same time, by the monetary policy since inflation has a direct effect on budgetary solvability. These insights suggest the need for a balanced approach to tax and monetary policy to ensure the long-term sustainability of pension systems in the CEE countries.

Lusardi (2011) states the importance of financial literacy in maintaining the stability of economic systems and, therefore, also of public pension systems. Gustafsson (2023) observed that pension illiteracy has a negative effect on the efficiency of public pension reform, promoting income inequality and low labour supply. Xie et al. (2023) agree that financial literacy is an important factor in supporting pension system sustainability, but also observed the influence of trust in public institutions to provide financial support in old age. Rothstein et al. (2012) established a direct influence of government quality and social protection policy promoted by a state. Government quality was found to be an important factor in determining the sustainability of pension systems in CEE countries (Popa et al., 2022).

Hinrichs (2021) analysed the reforms in European countries related to pension systems and underlined that parametric changes focusing on maintaining financial sustainability could lead to increased old-age poverty, therefore falling to be adequate. Pension benefit adequacy means that retirees obtain a sufficient income to maintain consumption compared to earnings gained during working life. The literature uses the replacement rate as an indicator to measure the adequacy of pension benefits. Therefore, Fernández et al. (2018) indicate that the replacement rate is correlated with wage and, in the case of contributory systems, with contribution rate, but at the same time, with the expenditures of retirees and inflation.

Davis & Padley (2018) observed that in recent years, developments in technology changed the forms of social engagement and the minimum living standards. As a result, the public pension system should consider technology as a factor that influences the adequacy of the provided pension benefits. Casas & Roman (2023) point out that technological changes influence the retirement decision. Therefore, the policy of increasing the working life should be associated with training programs for older workers that support labour performance.

Factors such as demographic trends, migration, financial literacy, and the broader macroeconomic environment all play crucial roles in shaping the resilience of public pension systems. Outlioua and Fazouane (2023) found that employment, political stability, life expectancy, and pension system coverage are the main factors ensuring their success. A holistic approach, balancing sustainability and adequacy, is needed to ensure the long-term viability of these systems. Building on the findings presented above, this study proposes the following research hypothesis to investigate further the factors influencing the resilience and sustainability of public pension systems:

H1: Working life and employment in CEE countries significantly influence the solvency of public pension systems and pension benefit adequacy in CEE countries.

H2: Migration flows and population structure significantly influence the solvency of public pension systems and pension benefit adequacy in CEE countries.

H3: Tax policy and government quality significantly influence the solvency of public pension systems and pension benefit adequacy in CEE countries.

H4: Financial literacy significantly influences the solvency of public pension systems and pension benefit adequacy in CEE countries.

H5: Technological development influences the solvency of public pension systems and pension benefit adequacy in CEE countries.

3. Research Methodology and Data

This paper aims to deepen the research on key factors that contribute to the resilience of public pension systems in CEE countries, focusing on exploring the influence of demographic factors, labour market characteristics, financial and taxation features, financial education, technical development, and government effectiveness on the social security budget sustainability and on the pension benefits adequacy. The database consists of relevant variables for the research purpose for the period 2011-2021. Table 1 provides a description of the variables considered.

Table 1. Variable description

Variable	Description	Unit of measure	*Source*
Endogenous variables			
Pension benefits expenditures (PEX)	Total expenditures with pension benefits.	Percentage of gross domestic product (GDP)	Eurostat database
Social Security Budget Revenues (SSBR)	Total revenues from the Social Security Budget.	Percentage of gross domestic product (GDP)	Eurostat database
Aggregate replacement rate (PRR)	The ratio of the median individual gross pensions of the 65-74 age category relative to the median individual gross earnings of the 50-59 age category, excluding other social benefits.	Percentage.	Eurostat database
Median relative income of elderly people (MRI)	The ratio between the median equivalised disposable income of persons aged 65 or over and the median equivalised disposable income of persons aged between 0 and 64.	Percentage.	Eurostat database

Variable	Description	Unit of measure	*Source*
Exogenous variables			
Migration rate (MIGR)	The difference between the number of immigrants and the number of emigrants.	Crude rate of net migration.	Eurostat database
Gross earnings (EAR_G)	Remuneration in cash of a single person without children earning 100% of the average earning, paid during the reference year by the employer, before tax deductions and social security contributions payable.	Euro per year.	Eurostat database
Social contributions (SC)	Social security contributions paid by wage earners and retained by the employer.	Euro per year.	Eurostat database
Duration of working life (DWL)	The number of years a person aged 15 is expected to be active in the labour market throughout his/her life.	Years.	Eurostat database
Employment rate (EMPR)	The percentage of employed persons compared to the total population.	Percentage of the total population.	Eurostat database
Harmonized index of consumer prices (HICP)	Measures the country's inflation for all goods and services acquired by households.	Annual average index.	Eurostat database
Old age dependency ratio (OADR)	This is the ratio between the number of people aged 65 and over and the number of people aged 15 and 64.	The value is expressed per 100 working-age persons (15-64).	Eurostat database
Government effectiveness (GOVEF)	Perceptions of citizens about the quality of public services.	The score between –2.5 points (weak) to 2.5 points (strong) in governance performance	World Bank database
Research and development expenditures (RDEXP)	Total expenditures with research and development.	Percentage of government expenditure.	Eurostat database
Financial literacy (FINLIT)	Basic knowledge of the population aged 15 and above at four fundamental concepts in financial decision-making: knowledge of interest rates, interest compounding, inflation, and risk diversification.	Percentage.	S&P Ratings Global FinLit Report

Source: Own compilation.

The relationships between the selected variables were studied using Vector Autoregression (VAR). This method allows the analysis of the link between variables that have simultaneous interactions, using a simultaneous system of equations for all variables, where all variables are dependent variables, and establishing a lag length for testing the serial correlation. Therefore, VAR models do not distinguish between dependent and independent variables.

$$Y_t = \alpha_0 + \sum_{i=1}^{m} \alpha_i Y_{t-i} + \sum_{i=1}^{m} \beta_i X_{t-i} + u_t \quad (1)$$

$$X_t = \gamma_0 + \sum_{i=1}^{m} \gamma_i X_{t-i} + \sum_{i=1}^{m} \varphi_i Y_{t-i} + \vartheta_t \quad (2)$$

This research on public pension systems' long-term stability and resilience in CEE countries follows two directions. First, the sustainability of social security budgets was studied, focusing on pension benefits expenditures and social security revenues. Second, it investigated the pension benefits adequacy, concentrating on the aggregate replacement rate and the median relative income of elderly people.

4. Results and discussion

The descriptive statistics of the variables used in the study of the long-term stability and resilience of public pension systems of the CEE countries reflect by the Jarque-Bera test the normal distribution of social contribution, harmonised index of consumer prices, financial literacy, and pension expenditure. Most variables present a negative skewness and a platykurtic kurtosis (Table 2).

Table 2. Descriptive statistics

	DWL	EAR_G	EMPR	FINLIT	GOVEF	HICP	MIGR
Mean	33.49636	11394.25	64.70545	44.80000	0.536047	102.8438	0.489091
Median	33.50000	11460.60	65.70000	48.00000	0.596361	100.4500	0.600000
Maximum	36.30000	17230.25	75.10000	58.00000	1.070697	119.0400	4.800000
Minimum	29.60000	5634.970	51.90000	22.00000	-0.286919	92.84000	-3.300000
Std. Dev.	1.455000	2613.019	6.420552	12.74014	0.367679	5.878761	1.736821
Skewness	-0.175596	-0.282473	-0.221787	-0.871180	-0.757539	0.827226	0.030339
Kurtosis	3.146821	3.022825	2.037746	2.425013	2.723951	3.125035	3.229399
Jarque-Bera	0.332044	0.732609	2.572832	7.714730	5.435072	6.308601	0.129034
Probability	0.847028	0.693291	0.276259	0.021124	0.066037	0.042668	0.937520
	MRI	OADR	PEX	PRR	RDEXP	SC	SSBR
Mean	0.905818	25.06909	9.056364	0.581636	0.925091	1819.565	18.79273
Median	0.900000	25.20000	8.500000	0.590000	0.900000	1761.060	19.30000
Maximum	1.050000	32.30000	12.10000	0.690000	1.540000	3824.580	23.20000
Minimum	0.730000	17.50000	7.000000	0.410000	0.410000	730.4800	14.40000
Std. Dev.	0.084233	3.695687	1.315261	0.065539	0.325689	689.2730	2.213499
Skewness	-0.200586	-0.201895	0.976853	-0.590041	0.537490	0.903011	-0.458712
Kurtosis	2.283006	2.326588	2.772262	3.134530	2.241961	3.857115	2.401097
Jarque-Bera	1.546918	1.412883	8.866081	3.232835	3.965057	9.158323	2.750809
Probability	0.461414	0.493397	0.011878	0.198609	0.137721	0.010263	0.252737

Source: Own processing.

4.1 Empirical results on the sustainability of social security budgets

The long-term stability and resilience of public pension systems of CEE countries, expressed by the sustainability of social security budgets, are researched by exploring the relationship established between pension expenditures, the revenues of the social security budget, and demographic factors, labour market characteristics,

financial and taxation features, financial education, technical development, and government effectiveness.

The first step in performing a VAR model is determining the optimum lag length based on Akaike, Schwarz or Hannan-Quinn information criterion (Table 3). The optimal lag length for performing the VAR models is three, meaning that the tests will be performed for three prior periods.

Table 3. Variable description

	Endogenous variables: PEX MIGR EAR_G SC DWL EMPR HICP OADR GOVEF RDEXP FINLIT						**SSBR MIGR EAR_G SC DWL EMPR HICP OADR GOVEF RDEXP FINLIT**					
Lag	LogL	LR	FPE	AIC	SC	HQ	LogL	LR	FPE	AIC	SC	HQ
0	-1533.451	NA	1.74e+12	59.40195	59.81471	59.56019	-1539.204	NA	2.17e+12	59.62321	60.03598	59.78146
1	-1148.170	592.7395	735718 07	49.23730	54.19046	51.13623	-1178.667	554.6718	2.38e+08	50.41026	55.36342*	52.30919
2	-942.6115	229.2766	533477 7.	45.98506	55.47861	49.62466	-996.6392	203.0308	42616212	48.06305	57.55660	51.70265
3	-664.8361	192.3061*	104579 .4*	39.95523*	53.98918*	45.33552*	-761.6732	162.6688*	43348 92.*	43.67974*	57.71368	49.06002*
* indicates lag order selected by the criterion												
LR: sequential modified LR test statistic (each test at 5% level)												
FPE: Final prediction error												
AIC: Akaike information criterion												
SC: Schwarz information criterion												
HQ: Hannan-Quinn information criterion												

Source: Own compilation.

The results of the VAR models presented in Table 4 show the complex relationship between the variables and their influence on each other over time. Related to pension benefits expenditures, it highlights the negative impact of migration and research and development expenditures and the positive influence of gross earnings and government effectiveness in the long term. On the other hand, the results regarding the revenues of the Social Security budget reflect a more divergent relationship between variables over time, enhancing the negative influence of the duration of working life on the revenues of the Social Security budget in the long term.

Table 4. Results of Vector Autoregression Estimates

Vector Autoregression Estimates PEX				**Vector Autoregression Estimates SSBR**			
Variables	Coefficient	Std. Error	t-Statistic	Variables	Coefficient	Std. Error	t-Statistic
PEX(-1)	0.192442	(0.40384)	[0.47653]	SSBR(-1)	0.237908	(0.35070)	[0.67839]
PEX(-2)	0.226344	(0.54535)	[0.41504]	SSBR(-2)	-0.5674	(0.37751)	[-1.50302]
PEX(-3)	-0.061324	(0.59974)	[-0.10225]	SSBR(-3)	-0.025377	(0.43825)	[-0.05791]
MIGR(-1)	-0.221464	(0.27185)	[-0.81465]	MIGR(-1)	-0.310148	(0.41529)	[-0.74682]
MIGR(-2)	-0.599865	(0.23967)	[-2.50291]	MIGR(-2)	-0.151089	(0.45762)	[-0.33016]

Vector Autoregression Estimates PEX				Vector Autoregression Estimates SSBR			
MIGR(-3)	-0.243834	(0.29783)	[-0.81870]	MIGR(-3)	0.327997	(0.46751)	[0.70158]
EAR_G(-1)	0.000620	(0.00047)	[1.30641]	EAR_G(-1)	0.001760	(0.00084)	[2.10036]
EAR_G(-2)	6.22E-05	(0.00055)	[0.11272]	EAR_G(-2)	-0.000698	(0.00105)	[-0.66778]
EAR_G(-3)	5.30E-05	(0.00042)	[0.12556]	EAR_G(-3)	0.000748	(0.00096)	[0.77825]
SC(-1)	-0.001463	(0.00086)	[-1.70006]	SC(-1)	-0.001867	(0.00159)	[-1.17590]
SC(-2)	0.000697	(0.00077)	[0.90625]	SC(-2)	0.002601	(0.00151)	[1.71834]
SC(-3)	0.000526	(0.00072)	[0.72659]	SC(-3)	-0.001096	(0.00132)	[-0.83174]
DWL(-1)	0.521025	(0.27651)	[1.88432]	DWL(-1)	-1.344715	(0.54491)	[-2.46779]
DWL(-2)	0.090919	(0.53565)	[0.16974]	DWL(-2)	-0.458816	(0.71720)	[-0.63973]
DWL(-3)	-0.329597	(0.81573)	[-0.40405]	DWL(-3)	-0.250303	(0.93717)	[-0.26708]
EMPR(-1)	-0.575889	(0.21647)	[-2.66033]	EMPR(-1)	-0.337169	(0.41951)	[-0.80373]
EMPR(-2)	0.252269	(0.29914)	[0.84332]	EMPR(-2)	0.749869	(0.55907)	[1.34128]
EMPR(-3)	-0.023408	(0.37409)	[-0.06257]	EMPR(-3)	-0.325325	(0.56991)	[-0.57083]
HICP(-1)	0.303979	(0.16757)	[1.81405]	HICP(-1)	-0.136112	(0.34350)	[-0.39625]
HICP(-2)	-0.345211	(0.24373)	[-1.41637]	HICP(-2)	-0.266948	(0.46885)	[-0.56936]
HICP(-3)	0.023531	(0.13937)	[0.16885]	HICP(-3)	0.040937	(0.29309)	[0.13968]
OADR(-1)	-0.189088	(0.30369)	[-0.62263]	OADR(-1)	0.372671	(0.53520)	[0.69632]
OADR(-2)	0.569008	(0.41222)	[1.38034]	OADR(-2)	-0.251478	(0.67678)	[-0.37158]
OADR(-3)	-0.052511	(0.34510)	[-0.15216]	OADR(-3)	-0.065534	(0.47764)	[-0.13720]
GOVEF(-1)	3.282259	(2.54684)	[1.28876]	GOVEF(-1)	3.718340	(3.86110)	[0.96303]
GOVEF(-2)	5.810158	(2.42244)	[2.39847]	GOVEF(-2)	4.832616	(5.04418)	[0.95806]
GOVEF(-3)	1.355664	(2.86072)	[0.47389]	GOVEF(-3)	-5.175964	(4.55757)	[-1.13569]
RDEXP(-1)	-2.415708	(1.30434)	[-1.85205]	RDEXP(-1)	-0.387107	(1.95511)	[-0.19800]
RDEXP(-2)	-1.925642	(1.15656)	[-1.66498]	RDEXP(-2)	1.898452	(2.14242)	[0.88613]
RDEXP(-3)	-1.709877	(1.09932)	[-1.55540]	RDEXP(-3)	1.835280	(2.08317)	[0.88100]
FINLIT(-1)	0.002343	(0.08602)	[0.02723]	FINLIT(-1)	-0.046792	(0.15022)	[-0.31150]
FINLIT(-2)	-0.124104	(0.09972)	[-1.24449]	FINLIT(-2)	-0.25162	(0.18998)	[-1.32443]
FINLIT(-3)	0.101837	(0.13145)	[0.77473]	FINLIT(-3)	0.168314	(0.16782)	[1.00297]
C	5.875134	(18.7854)	[0.31275]	C	105.4319	(36.8640)	[2.86002]
R-squared		0.920314		R-squared			0.891325
Adj. R-squared		0.774223		Adj. R-squared			0.692089
Sum sq. resids		7.437074		Sum sq. resids			27.90755
S.E. equation		0.642784		S.E. equation			1.245159
F-statistic		6.299598		F-statistic			4.473699
Log likelihood		-23.22088		Log likelihood			-57.60380
Akaike AIC		2.200803		Akaike AIC			3.523223
Schwarz SC		3.476616		Schwarz SC			4.799036
Mean dependent		9.048077		Mean dependent			18.70385
S.D. dependent		1.352774		S.D. dependent			2.243943

Source: Own compilation.

The impulse-response functions were performed to better understand VAR model parameters (Figure 1). The graphics show that a shock of pension expenditures will produce a decrease in them in the long term. Pension expenditures respond to a shock in migration rate and old dependency ratio by an increase of pension expenditures in the second year after the shock, followed by a drop in the third year and a slow increase in the next years. A shock of gross earnings, social contribution, duration of working life, employment rate, inflation, and government

effectiveness will lead to a growing trend of pension expenditures in the first four years, followed by a decreasing trend in the next periods. The pension expenditures react to a shock of research and development expenditures and financial literacy with an increase in the first six years, followed by a decrease in the next periods.

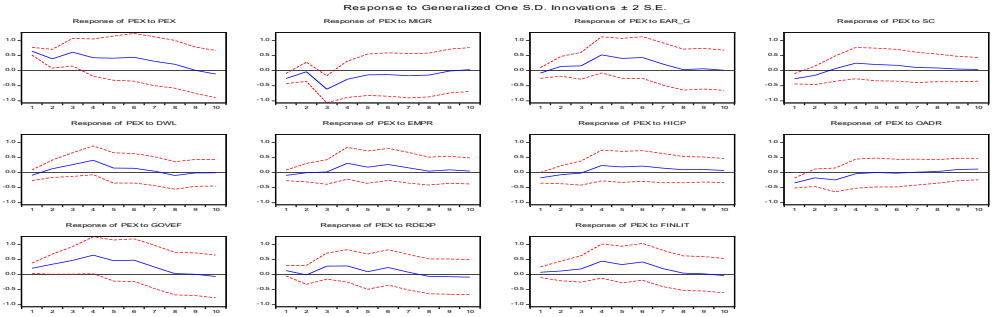


Figure 1. Results of the impulse-response functions – pension expenditures
Source: Own processing.

Figure 2 shows that a shock in the revenues of the social security budget will produce a major decrease in the first four years, followed by small fluctuations in the next periods. The social security budget revenues initially increased for four years following a migration rate shock but declined afterwards. Shocks in gross earnings and employment rates cause a slight revenue decrease, while social contribution shocks lead to long-term revenue growth. A working life duration shock results in an initial decline, then growth until year six, followed by a drop. Old-dependency ratio and inflation shocks slightly reduce revenues, but drive growth after six years. Government effectiveness and financial literacy shocks have minimal impact initially, but later reduce revenues. Research and development expenditure shocks decrease revenues for four years, increase them for two, and then cause a decline from year six onward.

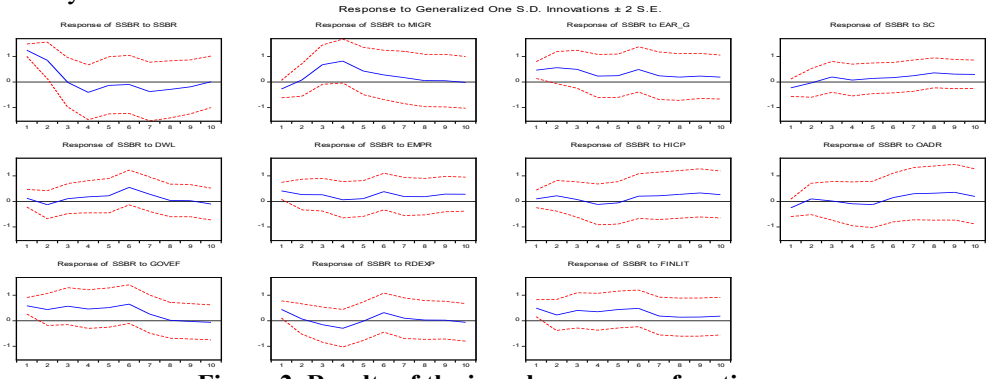
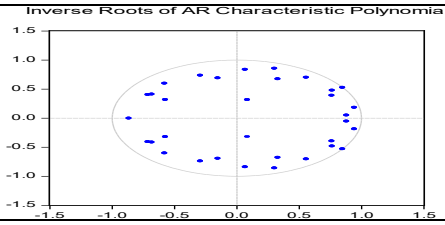


Figure 2. Results of the impulse-response functions - revenues of the social security budget
Source: Own processing.

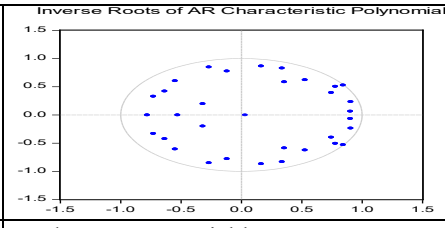
The reliability of the VAR models is tested by the Inverse Roots AR Characteristic Polynomial. All the roots are located inside the circle, reflecting the stability of the two VAR models used (Figure 3 and Figure 4).



Endogenous variables: PEX; MIGR; EAR_G; SC; DWL; EMPR; HICP; OADR; GOVEF; RDEXP; FINLIT.

Figure 3. Inverse Roots AR

Source: Own processing.



Endogenous variables: SSBR; MIGR; EAR_G; SC; DWL; EMPR; HICP; OADR; GOVEF; RDEXP; FINLIT.

Figure 4. Inverse Roots AR

Source: Own processing.

4.2 Empirical result on the adequacy of pension benefits

The long-term stability and resilience of public pension systems of CEE countries expressed by the adequacy of provided pension benefits is researched by exploring the relationship established between pension replacement rate and median relative income, and demographic factors, labour market characteristics, financial and taxation features, financial education, technical development, and government effectiveness, following the same steps.

The optimum lag length based on Akaike, Schwarz or Hannan-Quinn information criterion (Table 5) for performing the VAR models is three.

Table 5. Variable description

	Endogenous variables: PRR MIGR EAR_G SC DWL EMPR HICP OADR GOVEF RDEXP FINLIT						MRI MIGR EAR_G SC DWL EMPR HICP OADR GOVEF RDEXP FINLIT					
Lag	LogL	LR	FPE	AIC	SC	HQ	LogL	LR	FPE	AIC	SC	HQ
0	-1367.785	NA	2.98e+09	53.03020	53.44296	53.18844	-1370.351	NA	3.28e+09	53.12888	53.54164	53.28712
1	-1002.528	561.9343	271619.7	43.63569	48.58885*	45.53461	-997.3121	573.9057	222248.0	43.43508	48.38824*	45.33400
2	-832.9850	189.1056	78696.21	41.76865	51.26220	45.40826	-826.4161	190.6147	61126.59	41.51600	51.00956	45.15561
3	-576.7472	177.3954*	3532.170*	36.56720*	50.60115	41.94748*	-575.9567	173.3949*	3426.401*	36.53680*	50.57074	41.91708*
* indicates lag order selected by the criterion												
LR: sequential modified LR test statistic (each test at 5% level)												
FPE: Final prediction error												
AIC: Akaike information criterion												
SC: Schwarz information criterion												
HQ: Hannan-Quinn information criterion												

Source: Own compilation.

Table 6 presents the relationship between the variables and their influence on each other over time. The migration rate positively influences the aggregate replacement rate over time, but has a negative link with financial literacy. The migration rate has a negative impact on the median relative income of elderly people.

Table 6. Results of Vector Autoregression Estimates

Vector Autoregression Estimates PRR				Vector Autoregression Estimates MRI			
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Variables**	**Coefficient**	**Std. Error**	**t-Statistic**
PEX(-1)	1.042683	(0.24295)	[4.29175]	SSBR(-1)	1.504850	(0.29407)	[5.11737]
PEX(-2)	-0.252097	(0.28699)	[-0.87842]	SSBR(-2)	-0.273558	(0.25209)	[-1.08516]
PEX(-3)	-0.045101	(0.25244)	[-0.17866]	SSBR(-3)	-0.134577	(0.24412)	[-0.55127]
MIGR(-1)	0.003768	(0.00852)	[0.44218]	MIGR(-1)	-0.003385	(0.00898)	[-0.37706]
MIGR(-2)	0.002053	(0.00952)	[0.21555]	MIGR(-2)	-0.010567	(0.00926)	[-1.14110]
MIGR(-3)	0.005755	(0.01026)	[0.56076]	MIGR(-3)	-0.003558	(0.01004)	[-0.35442]
EAR_G(-1)	-1.88E-05	(1.7E-05)	[-1.10249]	EAR_G(-1)	2.52E-05	(1.7E-05)	[1.48089]
EAR_G(-2)	-1.67E-05	(2.4E-05)	[-0.69092]	EAR_G(-2)	-4.96E-05	(2.3E-05)	[-2.17059]
EAR_G(-3)	1.67E-05	(1.8E-05)	[0.93848]	EAR_G(-3)	5.45E-05	(1.7E-05)	[3.18181]
SC(-1)	-2.93E-05	(3.1E-05)	[-0.94544]	SC(-1)	-8.38E-05	(2.8E-05)	[-2.95671]
SC(-2)	6.95E-05	(3.6E-05)	[1.92760]	SC(-2)	9.48E-05	(3.6E-05)	[2.64274]
SC(-3)	-4.40E-05	(3.2E-05)	[-1.38894]	SC(-3)	-9.56E-05	(2.9E-05)	[-3.34116]
DWL(-1)	-0.042886	(0.01161)	[-3.69397]	DWL(-1)	-0.003546	(0.01003)	[-0.35338]
DWL(-2)	0.036452	(0.01635)	[2.22977]	DWL(-2)	0.030672	(0.01496)	[2.04964]
DWL(-3)	-0.042854	(0.01567)	[-2.73521]	DWL(-3)	-0.03766	(0.01483)	[-2.53944]
EMPR(-1)	0.019223	(0.00874)	[2.19980]	EMPR(-1)	-0.005648	(0.00769)	[-0.73408]
EMPR(-2)	-0.011444	(0.01316)	[-0.86934]	EMPR(-2)	0.011647	(0.01191)	[0.97757]
EMPR(-3)	0.006247	(0.01151)	[0.54260]	EMPR(-3)	-0.009783	(0.00998)	[-0.97984]
HICP(-1)	0.002806	(0.00616)	[0.45555]	HICP(-1)	0.009217	(0.00576)	[1.60048]
HICP(-2)	0.010643	(0.00949)	[1.12130]	HICP(-2)	0.002680	(0.00895)	[0.29932]
HICP(-3)	-0.001682	(0.00556)	[-0.30236]	HICP(-3)	-0.000178	(0.00559)	[-0.03188]
OADR(-1)	0.010959	(0.00868)	[1.26300]	OADR(-1)	0.001571	(0.00817)	[0.19218]
OADR(-2)	-0.022589	(0.01337)	[-1.69007]	OADR(-2)	-0.01353	(0.01222)	[-1.10760]
OADR(-3)	0.009729	(0.00871)	[1.11660]	OADR(-3)	0.014338	(0.00844)	[1.69813]
GOVEF(-1)	0.074653	(0.08760)	[0.85222]	GOVEF(-1)	-0.023594	(0.08121)	[-0.29051]
GOVEF(-2)	0.036158	(0.10544)	[0.34292]	GOVEF(-2)	0.063362	(0.09828)	[0.64472]
GOVEF(-3)	-0.019247	(0.09789)	[-0.19662]	GOVEF(-3)	0.011476	(0.09800)	[0.11710]
RDEXP(-1)	0.020661	(0.04371)	[0.47270]	RDEXP(-1)	0.012455	(0.04600)	[0.27077]
RDEXP(-2)	-0.023928	(0.05559)	[-0.43040]	RDEXP(-2)	-0.052434	(0.05689)	[-0.92160]
RDEXP(-3)	0.090032	(0.04750)	[1.89524]	RDEXP(-3)	0.021642	(0.04701)	[0.46041]
FINLIT(-1)	-0.004299	(0.00362)	[-1.18618]	FINLIT(-1)	0.002564	(0.00315)	[0.81302]
FINLIT(-2)	-0.000642	(0.00483)	[-0.13288]	FINLIT(-2)	-0.001298	(0.00397)	[-0.32717]
FINLIT(-3)	-0.001342	(0.00380)	[-0.35285]	FINLIT(-3)	-0.001892	(0.00336)	[-0.56251]
C	0.093059	(0.53732)	[0.17319]	C	-0.913991	(0.60217)	[-1.51783]
R-squared		0.941603		R-squared			0.968047
Adj. R-squared		0.834541		Adj. R-squared			0.909468
Sum sq. resids		0.013313		Sum sq. resids			0.011742
S.E. equation		0.027196		S.E. equation			0.025541
F-statistic		8.794944		F-statistic			16.52534
Log likelihood		141.2414		Log likelihood			144.5056
Akaike AIC		-4.124670		Akaike AIC			-4.250216
Schwarz SC		-2.848857		Schwarz SC			-2.974403
Mean dependent		0.583462		Mean dependent			0.909808
S.D. dependent		0.066859		S.D. dependent			0.084887

Source: Own compilation.

The impulse-response functions were performed to have a better understanding of the VAR model parameters related to the adequacy of pension systems (Figure 5). The graphics show that a shock in the pension aggregate replacement rate will decrease it in the long term. A shock in the migration rate will determine an increase in the replacement rate after three years, which will be reduced starting with the seventh year. The pension aggregate replacement rate reacts to a shock in gross earnings by increasing trend, but with regression periods. A similar reaction is noted in the case of shocks on employment rate, inflation, and old-dependency ratio. A shock in the duration of working life and research and development expenditures lead to a reduction in pension aggregate replacement rate, followed by an increase starting with the fifth year and a decrease after two more years. The pension aggregate replacement rate responds to the shock in government effectiveness and financial literacy with a reduction in the first two years, followed by an increased trend afterwards.

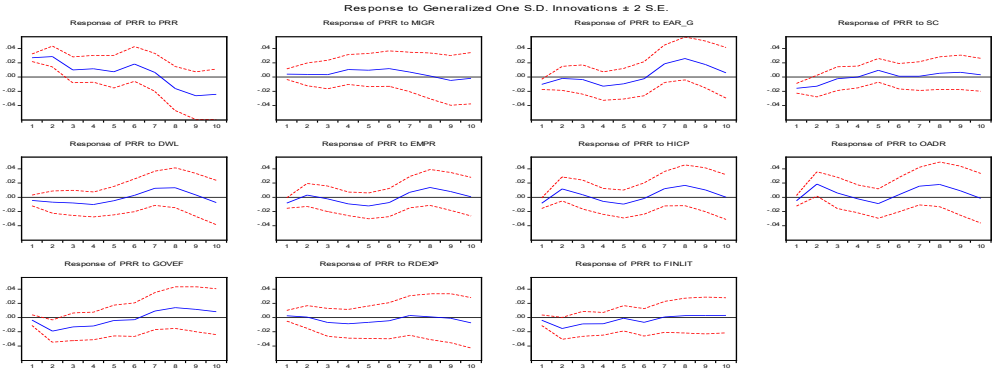


Figure 5. Results of the impulse-response functions - pension aggregate replacement rate
Source: Own processing.

In the case of median relative income, a shock of it will determine its reduction over time. A shock in the migration rate will produce the growth of median relative income in the first two years, followed by a reduction in the next two years and an increase in the following periods, which is reduced in the last two years of the tested period. The response of median relative income to the shock in gross earnings, employment rate, inflation, and the old-dependency ratio is similar, but the decreasing trend from the latest periods is more accentuated. A shock in social contributions and the duration of working life will cause a small increase in median relative income. The relative income reacts to the shock in government effectiveness and financial literacy by a growing trend. A shock in research and development expenditures will increase in the first two years, followed by a decrease until the eighth year, when a small increase in median relative income is recorded (Figure 6).

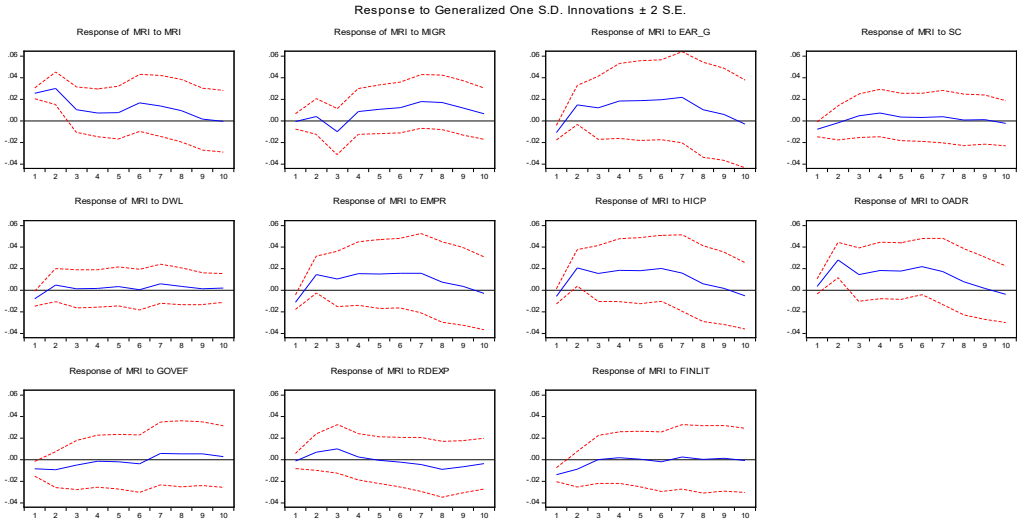
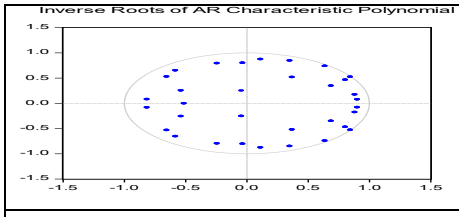


Figure 6. Results of the impulse-response functions - median relative income

Source: Own processing.

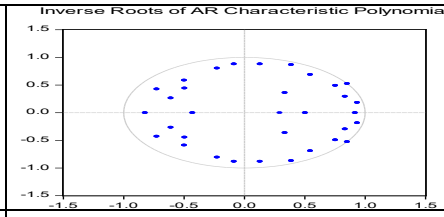
The VAR models were tested by the Inverse Roots AR Characteristic Polynomial to assess their reliability. All the roots are located inside the circle, reflecting the stability of the two VAR models used (Figures 7 and 8).



Endogenous variables: PRR; MIGR; EAR_G; SC; DWL; EMPR; HICP; OADR; GOVEF; RDEXP; FINLIT.

Figure 7. Inverse Roots AR

Source: Own processing.



Endogenous variables: MRI; MIGR; EAR_G; SC; DWL; EMPR; HICP; OADR; GOVEF; RDEXP; FINLIT.

Figure 8. Inverse Roots AR

Source: Own processing.

4.3 Discussions

According to Brosig & Hinrichs (2022), the sustainability of European pension systems cannot be improved without ensuring the adequacy of pension benefits. These two dimensions were investigated for the public pension systems implemented in CEE countries to find new evidence to improve their long-term stability and resilience in the region.

Empirical findings show that public pension benefits expenditures are influenced by gross earnings, employment rate, and government effectiveness, but only the latter two are significant causal factors. Social security budget revenues are

shaped by migration rate, gross earnings, working life duration, employment rate, and government effectiveness, with only working life duration being a significant driver. Enhancing employment rate, government effectiveness, and working life duration could improve the sustainability of social security budgets in CEE countries.

The aggregate replacement rate is determined by gross earnings, social contributions, working life duration, employment rate, and the harmonised index of consumer prices, with the latter two being key causal factors. The median relative income of elderly people depends on migration rate, gross earnings, social contributions, working life duration, and the harmonised index of consumer prices, but only gross earnings, social contributions, and the harmonised index are significant. Pension benefit adequacy in CEE countries relies on gross earnings, social contributions, working life duration, and the harmonised index of consumer prices.

The empirical results reflect the specific modus operandi of Bismarckian public pension systems and the direct influence of demographic factors, labour market characteristics, financial and taxation characteristics, and government effectiveness on the long-term stability and resilience of public pension systems, confirming the first three research hypotheses. In an aging society, public pension systems must readjust to fulfil the purpose of what was implemented (Baurin & Hindriks, 2023). As in the results of Gutierrez et al. (2023), this paper emphasises the need for better public services and wise public expenditure policies. Considering the latest major international crises have shaped global policies and economies, our work outlines the importance of aligning national policies to the international framework, especially in terms of defense (European Defence Agency, 2024), health care (Bocean & Vărzaru, 2025), welfare (Schmidt, 2024), labour rights (Mihalca, 2021), education (Dima et al., 2022), energy and infrastructure (Delcea et al., 2024), to ensure sustainable and coordinated global development.

5. Conclusions

Demographic changes in the last decades have had a significant effect on the public pension system financing and allocations, threatening the sustainability of the social security budget and the adequacy of provided benefits. To maintain the long-term stability and resilience of the public pension systems, CEE countries adopted some parametric reforms, starting with increasing the retirement age, increasing the minimum contributory period, stopping early retirement, and increasing the social contribution rate.

The results obtained in this research point to the necessity to link the policies of the pension system with demographic trends, labour market regulations, education and ITC developments, and the political environment. In an ageing society, empirical findings suggest the need to improve the accessibility of people over 45 years of age in the labour market, a sustainable increase in earnings, and the integration of immigrants. The most important factor in ensuring the long-term stability and resilience of public pension systems in CEE countries is the development of the socioeconomic attractiveness of these countries.

The paper's shortcomings lie in the limited availability of statistical data regarding pension systems and the sample size. Therefore, future developments can explore this topic by expanding the country sample, the data and variables, and the research method.

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