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No Country for Old Men (or Women): The Impact of Migration on Pension Funding Adequacy and Sustainability

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Abstract

This study explores factors influencing pension fund adequacy and sustainability across 21 EU countries from 2007-2018, with a specific focus on the role of migration. Results from Bayesian and regularized linear models reveal no significant evidence that migration bolsters pension funding. Public debt and fertility negatively affect funding in new EU countries, while private debt has a positive effect. The greatest factor is a country's socialist history. Policymakers are advised to consider strategies to integrate migrants across the EU for better pension contributions and recognize the disparities between former socialist and wealthier EU nations.

Keywords

Pensions, Pension Adequacy, Migration, Machine Learning, EU Countries

1. Introduction

Pension funding adequacy and sustainability are complex issues that have challenged societies worldwide, with the European Union (EU) dedicating substantial resources to fortifying pension finances (European Commission, 2021a, 2021b). Adequacy speaks to the individual's need for sufficient retirement income, while sustainability signifies a country's capacity to fund its citizens' pensions. Various income sources can contribute to an individual's retirement income, aiming to meet projected payments to retirees (American Academy of Actuaries, 2014; Richmont, 2019).

Challenges to pension funding adequacy and sustainability include demograph-

ic shifts such as reduced fertility rates and longer lifespans, economic crises, global events such as the COVID-19 pandemic, and geopolitical tensions. These factors have adversely affected incomes across all age groups, impacting pension fund contributions.

EU member-states have embarked on reforms to safeguard pensions against poverty and ensure income maintenance. These changes involve extending working lives and retirement ages, enhancing the capacity of pensions to support income, implementing measures to reduce poverty, and reforming pension financing strategies (European Commission, 2021a, 2021b). Despite these efforts, demographic challenges remain largely unaddressed.

One potential solution is capitalizing on the growing immigrant population in the EU. Immigrants and their descendants can bolster the workforce, expanding the population base and possibly relieving demographic pressure on pension funds. Conversely, emigration could negatively impact pension funding, as it reduces contributions from departing residents. Of note is the impact of non-EU-nationals settling in the EU, as they may contribute to pension funds upon entering the workforce.

This study investigates the demographic effects of migration on private pension funding adequacy in the EU. Using a variety of regularized and Bayesian linear models on data from 21 EU countries spanning 2007-2018, the research explores the relationship between migration and pension funding, among other variables.

The funding ratio, defined as the ratio of assets to benefits times the weighted average of expected retirement years for male and female workers, serves as the dependent variable, indicating the pension assets' capacity to cover current and future benefits. Independent variables include immigration and emigration rates, valid permits, fertility, private and public debt as a percentage of GDP, and market performance. A "socialism" dummy variable is used to differentiate between old and new (formerly socialist) EU countries.

Findings reveal a negative impact of inflow from non-EU countries on pension funding adequacy, applying to both old and new EU countries. However, overall migration showed minimal statistical significance. These outcomes suggest that integrating migrants may not be a reliable strategy for improving pension funding adequacy and sustainability.

Therefore, policymakers cannot rely on a flat migrant admission policy, but need to dig further into the particulars of migrants. Furthermore, it seems that they cannot apply a uniform policy neither to the country of origin nor to the country of reception. As far as the former is concerned, a potential policy may need to distinguish between EU and non-EU countries so as to better capture the specifics of non-European national settlements and labor force entry. The latter indicates that the applied policy should also account for differences between old and new EU member-states, as according to our findings, there is strong evidence that this is a key differentiating factor. Moreover, policymakers may need

to focus—among others—on the exact country of origin, gender, family status (including the number of family members), the (projected) years of employment, the (projected) sector of employment, and the level of education (existing and required). These parameters could influence the actual impact of migration on pension funding and are set for future investigation as far as this study is concerned.

This research contributes by providing a new perspective on the factors affecting private pension funding, emphasizing the role of migration, and introducing novel machine learning methods for data evaluation. Thus, it enhances understanding of the interplay between migration and pension funding while expanding the methodological toolkit for panel data analysis.

2. Descriptive Background

Literature review proceeds in two parts, each corresponding to one of this paper's two novel contributions. First, we will review study of pension funding adequacy and sustainability. Second, we will present machine-learning enhancements that enable traditional linear regression methods to combat collinearity and strengthen causal inferences drawn from the vector of predictive variables.

2.1. Part 1: Pension Financial Adequacy and Sustainability

The examination of disparities between pension assets and benefits within European contexts reveals a complex interplay of demographic, economic, social, and policy factors, extensively documented by a plethora of studies (Eichhorst et al., 2011; European Commission, 2010, 2015a, 2015b, 2021a, 2021b; Pensions Europe, 2020; Serrano & Peltonen, 2020).

Recent research has significantly advanced our understanding of pension adequacy and sustainability, particularly in the context of diverse economic environments and demographic shifts. Yohane, Mwanza, and Chowa (2022) offer valuable insights into the Zambian context, highlighting the interplay of institutional policies, economic conditions, and demographic variables in shaping pension outcomes. Their emphasis on affordability and sustainability underscores the need for tailored policy interventions to address regional challenges. Orenstein (2011) broadens the discussion by examining global trends in pension privatization, particularly in Eastern Europe, emphasizing the potential reversals and challenges associated with such reforms. Grech (2013) provides a comprehensive overview of methodologies for measuring pension adequacy, offering crucial tools for assessing the impact of demographic changes, including migration. Krieger (2014) further enriches the discourse by analyzing the relationship between public pensions and immigration, suggesting that effective migration policies can significantly influence the adequacy and sustainability of pension funding.

However, the literature suggests that the potential for immigration to address

these disparities and enhance pension funding has not been as thoroughly investigated. The significance of demographic characteristics, employment status, and other personal factors on pension incomes and the timing of retirement is evident in the works of Taubman (1985) and Scharn et al. (2018), highlighting varied effects based on marital status, education level, and occupation among others. Barr (2013) proposes an integrated view of pension funding adequacy and the asset-benefit ratio, with Finland's policy framework serving as a noteworthy model.

In exploring financial factors specific to certain geographies, Surjandari et al. (2019) and Sunaryo et al. (2020) provide insights into the Indonesian pension system, while Grech (2013) and Wolf and Del Rio (2021) discuss individual-level pension adequacy, revealing factors that mitigate poverty risk in retirement. The discourse around immigration's role in pension sustainability is nuanced, with Blake (2003) offering an optimistic view under certain conditions, whereas Munz and Werding (2005) present a more conditional stance, emphasizing the importance of immigrant characteristics and migration patterns. Krieger (2014) and Poufinas (2022) caution against viewing immigration as a straightforward solution, urging for immigration policies that align with each country's labor market, pension system, and citizenship laws.

This study advances the dialogue by juxtaposing pension funding adequacy against the asset-benefit gap through the lens of regularized and Bayesian linear methods, uncovering significant disparities between older, Western EU member states and their newer, Eastern counterparts—a reflection of the intricate relationship between political history, EU membership, and pension sustainability as recognized by scholars such as Velladics et al. (2006) and Wagner (2005).

2.2. Part 2: Machine-Learning Enhancements in Traditional Linear Methods

The concerns surrounding the misinterpretation and misuse of p-values in statistics have underscored the critical role of regression coefficients in causal inference (Cohen, 2011; Wasserstein & Lazar, 2016). In the context of this study, it investigates the dynamics between pension funding adequacy and sustainability, the focus shifts towards understanding the influence of migration through the lens of regression coefficients. These coefficients, particularly their signs and magnitudes, serve as pivotal indicators of the direction and intensity of migration-related variables on pension funding ratios. The concept of coefficient importance emerges as a fundamental aspect, suggesting that the value and significance of coefficients in a multiple regression model transcend traditional p-value considerations, offering a more direct route to causal interpretations (Thompson et al., 2017).

The analytical challenges posed by collinearity among predictors are addressed through innovative methodologies, including machine learning techniques and data preprocessing measures like Gaussian scaling, which facilitate the integra-

tion of linear and machine learning approaches for a more stable interpretation of coefficients (Newman & Browner, 1991; Tipping & Bishop, 1999a, 1999b). The adoption of regularized regression techniques, such as Ridge regression, enhances the model's robustness by mitigating the impact of collinearity and refining the interpretation of coefficient importance through the manipulation of the complexity parameter α (Dhillow et al., 2013; Marquardt & Snee, 1975; McDonald, 2009; Smith & Campbell, 1980; Tikhonov, 1963).

Further refinement in handling collinearity and enhancing model interpretability is achieved via feature selection strategies aimed at inducing sparsity within the regression model. This approach, which leverages the least absolute shrinkage and selection operator (Lasso) and Orthogonal Matching Pursuit (OMP), strives to minimize the presence of non-essential predictors while preserving the model's predictive accuracy and explanatory power (Donoho, 2006; Brank et al., 2011; Guyon & Elisseef, 2003; Mallat & Zhang, 1993; Tibshirani, 1996, 1997).

The integration of Bayesian learning frameworks into regression analysis introduces additional methods, such as Bayesian Ridge and sparse Bayesian learning (also known as ARD or Bayesian Lasso), offering robust alternatives to conventional regression techniques by accounting for collinearity and promoting a sparser representation of influential variables (MacKay, 1992; Neal, 1996; Tipping, 2001; Pasanen, Holmström, & Sillanpää, 2015). The confluence of these diverse linear and Bayesian regression methods culminates in a sophisticated analytical framework that not only addresses the intrinsic challenges of regression analysis, but also illuminates the complex relationship between migration and pension funding adequacy.

3. Data, Variables and Methodology

3.1. Data

The dataset employed in this study covers 21 EU countries from 2007 to 2018: Austria, Belgium, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, and the United Kingdom (which was still a member of the European Union during the period under investigation). The countries excluded due to lack of comprehensive benefits data include Bulgaria, Croatia, Cyprus, Malta, Ireland, Sweden and Romania. In addition, data from the latest 5 years were excluded due to inconsistencies and gaps in the available data, which would have compromised the accuracy and reliability of the analysis. The sources of the data are 1) the Organization of Economic Cooperation and Development (OECD, 2020, 2021) for assets, benefits and the expected years in retirement; 2) the World Bank (2020a, 2020b, 2020c, 2020d, 2020e) for the annual percentage change in Standard & Poor's (S&P) Global Indices, inflation, private debt (as a percent of Gross Domestic Product (GDP)), fertility and the female proportion

of the total population; and 3) Eurostat (2020a, 2020b, 2020c, 2020d) for immigration, emigration, the number of all valid permits (by reason) as of 31 December of each year, unemployment, public debt (expressed as a percent of GDP) and the house index.

Linear interpolation supplied missing values. Although we examined values derived from higher-degree polynomial splines, combined with LOESS local regression (Cleveland & Devlin, 1988), quadratic and cubic regression generated values that appeared less plausible. We therefore adopted the more conservative values generated by linear interpolation.

3.2. Variables

This paper evaluates the impact of migration on funding adequacy and sustainability for autonomous pension schemes. Autonomous pension funds are "(social insurance) pension funds that are institutional units separate from the units that create them. Such autonomous funds have autonomy of decision and keep a complete set of accounts". In contrast, non-autonomous pension funds are "not institutional units and remain part of the institutional unit that sets them up" (Eurostat, 2010).

Whenever statistically plausible, we considered immigration and emigration as distinct variables. In one model where immigration and emigration showed excessive collinearity, we used Principal Component Analysis (PCA) to evaluate these phenomena as a unified "migration" variable.

The dependent variable chosen as a measure of pension funding adequacy is the pension funding ratio:

$$\text{Funding Ratio} = \frac{\text{Assets}}{\varphi \times \text{benefits}} \tag{1}$$

where φ is the weighted average of expected years in retirement for male and female workers. This is given by:

$$F\varphi = M \times (1 - F) + W \times F \tag{2}$$

where,

M is the expected years in retirement for men.

W is the expected years in retirement for women.

F is the female % of the total population.

The funding ratio captures not only private pension funding sustainability at a country-specific level but also adequacy at the level of an average individual. Country-level sustainability indicates that assets suffice to pay pensions, while individual adequacy means that a typical retiree will receive pension payments sufficient to cover the entirety of that person's retirement. The funding ratio refers to a pension fund's financial position and is calculated as the ratio of assets to liabilities of a pension fund. It reflects the ability of pension assets and reserves to cover current and future benefits (e.g. De Nederlandsche Bank, 2022).

At the level of a pension scheme, the funding ratio is typically calculated as the

ratio of the present value of assets (the pension scheme's investments to financial instruments) to the present value of liabilities (the current and future benefits to be disbursed), using the actuarial interest rate. Because we are investigating pension funding sustainability at the country level, we do not have data indicating the future evolution of assets and liabilities for all pension schemes in each country. Consequently, we use the variable defined in Equation (1) as a proxy that estimates the ability of current assets to pay current benefits to that country's retirees.

The funding ratio is a conservative measure of funding adequacy and sustainability. It presumes a zero rate of return. That conservative assumption offsets other risks, such as declines in birthrates, net migration, or workforce participation, or increases in longevity. Conceptually, pensions meeting a ratio of 1 can withdraw $1/\varphi$ in assets each year to satisfy benefits promised to workers retiring immediately. Notably, defining pension funding adequacy as the ratio of assets to benefits multiplied by the weighted average of years in retirement eliminates both the opportunity and the need to adjust the definition of adequacy according to each country's GDP per capita.

The independent variables in our models are the immigration rate, the emigration rate, total valid permits, fertility, private debt as a percent of GDP, public debt as a percent of GDP, and market performance (as measured by the percentage change in S&P's global indices). To combat collinearity, one model ultimately uses PCA to combine immigration and emigration into a unitary "migration" variable. Three control variables complement the models; unemployment, inflation and the housing index. All variables have been z-transformed, so that they can be directly compared with one another in terms of Gaussian distance.

One of our models introduces a dummy variable, called "socialist", in order to distinguish between old and new (former socialist) European Union countries. The rationale (which will be further elaborated below) is that the older member-states have more mature pension schemes, have accumulated assets for more years and exhibit materially higher benefits than the latter.

In order to justify the aforementioned choices, we realize that when migrants enter into the labor force, they make contributions not only to the state-guaranteed (usually pay-as-you-go—first pillar) pension scheme, but also to the respective occupational (usually autonomous or non-autonomous—second pillar) pension scheme. Consequently, the question of whether migration impacts the assets and the liabilities can be asked. Both funded and unfunded occupational pension schemes have as their purpose to maintain or even increase the amounts contributed by their members so as to receive the corresponding benefits at retirement. Even in the cases where there is no promised rate of return, the funds aim at preserving the contributions of their members against inflation increased by a reasonable interest rate. Even if this is not a contractual obligation, it is certainly an implicit target/wish. Otherwise, their members would have no initiative to contribute (except for the cases where these contributions are mandatory by

law). Migration may affect the number of members of the pension funds and thus may influence the total volume of assets and liabilities (benefits), which can impact the rate of return (as higher assets under management may yield more investment opportunities), the investment horizon, etc. Considering the afore mentioned argument, even funded pension schemes (although our dataset considers autonomous pension schemes) do have an implicit target to meet in terms of having the assets to meet future benefit payments. Therefore (with the admission of the limitation that we do not have projections of future benefits or assets), the funding ratio, for the purpose of studying the impact of migration on the assets and liabilities (of autonomous pension funds, combined) is a reasonable proxy.

Further descriptions of the variables are presented in Poufinas (2022). A detailed definition of each variable can be found in the sources described in the Data subsection above and in **Appendix**.

3.3. Methodology

Addressing the complexities of pension funding adequacy and sustainability, this study navigated through significant data challenges, starting with the absence of comprehensive benefits data which led to the exclusion of certain countries and the imputation of values for others. Notably, extreme values were capped at $\exp(\pi)$ to maintain data integrity, while also ensuring that all computed ratios remained within a plausible range. This preprocessing step, although unconventional, was essential for maintaining consistency across the dataset and preparing it for rigorous analysis.

The investigation revealed stark contrasts in pension benefits across Europe, with wealthier Western European countries typically offering more generous benefits compared to their Eastern European counterparts, which have a history of socialist economies. This dichotomy was addressed in two distinct ways: the introduction of a "socialism" dummy variable to distinguish between countries based on their political and economic histories, and the bifurcation of the dataset into two subsets for a more nuanced analysis. The latter approach, in particular, helped to avoid the oversimplification that might arise from using a single dummy variable and provided clearer insights into the disparities in pension funding adequacy and sustainability between the old West and the new East.

Given the dataset's limitations (7 out of EU28 countries with significant data gaps), including a total of 252 observations across 21 countries with varying historical and economic contexts, the study employed a multifaceted analytical approach. This encompassed everything from linear regression models to more sophisticated machine learning techniques, albeit with a cautious eye on the risks of overfitting and the inherent challenges of applying stochastic machine-learning methods to smaller datasets. This careful selection of methods ensured the reliability of causal inferences drawn from the analysis, emphasizing the importance of statistical rigor and methodological precision in economic re-

search.

Furthermore, the study's methodological framework was notably comprehensive, incorporating seven forms of linear regression alongside a soft-voting regress or to derive nuanced interpretations of the data. This approach was not primarily aimed at predictive accuracy but rather focused on understanding the causal relationships within the data, particularly how migration impacts pension funding adequacy and sustainability. The use of regularization and Bayesian methods was a deliberate choice to counteract potential overfitting and to refine the selection of predictive variables, demonstrating a sophisticated application of machine learning principles to enhance traditional econometric analysis.

This research makes significant contributions both in terms of policy implications, highlighting the nuanced impacts of migration on pension systems across different European contexts, and in methodological advancements, showcasing the application of regularized and Bayesian linear methods to economic data analysis. By integrating elements of supervised machine learning, this study advances the understanding of causal relationships in economic models, particularly in the context of pension funding adequacy and sustainability within the European Union.

4. Empirical Results

This study provides empirical evidence that the number of valid permits, as a measure of the population of non-EU nationals within a member-state of the European Union, has a negative and statistically significant impact on pension funding as measured by the funding ratio. This relationship holds in old as well as new member-states of the EU. By contrast, immigration and emigration exhibit no statistical significance.

In a joint analysis of all EU countries (that is, in a dataset that includes both new and old EU countries), public debt has a negative and significant effect on funding adequacy. The socialist dummy has a positive and significant effect. The socialist dummy is so dominant, however, that splitting the data into distinct cohorts for the old west and the new east is warranted.

Collinearity between immigration and emigration within the subset of old EU countries prompts the evaluation of those phenomena through a unified "migration" variable generated through PCA. That machine-learning innovation eliminates any suggestion that either immigration or emigration, or the permanent movement of people across these countries' borders in either direction, has any effect on pension funding. Only permits matter, statistically speaking, and they have a negative effect.

Eventually, in analysis focusing exclusively on the subset of new EU countries, fertility and public debt have a negative and statistically significant effect on the funding ratio. In those countries, private debt has a positive and statistically sig-

nificant effect.

4.1. All EU Countries

The initial panel of 11 predictive variables, including the socialist dummy, generates the set of 12 subplots (Figure 1) combining histograms and kernel density estimates. Out of these, 8 variables, including the target funding ratio, are

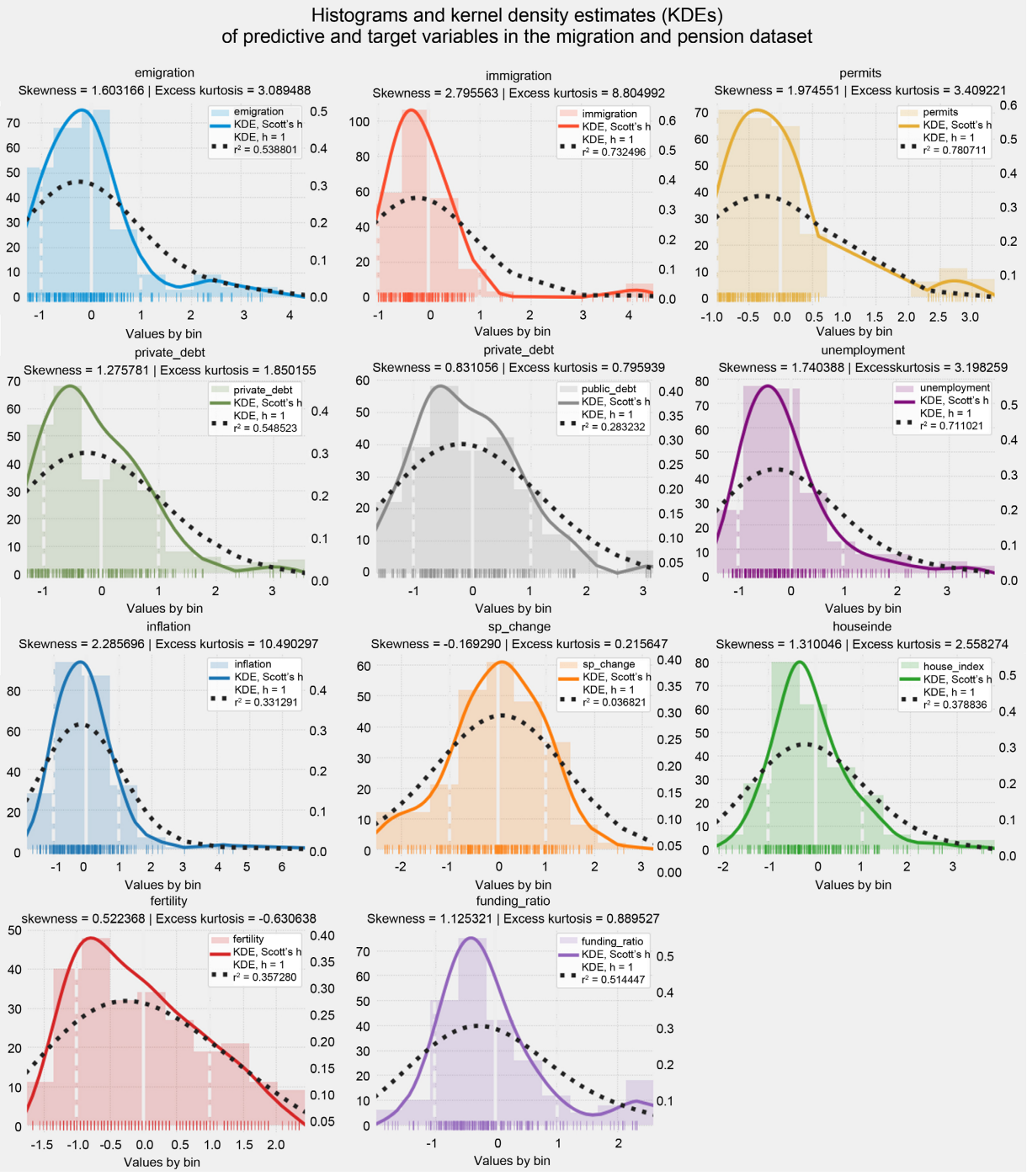

Figure 1. Histograms and kernel density estimates for all 21 EU countries.

right-skewed. By the same token, 9 of the variables bear at least some resemblance to the canonical bell curve of a normal distribution. The striking (but unsurprising) exception is the strictly bimodal distribution of the socialist dummy. The migration-related variables of emigration, immigration, and permits all reflect positive correlation with the funding ratio target variable, but not so much that they exhibit excessive collinearity (Figure 2 and Figure 3). Figure 3 presents the Variance Inflation Factor (VIF) analysis for all 21 EU countries, highlighting the collinearity issues among the variables. The final panel of subplots reports beta coefficients and statistical significance for all eight methods, from pooled Ordinary Least-Squared (OLS) to soft voting regression (Figure 4).

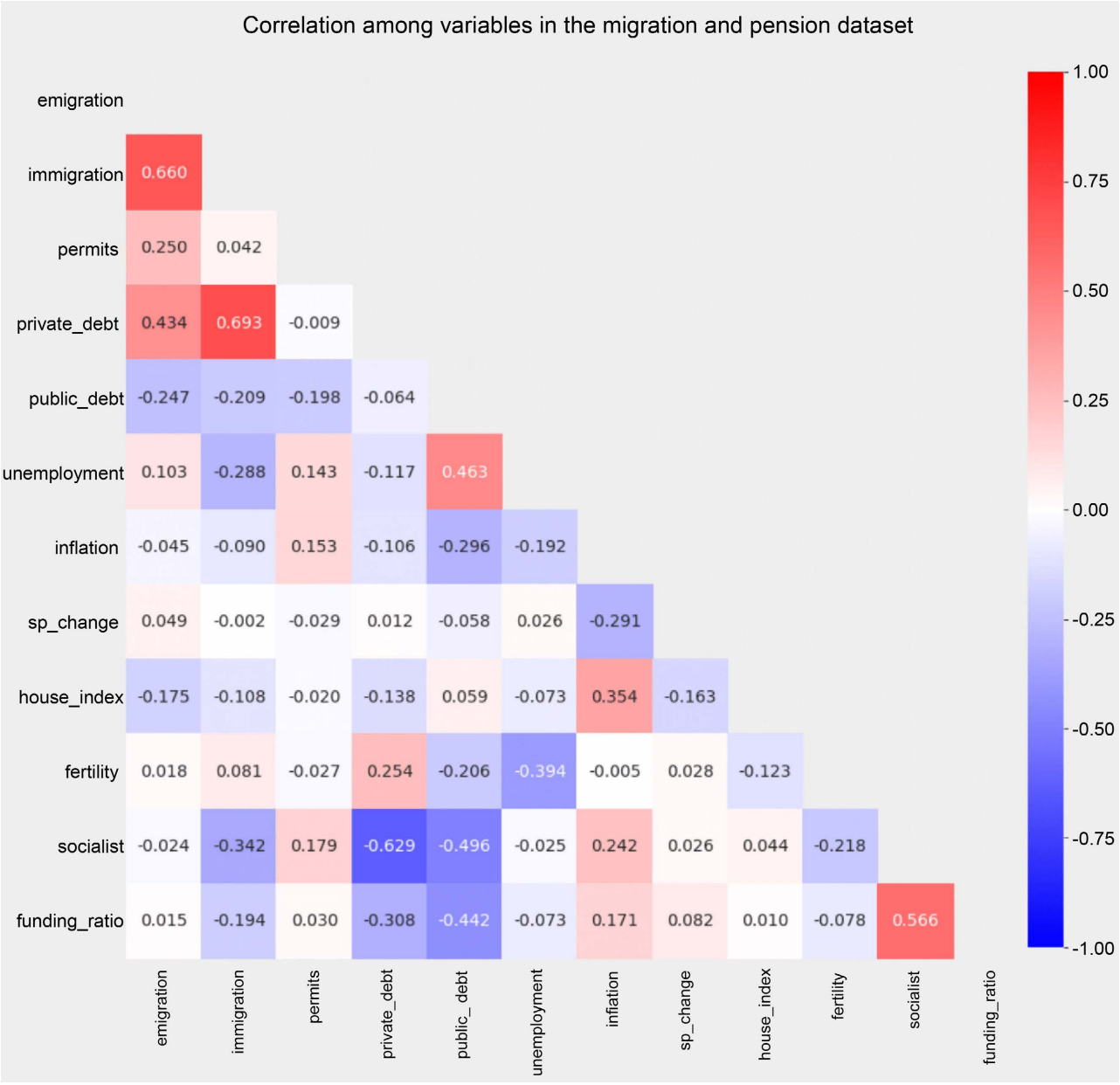

Figure 2. Correlation matrix for all 21 EU countries.

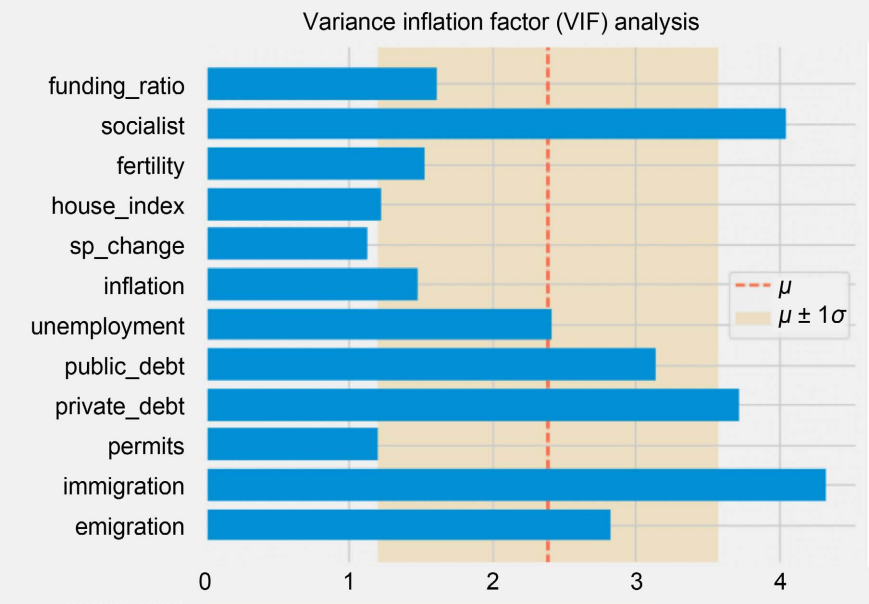

Figure 3. Variance Inflation Factor (VIF) analysis for all 21 EU countries.

The most influential variable, as indicated by the absolute value of the beta coefficient and the lone assignment of statistical significance at $p < 0.001$, is indeed the socialism dummy. The only other statistically significant predictor is public debt, with a strongly negative coefficient. Emigration and immigration point in opposite directions, and permits reflect a negative coefficient alongside immigration. None of these migration-related variables is statistically significant, however.

Orthogonal Matching Pursuit (OMP) reveals how nine out of 11 variables, including all three migration-related variables, could be weeded out of this model with less than 10 percent loss in accuracy as measured by r^2 (**Figure 5**). In fairness, the three migration-related variables are among the four most consequential of the nine variables that OMP removes from its streamlined design matrix.

This overview of all eight methods shows how pooled OLS begins with four significant variables, including both immigration and permits, only to yield coefficients and statistical significance as regularized and Bayesian methods, plus OMP, persistently eroded causal inferences that might otherwise be drawn from pooled OLS (**Figure 6**). Fitted values from the seven methods beyond OLS reflect how similarly and incrementally most alternatives moved, relative to OLS. ElasticNet is a palpable exception, while the comparably sparse OMP model hews closer to the baseline OLS model (**Figure 7**).

The dominance of the socialism dummy invites a separate look at old and new EU countries as distinct cohorts. Higher collinearity between this variable and the funding ratio, as indicated by the variable inflation factor, also counsels the splitting of the data into two geopolitical subsets. Focused analysis of these separate cohorts reveals different relationships between predictive variables (including the migration-related variables) and pension funding.

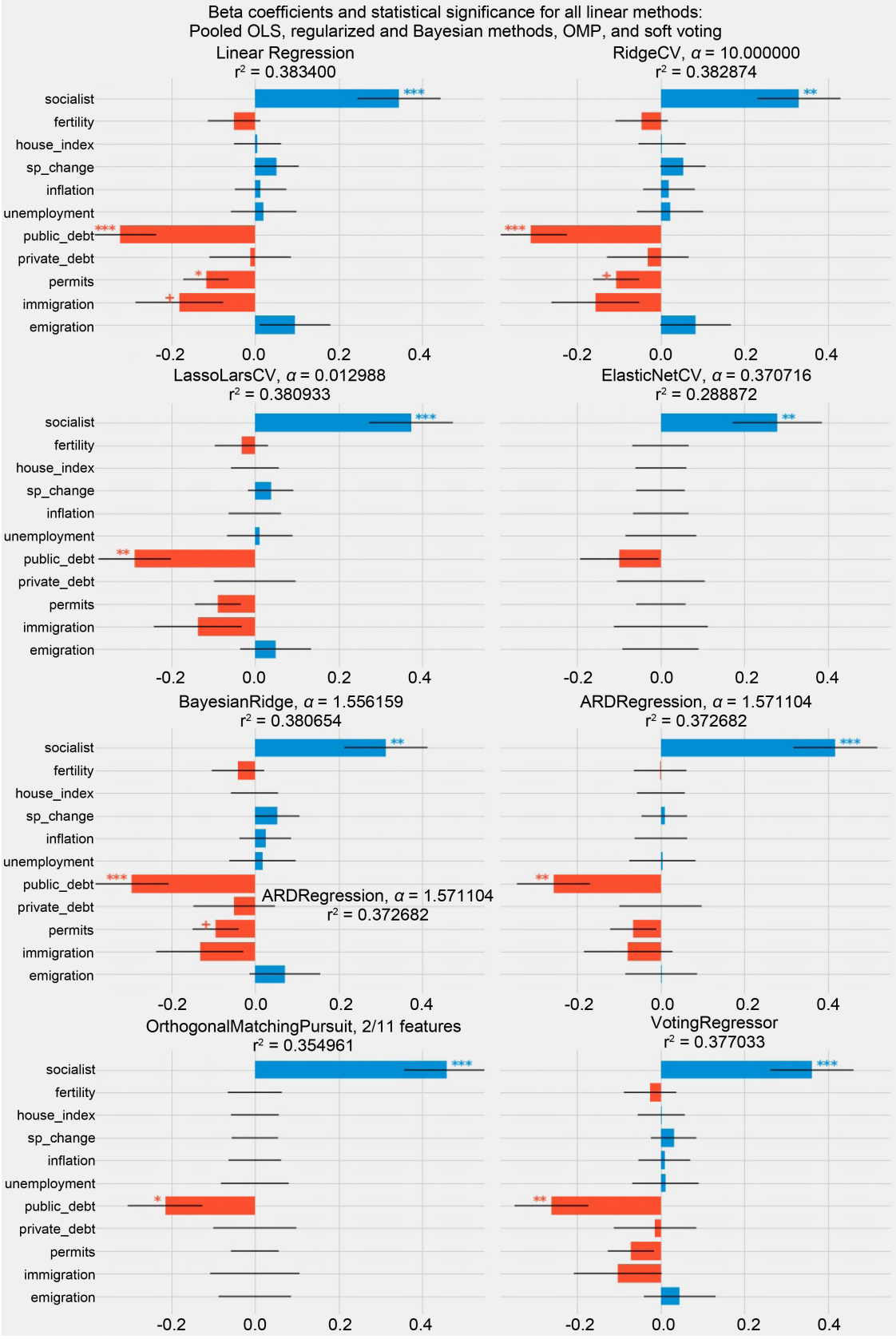

Figure 4. Beta coefficients and statistical significance for all linear methods for all 21 EU countries.

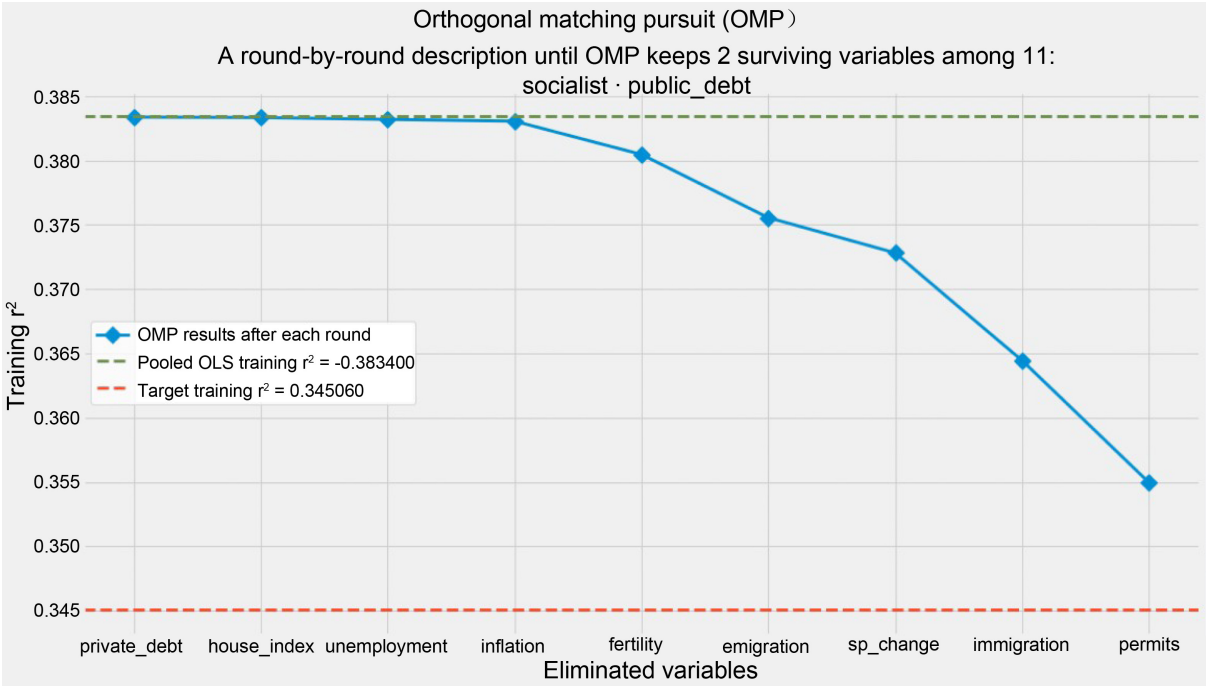

Figure 5. Orthogonal Matching Pursuit (OMP) for all 21 EU countries.

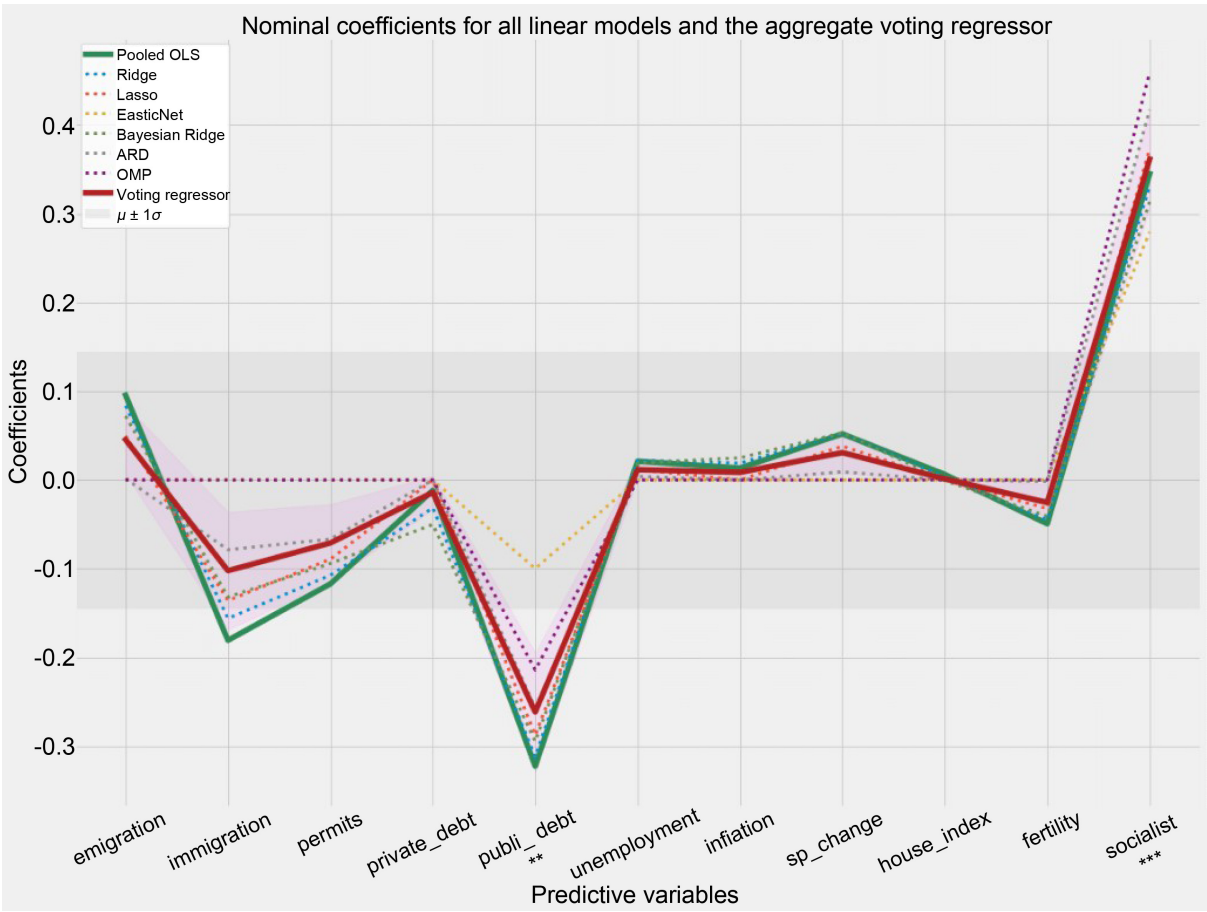

Figure 6. Nominal coefficients of all linear models and the aggregate voting regress or for all 21 EU countries.

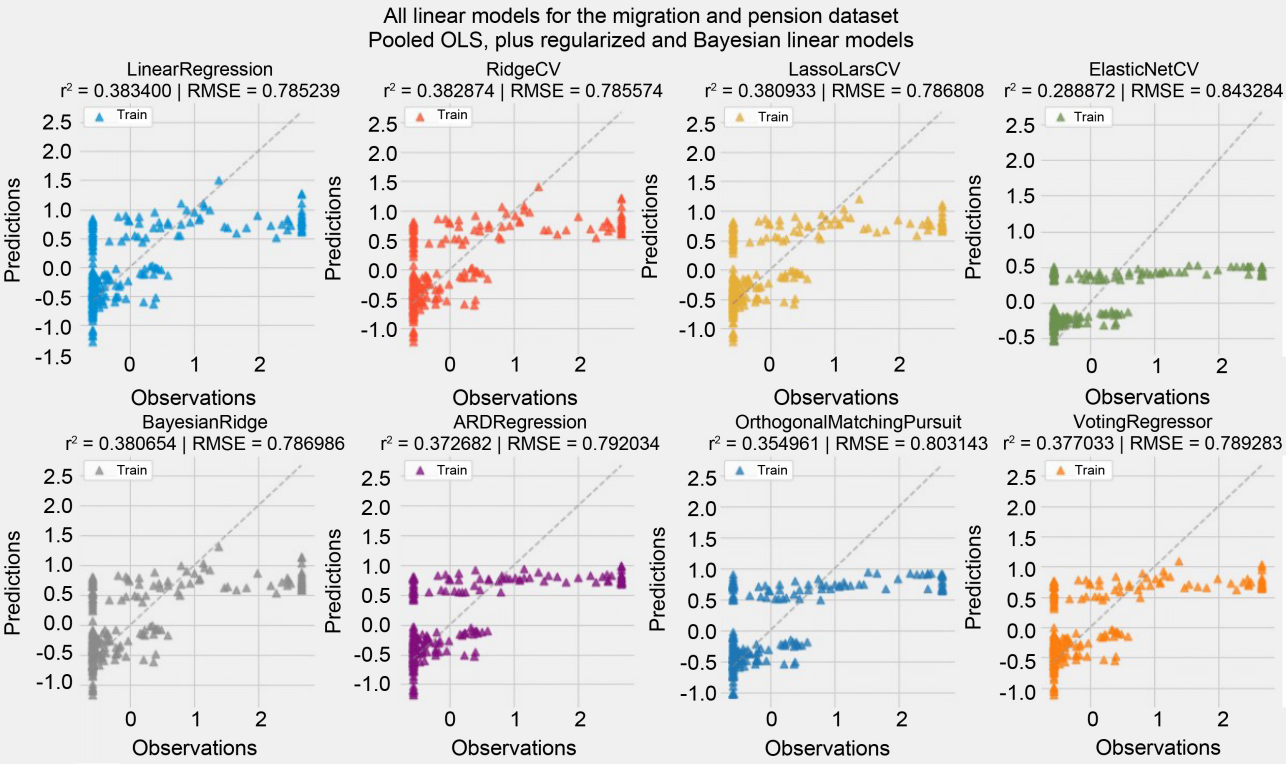

Figure 7. All linear models for the migration and pension dataset for all 21 EU countries.

4.2. Old EU Countries

Perhaps surprisingly, the uncensored western data proved more resistant to accurate fitting. Some of the difficulty arose from unusually low benefit levels in Denmark. Danish observations dominate the right-hand edge of all predictive subplots (**Figure 8**). But the ensemble of eight linear methods ultimately whittled this view of the data to a single significant predictor: Permits reflect a negative relationship with the funding ratio (**Figure 9**). Emigration and immigration do register visible though statistically insignificant coefficients, with opposite signs. Those two variables, unlike the persistent and stable permits variable, were subject to huge swings as regularization methods more aggressive than Ridge entered the scene (**Figure 10**).

Indeed, every method besides Ridge and the OLS baseline denied statistical significance to emigration and immigration. Even though emigration dominated the subvector of negative coefficients in OLS and Ridge, two of the sparsity-inducing methods, ElasticNet and OMP, eliminated emigration from their versions of the ℓ_0 quasi-norm. These methods' removal of emigration from the active set of predictive variables is a canonical demonstration of the interpretive power of sparsity and the swiftest path toward the ℓ_0 quasi-norm.

An even more dispiriting explanation for the relationship between emigration and immigration emerges from closer examination of correlation and collinearity for the old, non-socialist cohort (**Figure 11**). Variance Inflation Factor (VIF) analysis reveals how the variable inflation factors for both emigration and

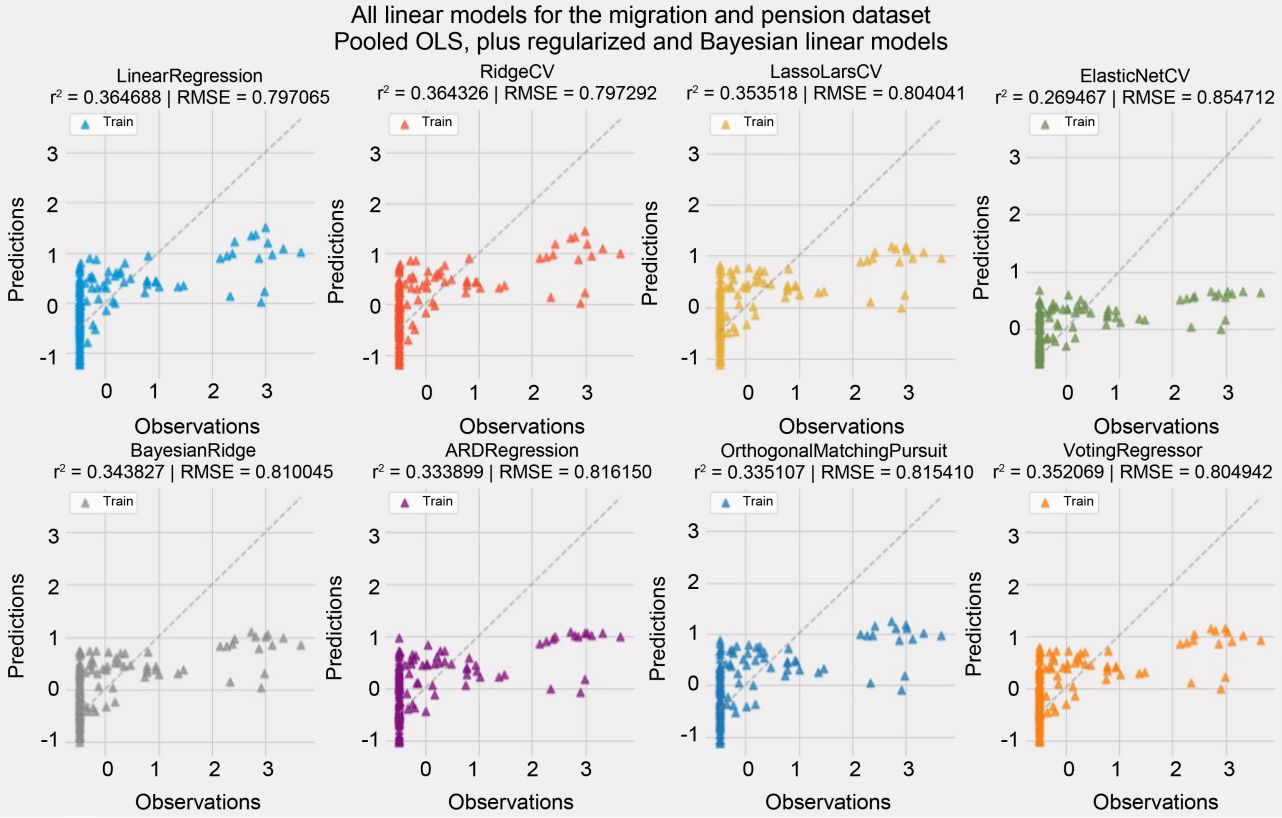

Figure 8. All linear models for the migration and pension dataset for the 13 old EU countries.

immigration exceed the conventional worry-free threshold of 5. Instead, VIF values for these variables approach the zone, near 10, where collinearity may cause closely correlated variables to spin off in opposite directions. Especially in light of the miniscule values of Pearson's r −0.007 and −0.066, respectively for emigration and immigration—relative to the funding ratio target variable, the curse of collinearity undermines the validity of inferences drawn from these two migration-related variables (**Figure 12**).

Any significance attributed to emigration or immigration by the OLS and Ridge methods must therefore be discredited. Some other method for managing immigration and emigration as collinear variables is strongly advised. The solution to this problem lies in the PCA transformation of the highly correlated emigration and immigration variables into a single, unified "migration" variable (**Figure 13**). This maneuver instantly releases VIF pressure on the entire dataset (**Figure 14**). The highest VIF value, just above 4 and safely below the worrisome threshold of VIF > 10, is associated with the PCA-transformed unitary migration variable. The results are remarkable. In the old (non-socialist) west, migration in either direction has no impact at all pension funding. Permits, on the other hand, are the lone statistically significant variable. Fertility lingers on the margins of significance and would positively affect pension funding (**Figure 15** and **Figure 16**).

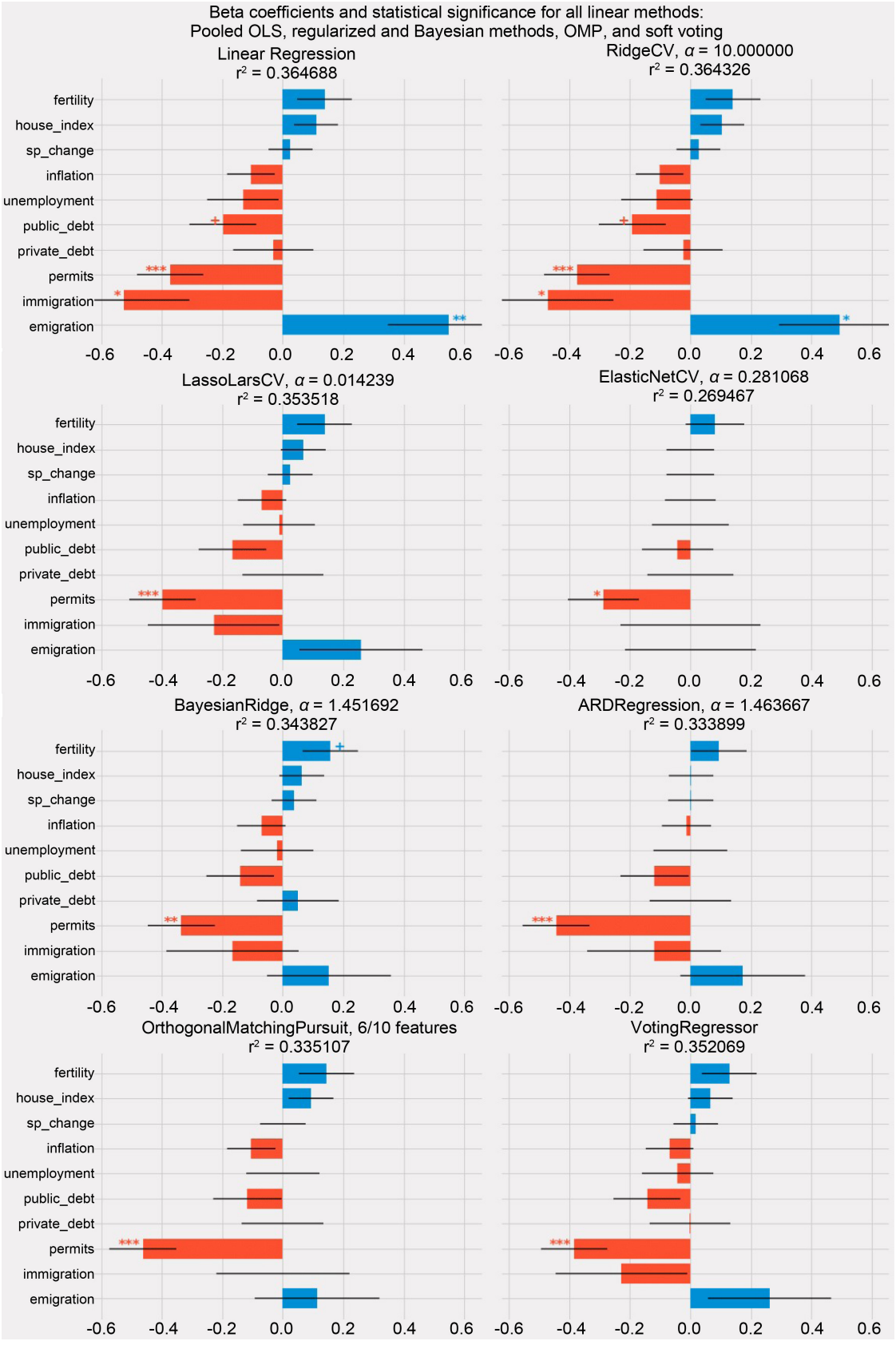

Figure 9. Beta coefficients and statistical significance for all linear methods for the 13 old EU countries.

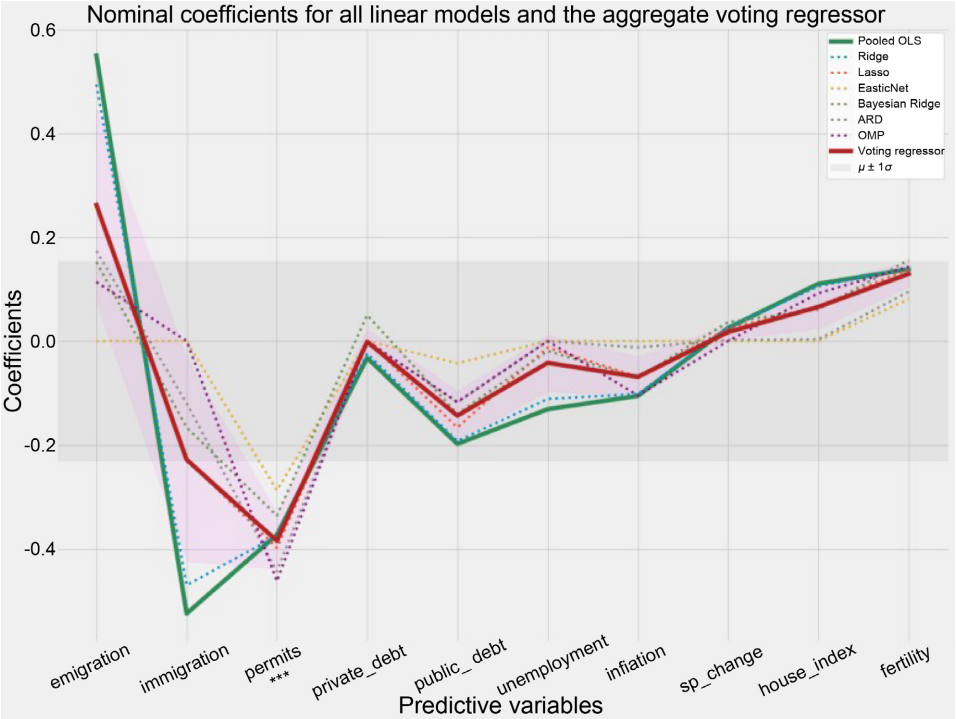

Figure 10. Nominal coefficients of all linear models and the aggregate voting regressor for the 13 old EU countries.

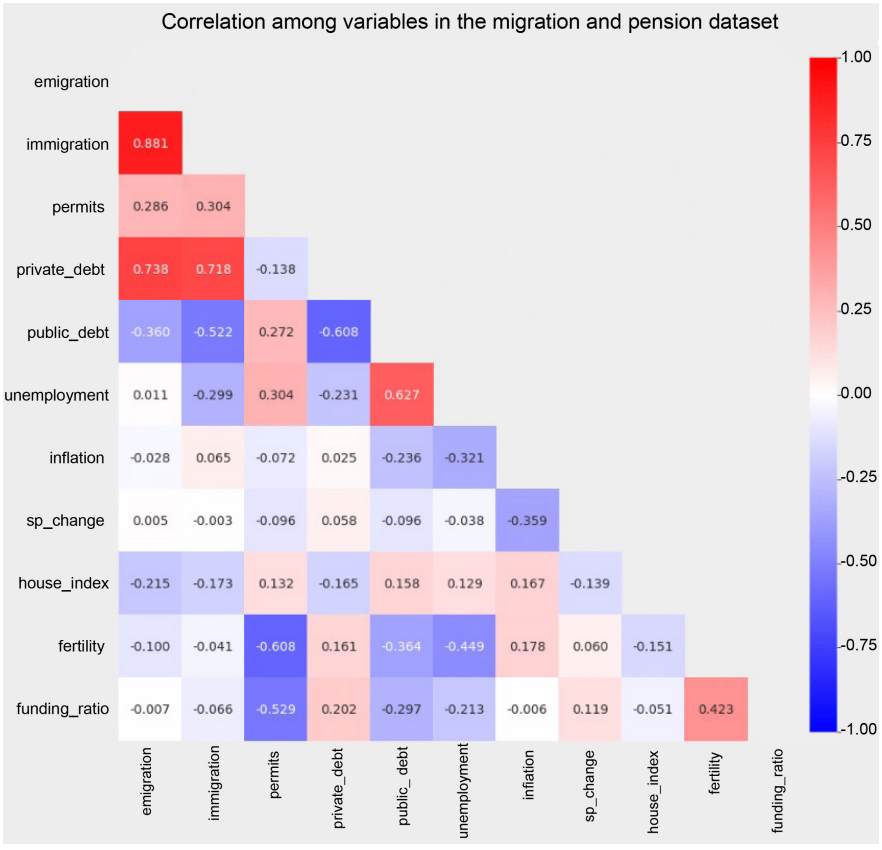

Figure 11. Correlation matrix for the 13 old EU countries.

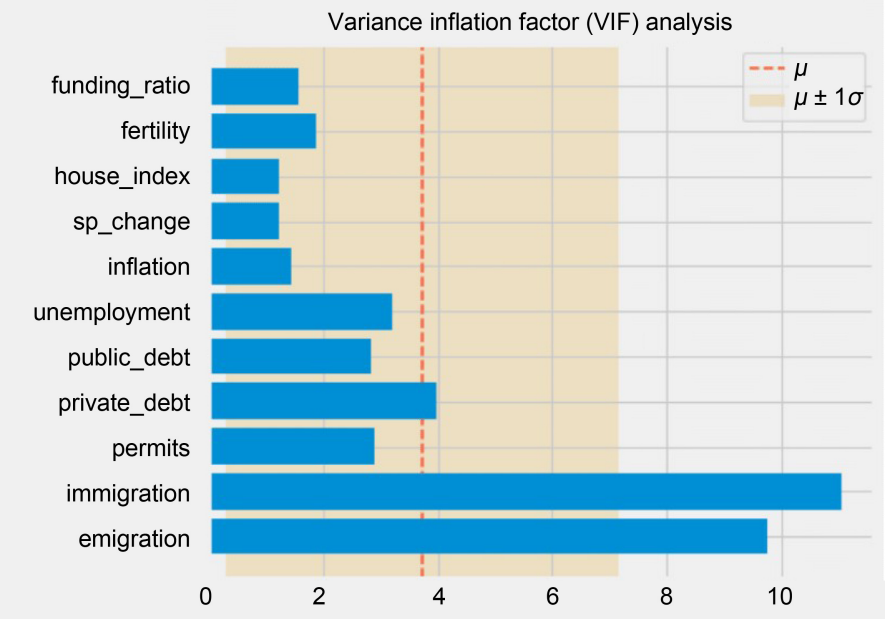

Figure 12. Variance Inflation Factor (VIF) analysis for the 13 old EU countries.

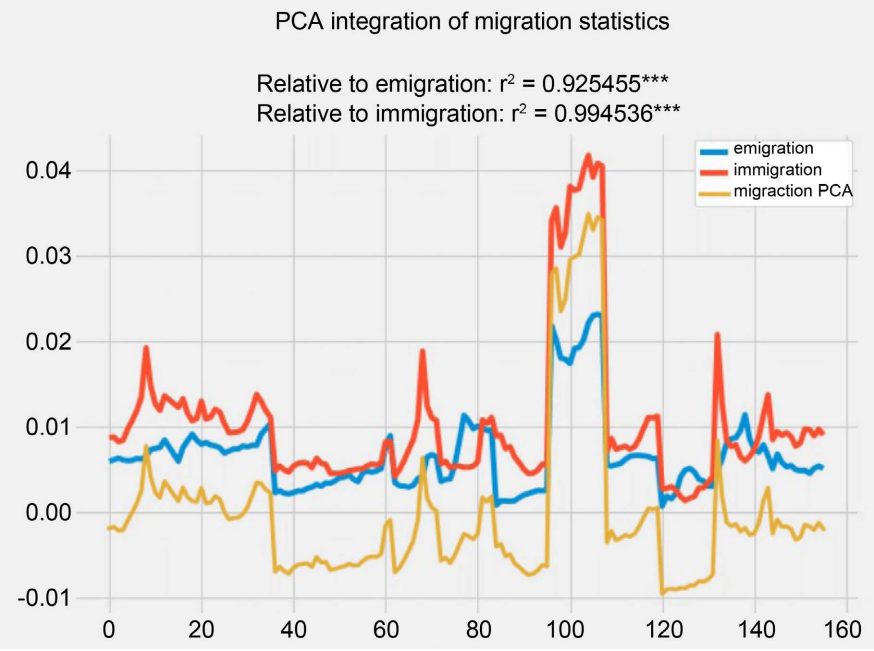

Figure 13. PCA integration of migration statistics the 13 old EU countries.

4.3. New EU Countries

Meanwhile, as expected, the new (formerly socialist) countries exhibit a radically different relationship between immigration, debt, and even fertility (on one hand), and pension funding adequacy and sustainability (on the other hand). Permits are negatively correlated at a statistically significant level. Private and public debt are both significant; they point in opposite directions. Elevated public debt maps negatively onto pension funding adequacy, while high levels of

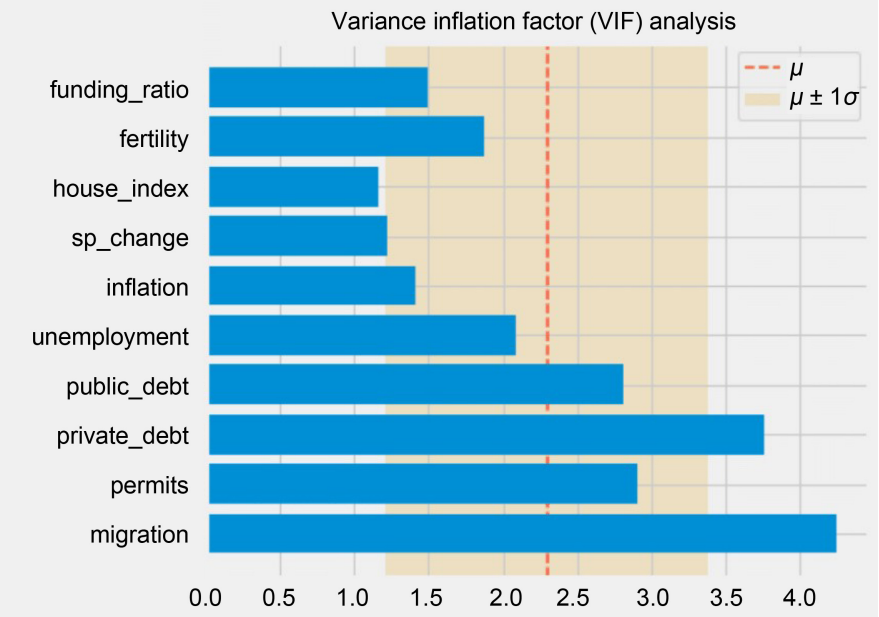

Figure 14. Variance Inflation Factor (VIF) analysis for the 13 old EU countries—unified migration variable.

private debt show the opposite effect. Perhaps surprisingly and counter intuitively, fertility points in the opposite direction from the west; higher fertility is associated with weaker pension funding. Figure 17 shows the beta coefficients and statistical significance for all linear methods for the 8 new EU countries. Unlike the west, fertility in new EU countries is statistically significant (Figure 17).

Agreement among the eight constituent linear methods is notably close, with the salient exception of ElasticNet (Figure 18 and Figure 19). Censoring, by the way, had the effect of stabilizing the eastern subset of the data and produced the most credible set of fitted values.

In sum, the factors affecting pension funding adequacy in the new (formerly socialist) EU countries differ markedly from the relevant factors in the old (non-socialist) EU countries. Indeed, the difference is so stark that this Boolean marker generates the highest beta coefficient in a combined analysis of 21 countries in the European Union. Consequently, we undertook to examine the old and the new EU-country blocs separately.

Statistically, valid evaluation of old EU countries shows that neither emigration nor immigration has any discernible impact on pension funding adequacy or sustainability. The factor that unequivocally reduces adequacy and sustainability is migration permits, which reflects the inflows of non-EU nationals. The ensemble of linear methods, with their emphasis on regularization and feature selection, cast rightful doubt on what ultimately proved to be the illusory relationship between emigration and immigration. Neither phenomenon, when the two are combined into a unitary "migration" variable, has any statistically significant impact.

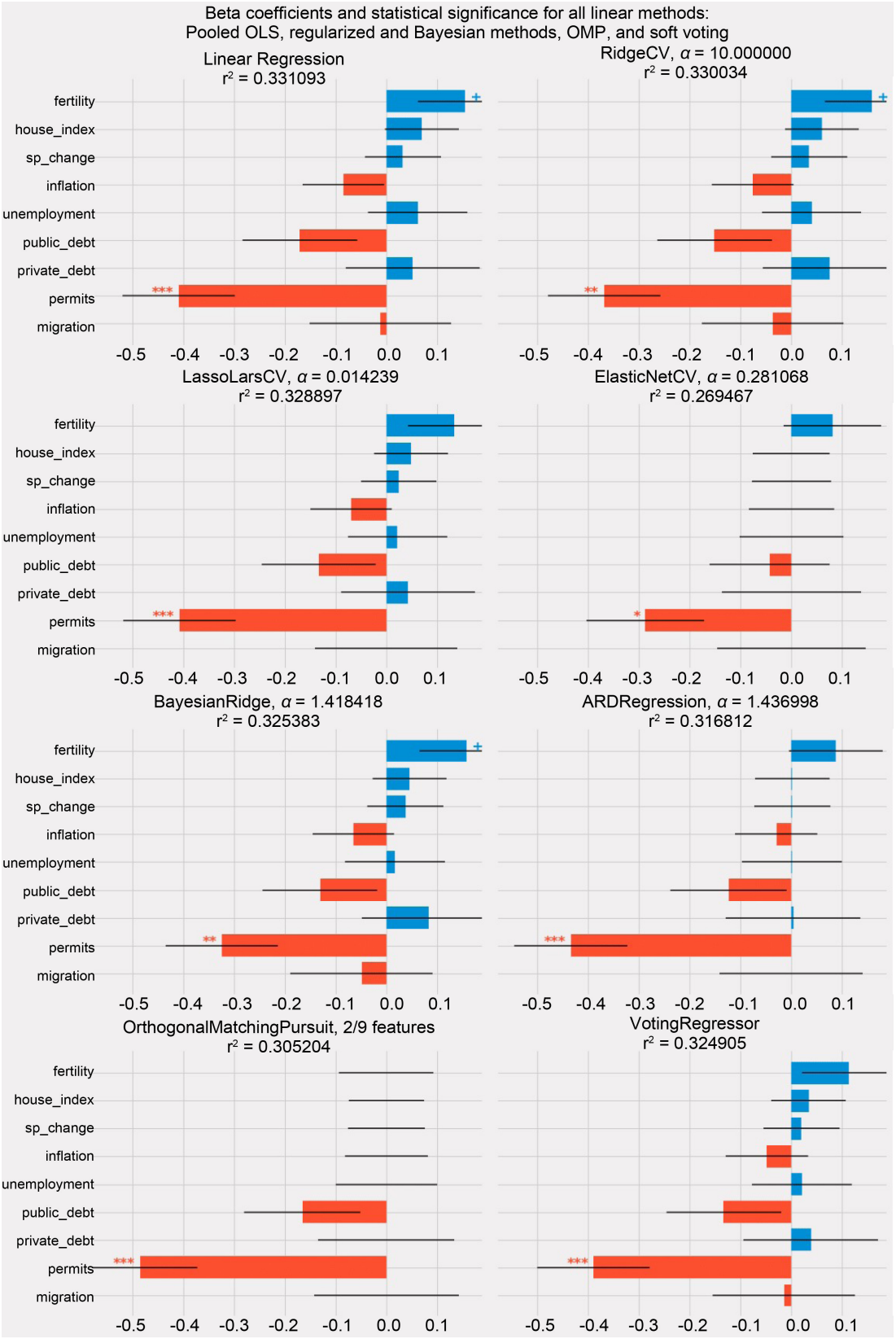

Figure 15. Beta coefficients and statistical significance for all linear methods for the 13 old EU countries—unified migration variable.

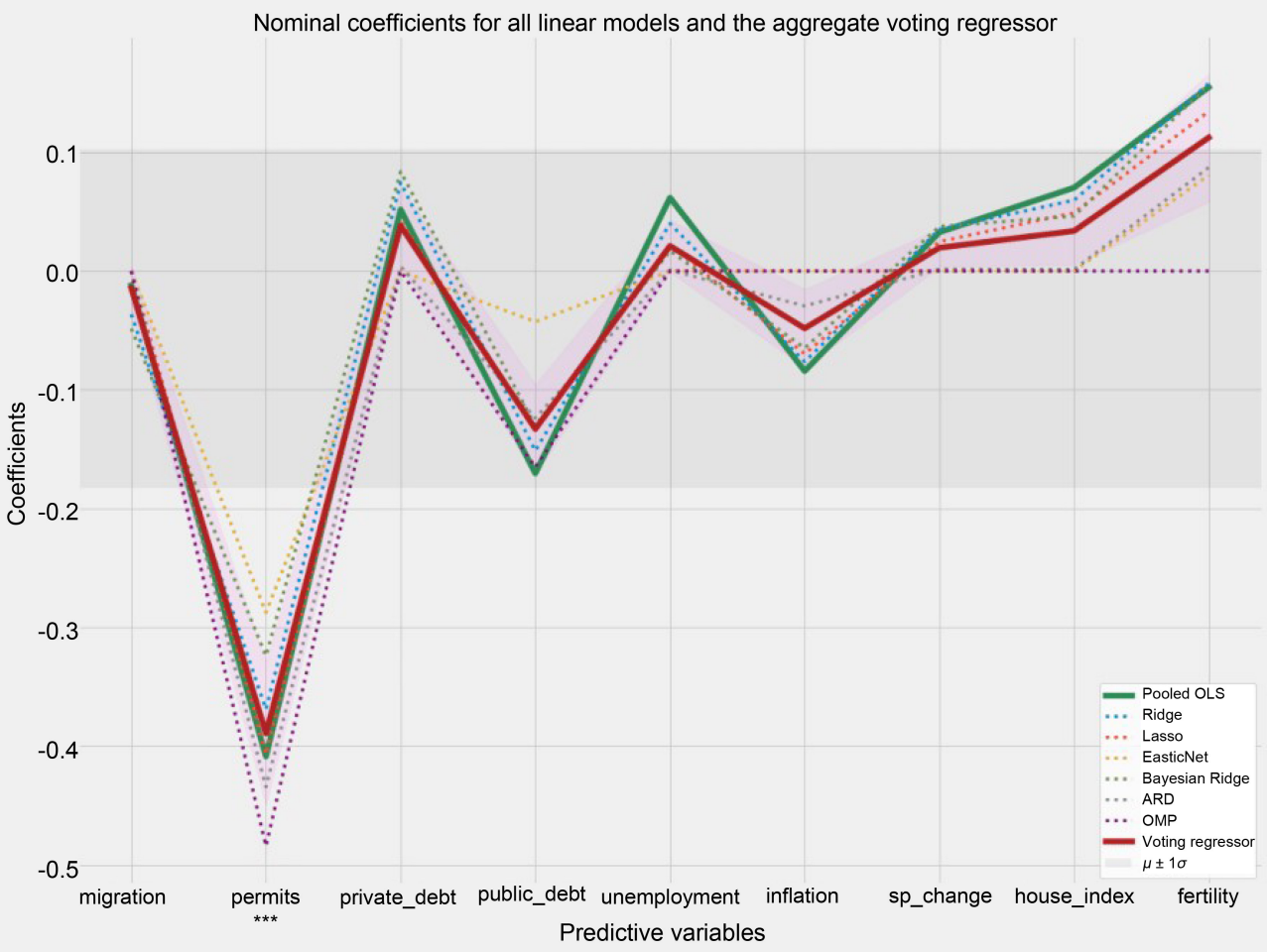

Figure 16. Nominal coefficients of all linear models and the aggregate voting regressor for the 13 old EU countries—unified migration variable.

In the new EU countries, permits also matter in the statistical sense. This variable bears a negative coefficient. Public debt is negatively related to pension funding adequacy, while private debt exhibits a positive coefficient. Perhaps most surprisingly, fertility has a negative relationship with pension funding. This is the opposite of the relationship in old EU countries, which is admittedly weaker and lacking in formal statistical significance in an aggregation of all regression methods. Emigration has a weakly positive and ultimately insignificant relationship with pension funding. Immigration to new (formerly socialist) EU countries has no impact whatsoever.

5. Interpretation of Results

In interpreting the results from the analysis of pension funding across all European Union countries, several key findings emerge, highlighting the complex interplay between public debt, migration, and the funding ratio of pension schemes. The study uncovers a statistically significant negative correlation between public debt and pension funding ratios, particularly within the "new" EU

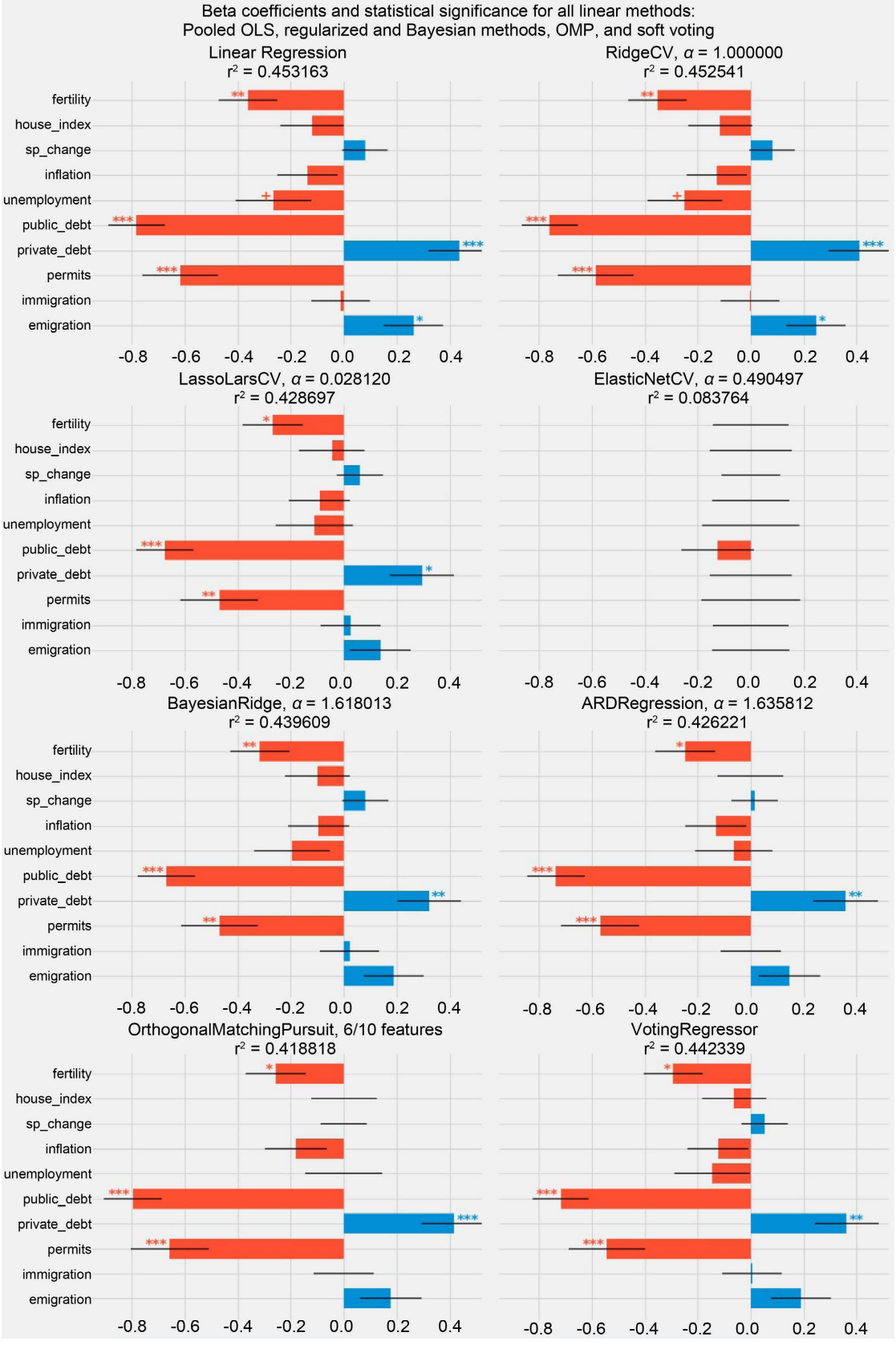

Figure 17. Beta coefficients and statistical significance for all linear methods for the 8 new EU countries.

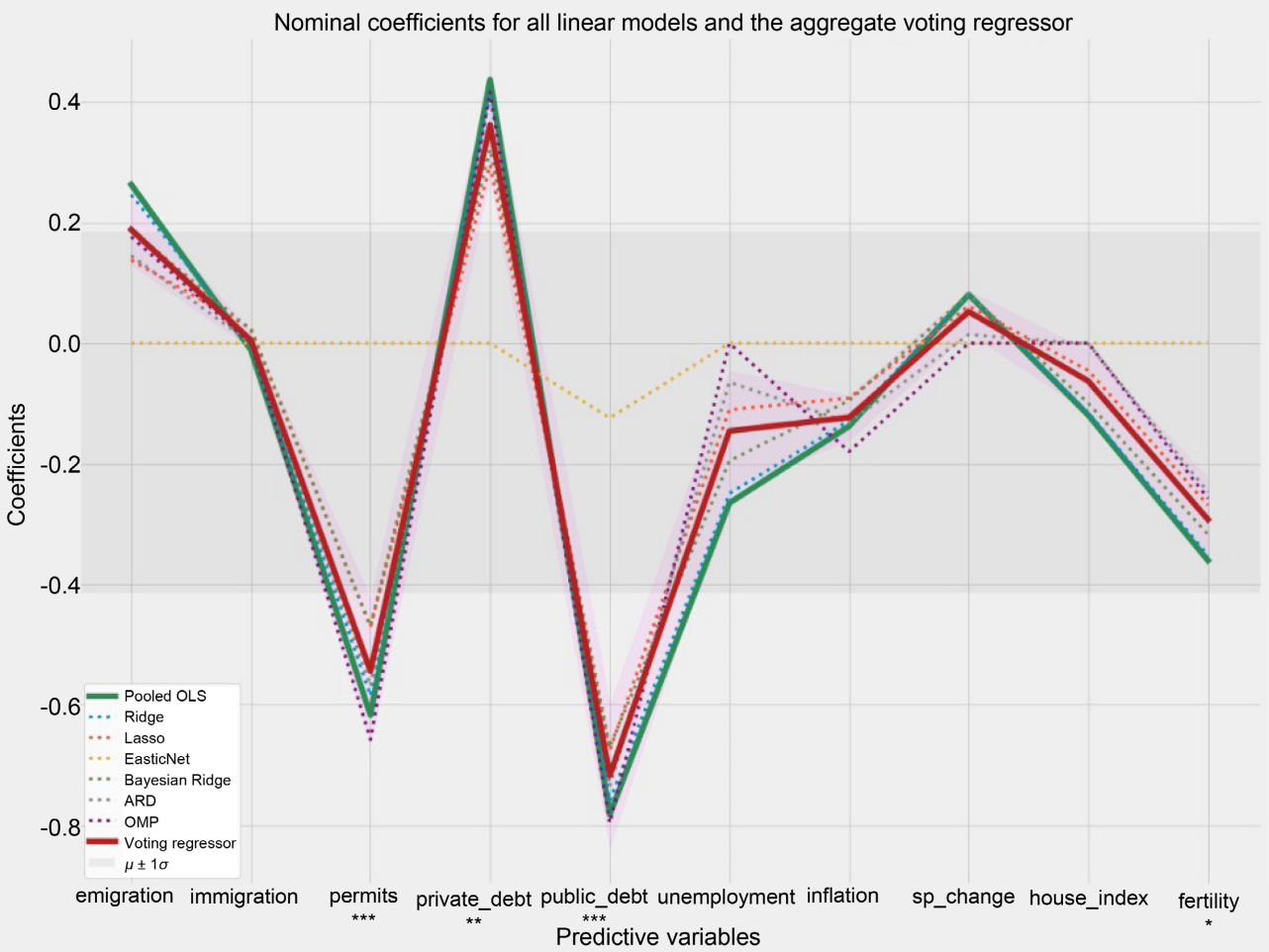

Figure 18. Nominal coefficients of all linear models and the aggregate voting regressor for the 8 new EU countries.

countries, suggesting that higher levels of public debt may detract from the capital available for pension funding. This relationship is intriguingly absent in older EU member states, hinting at a unique challenge faced by newer members with socialist legacies and relative economic disadvantages.

The analysis across both western and eastern EU countries reveals a uniformly negative impact of permits (representing third-country nationals entering the EU) on pension funding adequacy and sustainability. This suggests that the influx of third-country nationals does not straightforwardly bolster pension scheme assets, potentially due to their delayed integration into the workforce and social security systems. The complex dynamics of migration, employment, and pension contributions underscore the need for further investigation into how migration affects pension systems over the long term.

The study also finds that the inclusion of a socialism dummy variable significantly differentiates the behavior of newer EU countries from their older counterparts, highlighting the profound impact of Europe's geopolitical divisions on pension funding. In contrast, other variables, such as immigration, emigration, and fertility rates, display low statistical significance or unexpected directional

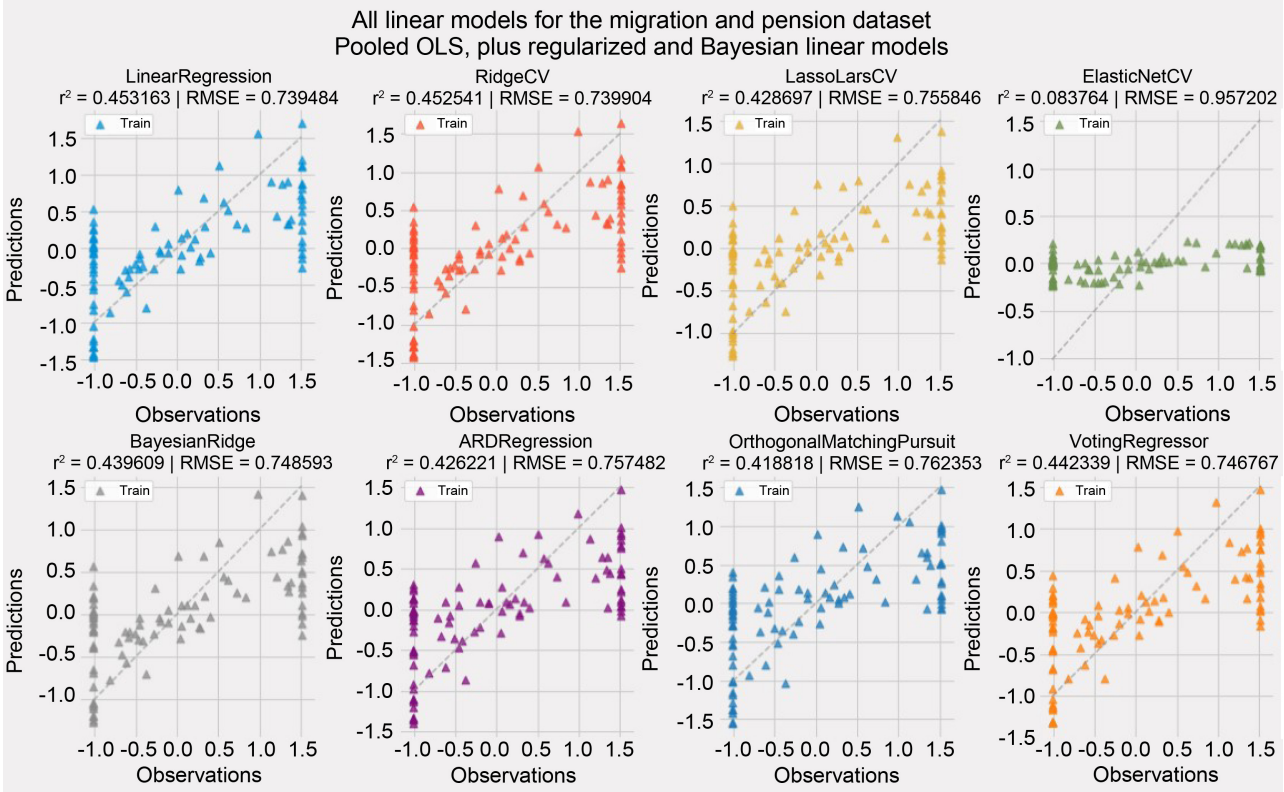

Figure 19. All linear models for the migration and pension dataset for the 8 new EU countries.

influences, challenging preconceived notions about their impact on pension schemes.

Focusing on the older, western EU countries, the study isolates permits as the only variable negatively correlating with the funding ratio, echoing findings from the broader EU analysis. This alignment suggests a consistent pattern across the EU, regardless of the region's economic history or current wealth. However, the interpretation of migration data through principal component analysis hints at the complications arising from collinearity, emphasizing the nuanced role of migration in pension funding.

In the newer, eastern EU member states, the relationship between pension funding and economic variables becomes even more nuanced. Public debt negatively correlates with pension funding ratios, while private debt shows a positive association, reflecting the unique economic strategies and challenges of these countries in the post-socialist era. The positive impact of private debt might relate to increased participation in privatized pension schemes, a trend accelerated by the global financial crisis and shifts towards less reliance on state-supported pensions. This counterintuitive finding, alongside the negative influence of fertility rates on pension funding, suggests complex socio-economic dynamics at play, meriting further exploration.

The study's insights into the demographic and economic factors affecting pension funding in the EU highlight significant gender disparities and the vary-

ing impacts of economic policies on women. The differential labor market experiences of migrant and native-born women, coupled with the distinct economic vulnerabilities faced by older women, point to the need for more focused research on gender within the context of pensions and labor markets.

Ultimately, this comprehensive analysis of pension funding across the EU underscores the importance of considering geopolitical history, economic strategies, and demographic trends in crafting policies to enhance pension sustainability. The application of regularized regression methods provides a refined understanding of the critical factors influencing pension schemes, paving the way for more targeted and effective policy interventions.

6. Conclusion

Advanced linear regression methods, based on ordinary and Bayesian implementation of the ℓ_1 and/or ℓ_2 regularization penalties, provide evidence that neither immigration nor emigration affects pension funding adequacy in the European Union. Whether measured by immigration, emigration, or by a unitary migration variable, migration does not significantly affect pension funding adequacy or sustainability. On the other hand, the number of third-country entrants has a negative and statistically significant impact on the funding ratio. Permits do not improve pension funding. These effects hold true for new as well as old EU countries. Policymakers within the European Union need to concentrate on other measures that can improve the pension funding adequacy, such as the containment of public debt.

Public debt has a negative and statistically significant impact in new EU countries. In these countries, fertility produces a negative and statistically significant impact, while private debt exhibits a positive and statistically significant effect. The funding ratio behaves in a fundamentally different way on either side of the geopolitical divide between the old EU countries of the west and the new EU countries of the formerly socialist east. Other variables show no statistical significance.

A common plan for the legal and structured incorporation of immigrants and refugees into the European workforce may improve pension funding adequacy. At the same time, European policymakers can offer incentives to employers as well as immigrants. Job flexibility and mobility as well as affordable starting salaries can motivate employers, while job training and opportunities can motivate foreign-born workers. The EU can also work toward a more balanced allocation of immigrants and refugees in each of its member states. In all events, pension-related policies should consider the economic and sociological differences between older and newer EU member-states. These are merely a few of the policy options available to European decision-makers.

We note two limitations of this study. First, available data does not distinguish refugees from ordinary immigrants. These groups may differ in the rates at which they join the labor force and in the levels of their contributions to pension fund-

ing. Second, benefit levels in less mature pension schemes, particularly in the new EU countries of the east, may be too low to support proper evaluation of the funding ratio. Future research should address those limitations.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix: Variable Definition and Notation

Variables	Description	Unit
assets	All forms of investment with a value associated to a pension plan over which ownership rights are enforced by institutional units, individually or collectively. This variable can be broken down into the following investment products or vehicles: Cash and deposits - Bills and bonds issued by the public and private sector - Loans - Equity - Land and buildings - Collective Investment Schemes (CISs) - Unallocated insurance contracts - Hedge funds - Private equity funds - Structured products - Other investments.	In millions of USD
benefits	Payment made to a pension plan/fund member (or dependants) after retirement. This excludes disability benefits. This variable should be the sum of the following: Lump sum − Pension.	In millions of USD
phi_i	Parameter φ: Based on the expected years in retirement and weighted by the female/male percentage of the population.	Float number
emigration	Total number of long-term emigrants leaving from the reporting country during the reference year.	Number of people
gdp	The indicator is calculated as the ratio of real GDP to the average population of a specific year. GDP measures the value of total final output of goods and services produced by an economy within a certain period of time. It includes goods and services that have markets (or which could have markets) and products which are produced by general government and non-profit institutions. It is a measure of economic activity and is also used as a proxy for the development in a country's material living standards. However, it is a limited measure of economic welfare. For example, neither does GDP include most unpaid household work nor does GDP take account of negative effects of economic activity, like environmental degradation.	Euro per capita
immigration	Total number of long-term immigrants arriving into the reporting country during the reference year	Number of people
permits	Residence permit means any authorisation valid for at least 3 months issued by the authorities of a Member State allowing a third country national to stay legally on its territory. All valid permits on 31st December (end of the year). This data include statistics on all valid permits at the end of reference period, therefore including first permits, change of status or reasons to stay and renewed permits.	Number of people
private_debt	Private debt, loans & securities.	% of GDP
public_debt	Government consolidated gross debt.	% of GDP
unemployment	The unemployment rate is the number of unemployed persons as a percentage of the labour force based on International Labour Office (ILO) definition. The labour force is the total number of people employed and unemployed. Unemployed persons comprise persons aged 15 to 74 who: are without work during the reference week; are available to start work within the next two weeks; and have been actively seeking work in the past four weeks or had already found a job to start within the next three months. Unit: rate	Percentage of the labour force
population	This dataset presents annual population data from 1950 to 2020 by sex and five-year age groups as well as the share of children, youth, the elderly, old-age and total dependencey ratios. The data is available for all 38 member countries as well as for the EU27 and G20 countries, Singapore and the World total.	Number of people
sp_change	S&P Global Equity Indices measure the U.S. dollar price change in the stock markets covered by the S&P/IFCI and S&P/Frontier BMI country indices.	Percentage

Continued

inflation	Inflation as measured by the consumer price index reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals, such as yearly. The Laspeyres formula is generally used.	Percentage
house_index	The deflated house price index (or real house price index) is the ratio between the House Price Index (HPI) and the national accounts deflator for private final consumption expenditure (households and Non-Profit Institutions Serving Households (NPISHs)). This indicator therefore measures inflation in the house market relative to inflation in the final consumption expenditure of households and NPISHs. Eurostat HPI captures price changes of all residential properties purchased by households (flats, detached houses, terraced houses, etc.), both new and existing, independently of their final use and their previous owners. Only market prices are considered, self-build dwellings are therefore excluded. The land component is included. The data are expressed as annual index 2015 = 100 and as 1 year % change. The MIP scoreboard indicator is the year-on-year growth rate of the deflated house price index, with an indicative threshold of 6%. The scoreboard indicator is calculated using the formula: $[((HPIt/DEFLt) - (HPIt\text{-}1/DEFLt\text{-}1))/(HPIt\text{-}1/DEFLt\text{-}1)] \times 100$.	Ratio
fertility	Total fertility rate represents the number of children that would be born to a woman if she were to live to the end of her childbearing years and bear children in accordance with age-specific fertility rates of the specified year.	Ratio