

Can Europe Stay Productive? Macroeconomic and Demographic Pressures on Labor Productivity

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Abstract

This study examines the impact of demographic shifts and broader macroeconomic factors on labor productivity in 23 European Union countries (EU-23) over the period 2005–2022. The analysis employs dynamic panel estimation techniques, including the Generalized Method of Moments (GMM), Random Effects (RE), and Autoregressive Distributed Lag (ARDL) models, to investigate the effects of population aging, unemployment, inflation, GDP per capita, research and development (R&D), life expectancy, and capital formation on productivity dynamics.

Unit root and cointegration tests confirm the existence of long-run relationships among variables with different levels of integration. The findings indicate that inflation exerts a significant negative effect on productivity, whereas GDP per capita and R&D investment consistently enhance efficiency and output per worker. Life expectancy appears to have a negative impact, likely reflecting demographic pressures, while unemployment shows an unexpected positive association with productivity – possibly due to structural changes in the labor market and the adoption of new technologies.

The ARDL error-correction model confirms long-run convergence, with persistent effects of productivity determinants over time. Overall, the results suggest that sustaining productivity growth in Europe depends on macroeconomic stability, innovation, human capital accumulation, and demographic adaptation.

Keywords

EU, Labor Productivity, Aging, GDP Growth, R&D, Panel Data

JEL codes: E24, J11, O47, C33

Introduction

Can Europe remain productive in the face of mounting macroeconomic and demographic challenges? The urgency of this question has grown in both policy and academic discussions. Economic performance is significantly influenced by labor productivity, which plays a crucial role in shaping material well-being, social progress, and international competitiveness (Van der Gaag and De Beer 2015). In European economies, where demographic shifts, structural transformations, and global disruptions converge, labor productivity growth is more than just an economic indicator – it is a prerequisite for preserving social welfare, sustaining growth, and ensuring resilience in a rapidly changing world. Over the past two decades, troubling signs have emerged, as productivity growth has persistently slowed across advanced economies such as those of the European Union, raising concerns about the continent's long-term capacity to remain competitive and prosperous (Crespo Cuaresma et al. 2016).

Productivity growth has been decelerating for some time. Since the Great Recession of 2007–2008, both the United States and the European Union have experienced declining productivity growth rates, a trend particularly pronounced in Europe (Trpeski et al. 2024). Despite decades of structural reforms aimed at boosting labor market flexibility, fostering innovation, and enhancing competitiveness, productivity growth has remained stubbornly low.

Global shocks such as the COVID-19 pandemic, widespread supply chain disruptions, surging global energy prices, and escalating geopolitical tensions have further aggravated these challenges. Collectively, they have exposed structural weaknesses within European economies and intensified concerns that Europe may struggle to sustain productivity growth amid growing macroeconomic and demographic pressures (Fernald et al. 2021).

Demographic change – particularly population aging – represents a major threat to labor productivity among these pressures. Across all EU member states, the share of the working-age population is projected to decline, placing increasing strain on economic performance due to the rising “demographic burden.” Research consistently demonstrates a negative relationship between population aging and labor productivity growth. Empirical evidence indicates that a 1% increase in the share of individuals aged 55–64 can reduce annual productivity growth by between 0.106% and 0.479% (Calvo-Sotomayor et al. 2019). Average workforce productivity is partly constrained because older, more experienced workers are replaced by younger, less experienced individuals upon retirement. Aging populations are also driving higher demand for labor-intensive care and health services, which not only diverts resources from more productive sectors but also exerts upward pressure on wages and labor supply (López et al. 2020).

The link between aging and productivity, however, is far from straightforward. Acemoglu and Restrepo (2018), among other scholars, argue that an aging workforce may stimulate the adoption of labor-saving technologies such as automation and robotics, which could offset or even reverse the negative effects of a shrinking labor force. Moreover, longer life expectancy and healthier aging may extend working lives, leading to lower capital-to-labor ratios and potentially higher productivity. While aging presents a fundamental demographic challenge, its ultimate effect on productivity will depend on the capacity of European economies to adapt through innovation, labor market reforms, and effective social policy (Calvo-Sotomayor et al. 2019).

Income levels and macroeconomic development play a crucial role in shaping productivity outcomes. Higher levels of economic development, typically measured by GDP per capita, are associated with significant technological progress, more dynamic labor markets, and greater capacity for structural transformation. Developed economies tend to exhibit more intensive innovation, stronger investment in research and development (R&D), and higher participation in high-value-added industries – all of which contribute to sustained productivity growth.

In contrast, many countries with relatively low levels of development, including some newer EU member states, remain dependent on traditional sectors such as agriculture, where productivity growth is constrained by limited technological advancement. This divergence raises serious concerns about whether Europe's more economically vulnerable countries can converge toward the productivity levels of more developed member states, or whether structural disparities will continue to widen (Goodhart and Pradhan 2017; O'Mahony et al. 2003).

Europe's productivity challenges are also shaped by labor market institutions and policies. Factors such as labor market flexibility, statutory minimum wages, unemployment rates, and labor force participation exert substantial influence on productivity trends. The Labor Freedom Index – which captures regulatory conditions related to hiring and firing, minimum wage legislation, and working hours – has been shown to affect productivity differently across Europe.

For example, increases in labor freedom in countries participating in the “Open Balkan” initiative (Albania, Serbia, North Macedonia) have been correlated with negative impacts on productivity, largely due to rigidities in hiring practices and working-time arrangements. In contrast, newer EU members in Southeastern Europe (Bulgaria, Romania, Croatia) have experienced positive productivity effects from greater labor freedom, suggesting that institutional environments play a decisive role. Similarly, statutory minimum wages can enhance productivity by improving efficiency and motivating workers, but in other cases, they may reduce productivity by increasing labor costs (Pariboni and Tridico 2020). Persistently high unemployment also has complex implications: while it erodes human capital and undermines long-term productivity, in some EU entrant economies, declines in unemployment have coincided with weak productivity gains, indicating the persistence of unproductive employment.

One crucial dimension relates to the labor market participation of women and older workers, as well as to average working hours. Mobilizing underutilized segments of the labor force represents a major policy instrument for enhancing productivity and mitigating demographic pressures. Increasing the effective retirement age or raising female labor force participation could significantly expand the available workforce and support long-term economic growth. The integration of vulnerable groups into the labor market is also shaped by both active and passive labor market policies, whose effectiveness differs between EU-13 and EU-15 member states. In certain cases, similar policy measures have unexpectedly reduced the employment rates of older workers, highlighting the need to reassess their design and implementation (Lopez-Garcia and Szörfi 2021; Maestas et al. 2022).

The accumulation of human capital and technological innovation remains fundamental to sustaining Europe's productivity. Education, skills development, and investment in research and development (R&D) are key drivers of innovation and long-term productivity growth. Countries that have made substantial investments in higher education, vocational training, and research capacity have achieved significant productivity gains – although such

benefits typically materialize only over time. Conversely, underinvestment in education and innovation risks perpetuating low-productivity traps.

Ongoing structural transformations further complicate the picture. Europe's gradual shift from manufacturing toward services carries profound implications for productivity dynamics. While service-sector expansion can diversify the economy, heavy reliance on low-productivity services – often constrained by Baumol's cost disease in sectors such as hospitality, logistics, and social care – may impede productivity growth by limiting opportunities for innovation and economies of scale (Cristea et al. 2020; Isham et al. 2021; Kornieieva et al. 2022).

Europe continues to face challenges related to labor market adaptability and the increasing prevalence of temporary work arrangements. While firm-level adjustments can be stimulated through labor market deregulation and enhanced flexibility, excessive dependence on temporary or precarious employment may undermine productivity by discouraging investment in skills, eroding social capital, and promoting short-term, low-value-added business strategies. Empirical research shows that temporary employment has a statistically significant negative effect on productivity growth, underscoring the inherent tension between labor flexibility and long-term economic performance (Ebeke 2016).

Taken together, these macroeconomic and demographic factors highlight the multifaceted nature of Europe's productivity challenge. Policy responses are complicated by the interplay between demographic pressures, structural transformation, institutional diversity, and global shocks. Europe's lack of homogeneity is particularly evident in the differences between its economies: the established EU-15 countries face distinct productivity constraints, while the developing EU-13 member states contend with their own structural and institutional limitations. Likewise, the countries participating in the "Open Balkan" initiative encounter specific challenges arising from transitional labor markets and regulatory fragmentation.

Comparative analysis of these regional patterns is crucial for understanding the diverse dynamics of productivity growth and designing effective, context-sensitive policy interventions (Caselli et al. 2016). Europe's long-term prosperity, competitiveness, and social cohesion will ultimately depend on policymakers' ability to formulate coordinated and forward-looking strategies that address demographic realities, strengthen labor market institutions, promote human capital formation and innovation, and guide structural change toward high-value-added sectors. Only through such measures can Europe secure sustainable productivity growth, maintain economic development, and safeguard the well-being of future generations in an era of profound demographic and macroeconomic transformation (Juselius and Takáts 2018; Landmann 2004).

This study investigates the macroeconomic and demographic determinants of labor productivity across 23 European Union member states (EU-23). It focuses on how population aging, unemployment, inflation, income per capita, and human capital accumulation shape productivity dynamics in both the short and long run. Using panel data econometric techniques, the analysis examines how demographic pressures – particularly the rising old-age dependency ratio – affect productivity growth, and whether these effects can be mitigated through institutional reforms, technological advancement, and greater labor market participation.

The study contributes to the understanding of Europe's economic resilience by providing new empirical evidence on the drivers of productivity in EU-23 economies. It also identifies policy strategies that can help sustain competitiveness, foster inclusive growth, and preserve social welfare in the face of intensifying demographic and macroeconomic challenges.

Review of literature

Extensive research within the European Union has examined the relationship between demographic aging and the macroeconomic factors influencing labor productivity. A substantial body of literature suggests that demographic shifts tend to hinder productivity growth. Aiyar et al. (2016) find that in Europe, a rising share of older workers slows labor productivity growth primarily through declines in total factor productivity (TFP), particularly in industries that rely heavily on innovation and labor mobility. This finding aligns with Maestas, Mullen, and Powell (2022), who, using U.S. state-level evidence, show that aging primarily reduces GDP per capita by lowering productivity rather than employment.

A complementary policy analysis by the ECB (2022) similarly concludes that demographic trends in the euro area will significantly affect potential growth by reducing TFP and altering capital–labor dynamics. On a global scale, Bloom, Canning, and Fink (2011) argue that the implications of aging extend beyond labor supply, influencing human-capital investment and long-term productivity. Taken together, this evidence suggests that without adequate adjustment, aging will translate into slower total factor productivity growth across the EU.

In contrast, a more optimistic line of research posits that demographic pressure can stimulate innovation and technological adoption. Acemoglu and Restrepo (2022) contend that countries undergoing rapid demographic aging often offset productivity losses by investing heavily in automation and robotics. Calvo-Sotomayor et al. (2019) demonstrate that digital transformation – particularly the spread of information and communication technology (ICT) and improvements in workforce e-skills – significantly mitigates the negative association between aging and productivity in European economies. Van der Gaag and de Beer (2015) situate this issue within the broader European demographic transition, where the shift from demographic dividend to demographic burden underscores the need for productivity-enhancing policies.

Similarly, Maestas et al. (2018) find that the relationship between demographics and productivity is strongly mediated by institutional quality and technological adoption, implying that the adverse effects of aging can be offset through complementary investments. Overall, the existing literature indicates that aging does not necessarily lead to lower productivity; its ultimate impact depends on how firms, institutions, and policymakers respond to demographic change.

EU labor productivity is shaped by several key factors – capital deepening, human capital, innovation, and institutional frameworks – which directly interact with the effects of population aging. Analyses based on the EU KLEMS datasets show that, since the mid-1990s, Europe’s productivity slowdown has been driven primarily by insufficient investment in information and communication technologies (ICT) and weak total factor productivity (TFP) growth relative to the United States (ECB 2022; Bloom et al. 2011). Recent research highlights that intangible assets – such as software, data, and organizational practices – have become major contributors to productivity growth, while the OECD and the European Commission have noted a widening “intangibles gap” between the EU and the U.S. (Maestas et al. 2018; Acemoglu and Restrepo 2022).

The productivity effects of aging are strongly mediated by the accumulation and adaptability of human capital. Lifelong learning initiatives and digital skills training are particularly effective in sustaining productivity when older cohorts constitute a growing share

of the labor force (Van der Gaag and de Beer 2015). Pension design and labor-market institutions further shape the incentives for older workers to remain active and for firms to invest in training (Acemoglu and Restrepo 2022).

Reallocation mechanisms – such as competition policy and bankruptcy regulation – also play a critical role, as aging can slow labor reallocation toward more productive firms, making stronger institutional frameworks essential for supporting TFP growth. Another potential buffer against demographic pressures is migration: the inflow of younger, skilled workers can complement technological adoption and reduce the productivity drag of aging (Bloom et al. 2010).

In summary, while aging affects productivity through multiple channels, its magnitude and direction ultimately depend on the flexibility of human-capital systems, the strength of institutions, and the effectiveness of technology and innovation policies.

The regional variations across Europe underscore the importance of accounting for country-specific circumstances when evaluating the impact of aging on productivity. Northern and Western European economies – with high levels of digital adoption, substantial investment in intangible assets, and well-developed lifelong learning systems – are better positioned to manage the challenges associated with demographic change (Fernald et al. 2023). In contrast, Southern and Eastern European countries, where old-age dependency ratios are rising more rapidly, face a greater risk of productivity stagnation unless they accelerate digital transformation and narrow the technological gap (André and Gal 2024; Pariboni and Tridico 2020).

Demographic pressures are often mitigated in manufacturing sectors through automation and process innovation, whereas service sectors tend to be constrained by their slower uptake of digital technologies (Calvo-Sotomayor and Atutxa 2025; Juselius and Takáts 2018). The emerging consensus is that aging exerts a largely mechanical effect on productivity growth, the magnitude of which depends on technology diffusion, human capital renewal, and institutional preparedness. Countries that invest in digital and intangible assets, foster adult education, and encourage competitive restructuring are more likely to mitigate – or even offset – the productivity effects of demographic change. Conversely, those that fail to adapt risk prolonged periods of productivity stagnation.

Despite a growing body of research that has explored the link between aging and labor productivity in Europe, substantial gaps still exist, which necessitate further study. Much of the literature, including studies by Aiyar et al. (2016) as well as Maestas et al. (2018), depends on aggregate or cross-country regressions that could obscure differences within EU member states and over time. Research highlighting the role of automation and technological advancements in responding to demographic shifts (Acemoglu and Restrepo 2022) offers significant insights yet often fails to test these factors empirically in a panel study framework that considers both cross-sectional and temporal differences across Europe. Furthermore, although Calvo-Sotomayor et al. (2019) underscore the impact of digital empowerment in countering the effects of aging, limited systematic data exist on how macroeconomic factors like capital deepening, human capital accumulation, and institutional frameworks interact with demographic trends in EU countries over the past two decades. Factors such as pension reforms and migration, along with fiscal pressures, identified by Van der Gaag and de Beer (2014) and other related studies, are typically considered in a theoretical sense but rarely incorporated into dynamic econometric models. Currently, existing research has yet to fully exploit advanced panel techniques – such as the Generalized Method of Moments (GMM),

which addresses endogeneity, or Random Effects (RE) models, which account for unobserved heterogeneity – to produce robust causal estimates. This gap presents an opportunity for empirical research employing contemporary panel methods and EU data from 2005 to 2022, which can provide new insights into how aging and macroeconomic factors jointly influence labor productivity within a heterogeneous and rapidly evolving regional context.

Data and methods

This study investigates how population aging and macroeconomic fundamentals influence labor productivity across 23 European Union countries over the period 2005–2022 using annual data. The analysis employs Panel Generalized Method of Moments (GMM), Random Effects Model (REM), and Autoregressive Distributed Lag (ARDL) approaches to examine both short-run and long-run relationships between the dependent and explanatory variables. The dependent variable is labor productivity (LP_{it}). Explanatory variables are the old-age dependency ratio ($OADR_{it}$), inflation (INF_{it}), natural log of GDP per capita ($LNGDPPC_{it}$), R&D intensity (RD_{it}), unemployment rate (UR_{it}), life expectancy (LE_{it}), and natural log of gross fixed capital formation ($LNGFCF_{it}$). Country-specific unobservable are denoted by μ_i , respectively. The baseline dynamic panel specification is:

$$LP_{it} = \alpha LP_{i,t-1} + \beta_1 OADR_{it} + \beta_2 INF_{it} + \beta_3 LNGDPPC_{it} + \beta_4 RD_{it} + \beta_5 UR_{it} + \beta_6 LE_{it} + \beta_7 LNGFCF_{it} + \mu_i + \varepsilon_{it}. \quad (1)$$

Including $LP_{i,t-1}$ captures persistence in productivity but makes the within estimators biased in short-to-moderate T panels. We therefore estimate the model with Generalized Method of Moments (GMM), one-step, using both Arellano–Bond difference GMM and (for persistence/weak instruments concerns) Blundell–Bond system GMM.

GMM Model

To eliminate μ_i , we first-difference:

$$\Delta LP_{it} = \alpha \Delta LP_{i,t-1} + \beta_1 \Delta OADR_{it} + \beta_2 \Delta INF_{it} + \beta_3 \Delta LNGDPPC_{it} + \beta_4 \Delta RD_{it} + \beta_5 \Delta UR_{it} + \beta_6 \Delta LE_{it} + \beta_7 \Delta LNGFCF_{it} + \Delta \varepsilon_{it}. \quad (2)$$

Endogeneity is addressed with internal instruments. We treat $LP_{i,t-1}$, $LNGDPPC_{it}$, $LNGFCF_{it}$, and RD_{it} as endogenous; UR_{it} , INF_{it} as predetermined; and LE_{it} as exogenous (we also test specifications that treat $OADR_{it}$ as endogenous vs. predetermined. In the difference GMM, lagged levels (e.g., $t-2$, $t-3$) instrument the differenced endogenous/predetermined regressors. In system GMM, we add the levels equation and use lagged differences as instruments, improving efficiency when regressors are persistent.

To curb instrument proliferation, we collapse the instrument matrix and restrict lag depth (e.g., use $t-2:t-3$ for endogenous/predetermined variables). Instrument validity is assessed with the Hansen J test of overidentifying restrictions (reported for the robust one-step estimator). Serial correlation is checked using Arellano–Bond AR (1) and AR (2) tests on differenced residuals; we expect significant AR (1) and no AR (2). We report the instrument count and ensure it is modest relative to the number of cross-sectional units.

Panel ARDL Model

The general panel ARDL (1,1) model is specified as:

$$Y_{i,t} = \alpha_i + \rho_i Y_{i,t-1} + \delta_{0i} X_{i,t} + \delta_{1i} X_{i,t-1} + u_{i,t}, \tag{3}$$

where Y is the vector of dependent variable LP, and X is the vector of regressors, i.e., OADR, INF, LNGDPPC, RD, UR, LE, and LNGFCF.

Re-parameterizing into the error-correction form yields:

$$\Delta Y_{i,t} = \varphi_i (Y_{i,t-1} - \theta_i X_{i,t-1}) + \gamma_i \Delta X_{i,t} + \varepsilon_{i,t}. \tag{4}$$

Here, φ_i is the error-correction coefficient, expected to be negative and statistically significant. The panel ARDL framework is well-suited for this analysis because it accommodates variables integrated of order zero, I (0), and order one, I (1), while excluding I (2). Estimation is carried out using the Pooled Mean Group (PMG) approach of Pesaran, Shin and Smith (1999), which allows heterogeneity in short-run coefficients and adjustment speeds across countries.

Random Effects Robustness

As a complementary, static benchmark that exploits both within- and between-country variation, we estimate a Random Effects (RE) model without the lagged dependent variable:

$$LP_{it} = \delta + \beta_1 OADR_{i,t} + \beta_2 INF_{i,t} + \beta_3 LNGDPPC_{i,t} + \beta_4 RD_{i,t} + \beta_5 UR_{i,t} + \beta_6 LE_{i,t} + \beta_7 LNGFCF_{i,t} + \mu_i + \varepsilon_{i,t}, \tag{5}$$

where, μ_i is the random country effect assumed to be uncorrelated with regressors.

Estimation uses feasible GLS with cluster-robust standard errors by country. We perform a Hausman test (RE vs. FE) on the static specification and a Breusch–Pagan LM test for the presence of random effects. The RE results are interpreted as descriptive/robustness evidence; causal interpretation relies on the dynamic one-step GMM framework.

Implementation and reporting

All variables exhibiting wide dispersion (e.g., INF) were examined for outliers, and logarithmic transformations were applied where specified to interpret coefficients as elasticities. All models include a full set of year dummies to control for time-specific effects. For the Panel GMM estimation, we report coefficient estimates, robust standard errors, AR(1) and AR(2) p-values, Hansen J test p-values (including the difference-in-Hansen test for system GMM blocks), the number of instruments, and sample size. For the Random Effects (RE) models, we report the Hausman test and the Lagrange Multiplier (LM) test statistics. The expected signs of the coefficients, based on a priori theoretical considerations, are as follows: $\alpha \in (0,1)$; $\beta_7 > 0$ (capital deepening), $\beta_4 > 0$ (R&D), $\beta_3 > 0$ (income level/transition), $\beta_5 < 0$ (unemployment), $\beta_1 \leq 0$ (aging headwind, subject to tech adaptation), β_2 ambiguous (inflation), and $\beta_6 \geq 0$ (health/productivity link).

Table 1 provides a concise description of the dependent and independent variables used in the study.

Table 1. Description of Variables

| Variable | Description | Source |
|----------|---|----------|
| LP | Labor Productivity per Hour Worked | Eurostat |
| GDPPC | Growth of Per Capita GDP (Current USD) | WDI |
| RD | Research and Development Expenditure (%GDP) | Eurostat |
| OADR | Old Age Dependency Ratio | Eurostat |
| GFCF | Gross Fixed Capital Formation (Current USD) | WDI |
| INF | Consumer Price Index Annual Percentage | WDI |
| UR | Unemployment Rate | WDI |
| LE | Life Expectancy | WDI |

Estimation and findings

The analysis begins with an examination of the variables' stationarity properties. The Levin–Lin–Chu unit root tests (Table 2) indicate a mixed order of integration, with some variables being stationary at level $I(0)$ and others at first difference $I(1)$. Variables such as GDP per capita, old-age dependency ratio, gross fixed capital formation, unemployment, and life expectancy are found to be stationary at their natural level, in contrast to labor productivity, research and development, and inflation, which exhibit stationarity only after first-order differencing. This combination of integration orders makes panel cointegration analysis appropriate, as it enables testing for the existence of a stable long-run relationship among the variables despite differences in their integration properties. The Pedroni cointegration test (Table 3) provides strong support for this, as all test statistics are highly significant, indicating the presence of a long-run equilibrium relationship among the selected variables.

Table 2. Levin-Lin-Chu Unit Root Tests

| Variables | t-statistic | P-value | O.I |
|-----------|-------------|---------|------|
| LP | -16.7831 | 0.0000 | I(1) |
| GDPPC | -10.2069 | 0.0000 | I(0) |
| RD | -4.8530 | 0.0283 | I(1) |
| OADR | -5.3587 | 0.0000 | I(0) |
| GFCF | -10.3906 | 0.0000 | I(0) |
| INF | -10.8400 | 0.0002 | I(1) |
| UR | -9.9468 | 0.0000 | I(0) |
| LE | -6.1514 | 0.0000 | I(0) |

Table 3. Panel Co-Integration Pedroni Test

| | Statistic | p-value |
|----------------------------|-----------|---------|
| Modified Phillips-Perron t | 5.7746 | 0.0000 |
| Phillips-Perron t | -12.6315 | 0.0000 |
| Augmented Dickey-Fuller t | -11.5808 | 0.0000 |

Both the GMM and Random Effects models (Table 4) yield robust and largely consistent estimation results. Labor productivity demonstrates persistence over time, as evidenced by the positive and statistically significant coefficients of the lagged dependent variable. Inflation exerts a substantial and adverse impact on labor productivity, illustrating how macroeconomic instability – specifically rising prices – can impede productivity improvements. In contrast, economic growth, measured as the natural log of GDP per capita growth, has a strong positive effect, underscoring the crucial role of income expansion in promoting efficiency and productivity gains. Research and development also show a positive influence, with the GMM model exhibiting a more pronounced effect than the REM, highlighting the importance of innovation and technological advancement in enhancing productivity.

Notably, there is a statistically significant and positive correlation between unemployment and labor productivity. This unexpected result can be attributed to structural shifts in the labor market, where changes in labor allocation or the substitution of workers with technology increase productivity per employee, even amid elevated unemployment rates. In contrast, life expectancy is associated with lower labor productivity, a relationship likely driven by demographic pressures from aging populations in the sample countries, which ultimately constrain overall productivity levels. Although gross fixed capital formation exhibits a positive coefficient, it remains statistically insignificant, suggesting that short-term capital accumulation alone does not automatically translate into productivity gains unless supported by complementary factors such as innovation, skilled labor, and efficient institutions.

Table 4. Panel GMM and REM Estimation Results

| Dependent Var: LP | (1) GMM | (2) REM |
|-------------------|----------------------|---|
| L.LP | 0.0883* (1.85) | 0.0878** (2.09) |
| OADR | 0.0194 (0.98) | 0.0207 (1.02) |
| INF | -0.120*** (-3.32) | -0.110*** (-3.28) |
| LNGDPPC | 0.273*** (10.18) | 0.290*** (11.30) |
| RD | 0.262** (2.03) | 0.202 (1.55) |
| UR | 0.0742*** (3.17) | 0.0538** (2.32) |
| LE | -0.336*** (-8.57) | -0.315*** (-8.14) |
| LNGFCF | 0.282 (0.47) | 0.361 (0.63) |
| _cons | 25.19*** (6.42) | 23.41*** (6.10) |
| N | 391 | 391 |
| AR(1) | 0.000 | Hausman Specification test X²₍₈₎ = 10.42 |
| AR(2) | 0.475 | |
| Hansen p-value | 0.621 | Prob>chi2 = 0.237 |

The ARDL model results (Table 5) further reinforce these findings by capturing both short-run and long-run dynamics. The error correction term is negative and statistically significant, confirming the presence of long-run convergence and adjustment toward equilibrium following deviations. Additional insights emerge from the lagged variables – specifically lagged values of inflation, GDP per capita, unemployment, research and development, and capital formation – all of which significantly affect current productivity levels. This highlights the dynamic nature of the productivity process, where past macroeconomic conditions, innovation efforts, and capital accumulation continue to shape present outcomes. In particular, delayed effects from capital investment and research and development are especially pronounced, illustrating the time lag required for such investments and innovations to yield tangible productivity improvements.

Table 5. Panel ARDL Estimation Results

| Long-run Results | (1) LP | (2) LP | Short-run Results | (3) LP |
|-------------------------|----------------------------------|----------------------------------|--------------------------|-----------------------------------|
| L.LP | 0.0883 [*] (1.85) | 0.0878 ^{**} (2.09) | L.INF | 0.219 ^{***} (16.46) |
| OADR | 0.0194 (0.98) | 0.0207 (1.02) | L.LNGDPPC | -0.118 ^{***} (-19.10) |
| INF | -0.120 ^{***} (-3.32) | -0.110 ^{***} (-3.28) | L.UR | 0.283 ^{***} (19.63) |
| LNGDPPC | 0.273 ^{***} (10.18) | 0.290 ^{***} (11.30) | L.RD | 0.882 ^{***} (6.60) |
| RD | 0.262 [*] (2.03) | 0.202 (1.55) | L.LE | 0.0137 (0.55) |
| UR | 0.0742 ^{***} (3.17) | 0.0538 ^{**} (2.32) | L.LNGFCF | 2.158 ^{***} (11.43) |
| LE | -0.336 ^{***} (-8.57) | -0.315 ^{***} (-8.14) | | |
| LNGFCF | 0.282 (0.47) | 0.361 (0.63) | | |
| _cons | 25.19 ^{***} (6.42) | 23.41 ^{***} (6.10) | | |
| EC | | | | -0.783 [*] (-1.95) |
| N | 391 | 391 | | 322 |

Overall, the study highlights that labor productivity across the panel of nations is influenced by a combination of macroeconomic stability, demographic trends, and growth-promoting factors, including innovation and rising income levels. Inflation emerges as a key challenge, eroding productivity, while demographic pressures associated with increasing life expectancy appear to negatively affect performance. Policies that stimulate economic growth, foster research and development, and effectively manage labor market fluctuations are shown to substantially enhance productivity. These findings carry significant policy implications, suggesting that sustainable productivity growth requires a careful balance between stabilizing inflation, addressing demographic changes, and promoting innovation-driven growth.

Discussion

In the European Union, rising inflation – largely driven by surging energy and food prices – has eroded the purchasing power of real incomes, disproportionately affecting low- and middle-income households. The resulting decline in domestic consumption and aggregate demand has constrained firm revenues and weakened incentives for investment in productivity-enhancing activities such as technological upgrades and process improvements. Inflation also amplifies tensions between wages and prices: collective bargaining mechanisms tend to push nominal wages upward without commensurate gains in output, thereby increasing unit labor costs and diminishing overall productivity. Persistent inflationary pressures compel central banks, including the European Central Bank (ECB), to pursue tighter monetary policies, raising borrowing costs and restricting firms' access to credit. Consequently, investment in innovation, capital equipment, and research – critical drivers of productivity growth – becomes increasingly constrained (Lewis et al. 2018; Yildirim 2015).

In contrast, growth in GDP per capita is closely linked to productivity gains, as higher income levels typically reflect improvements in efficiency, technological diffusion, and capital deepening that enhance output per worker. For instance, Poland's rapid rise in GDP per capita – supported by structural reforms, fiscal discipline, and effective use of EU accession funds – has translated into sustained productivity improvements, with labor productivity growing at nearly three times the OECD average between 2010 and 2019 (Bilenko 2022; Liotti 2022). However, despite such progress in individual member states, a significant productivity gap persists between Europe and the United States. This gap – reflected in a roughly 70% disparity in GDP per capita – largely stems from weaker productivity growth in Europe, which in turn is linked to structural fragmentation across markets that limits economies of scale, innovation diffusion, and cross-border investment (Bilenko 2022; Hammer et al. 2015; Pelinescu 2015).

The insignificance of gross fixed capital formation (GFCF) in the results initially appears to contradict conventional macroeconomic theory. However, this finding can be rationalized by the heterogeneity of investment types and the structural characteristics of European economies. As an aggregate measure, GFCF comprises both highly productive capital – such as information and communication technologies (ICT), research and development (R&D), and advanced infrastructure – and less productive forms of investment, including real estate projects or politically motivated expenditures that generate limited efficiency gains (Sadowska and Norkūnienė 2024; Rodríguez-Pose and Ganau 2022). In mature EU economies, where much of the traditional physical infrastructure is already established, additional capital accumulation tends to yield diminishing returns to productivity unless accompanied by innovation, a highly skilled workforce, and supportive institutional frameworks (Saha 2024; Simionescu et al. 2021).

Moreover, the productivity effects of capital accumulation typically materialize with a time lag, meaning that short-term panel estimations may not fully capture their long-run contribution. This helps explain why aggregate GFCF appears statistically insignificant, even though specific categories of capital investment – particularly ICT-related and intangible assets – have been consistently shown in the literature to enhance productivity. Hence, this outcome does not undermine the validity of the model but rather highlights the importance of disaggregating investment types. Future research could extend this analysis by distinguishing between physical and digital capital to provide a more nuanced understanding

of how the composition of investment influences productivity performance across Europe (Adarov and Stehrer 2021; Giordano and Zollino 2021).

The relationship between unemployment and productivity in European labor markets can be explained by underlying structural transformations. In many cases, increases in unemployment coincide with economic recessions or periods of technological transition, during which less efficient jobs – typically concentrated in labor-intensive industries – are eliminated, while output in capital-intensive, high-productivity sectors continues. This compositional shift raises average productivity among the remaining workforce (Krutova et al. 2021; Yildirim et al. 2022). Moreover, automation and digitalization frequently replace routine labor with technology, increasing output per worker even as overall employment declines – a dynamic consistent with the literature on job polarization and skill-biased technological change. Consequently, a positive association between unemployment and productivity should not necessarily be interpreted as an indicator of healthy labor market performance; rather, it reflects structural and compositional effects in employment and production patterns.

Future research on the EU could benefit from comparing EU-15 and EU-13 member states, as newer members have often undergone more pronounced structural transformations following accession. A sectoral perspective may also reveal whether productivity gains are primarily driven by ICT-intensive and export-oriented industries (Postuła et al. 2021; Simionescu et al. 2021).

Enhancing research and development (R&D) investment remains critical for sustaining EU productivity growth. Increased expenditure on R&D – especially when coupled with innovation and human capital development – directly stimulates productivity, particularly in high-technology sectors such as ICT, where the gains are most substantial. The European Commission has estimated that reaching the target of 3% of GDP in R&D investment could significantly raise productivity and income levels across the Union. However, concerns persist regarding the efficiency of R&D spending: EU research efforts often lag behind global peers in terms of technological impact, with comparatively less effective translation of innovation into marketable outcomes. This suggests that fostering productivity growth requires not only higher R&D intensity but also improvements in the quality, coordination, and practical implementation of research initiatives (Nekrep et al. 2018; Relich 2017).

Contrary to the conventional view of unemployment as detrimental to economic performance, evidence from certain EU economies reveals a surprisingly positive association between unemployment and labor productivity. This relationship may reflect structural changes and reallocation effects within the labor market, whereby less efficient workers exit the labor force while more productive ones remain, thereby raising average output per employee (Liotti 2022). Nonetheless, Europe's labor markets tend to exhibit relatively low flexibility due to stringent employment protection legislation and limited adaptability, which can hinder efficient labor reallocation and reduce potential productivity gains. These findings underscore the importance of adaptive labor market policies that facilitate smoother workforce transitions and encourage productivity-enhancing reorganization (Giannakis and Mameas 2022; Irandoust 2023; Liotti 2022).

More broadly, this pattern reflects the structural transformation of European labor markets. Periodic increases in unemployment often coincide with recessions or technological transitions, which eliminate less efficient, labor-intensive jobs while preserving or expanding output in capital-intensive and high-productivity sectors. This compositional shift drives an apparent increase in average productivity among the remaining workforce (Krutova et al.

2021; Yildirim et al. 2022). Automation and digitalization further reinforce this process by substituting routine tasks with technology – raising output per worker even as total employment declines. Such dynamics align with the literature on job polarization and skill-biased technological change, which highlights that technological diffusion can enhance productivity at the cost of employment in routine occupations.

Thus, a positive unemployment–productivity relationship should not be interpreted as an indicator of healthy labor market conditions but rather as a reflection of compositional effects and sectoral restructuring. Future research could fruitfully explore cross-country heterogeneity by distinguishing between EU-15 and EU-13-member states, as newer members have often experienced more intense structural adjustments since accession. Additionally, sectoral analyses could identify whether recent productivity gains stem primarily from ICT-intensive and export-oriented industries (Postuła et al. 2021; Simionescu et al. 2021).

Rising life expectancy exerts two contrasting effects on labor productivity across the EU. On one hand, population aging can constrain productivity when older workers face declining physical or cognitive capacities or when institutional rigidity limits their ability to adapt to new technologies or work environments. On the other hand, increasing longevity – when accompanied by policies that promote active aging and lifelong participation in the labor market – can generate positive productivity spillovers. Higher investments in healthcare and improved integration of individuals aged 55–64 into employment not only sustain labor supply but also capitalize on the accumulated experience and skills of older cohorts. This dynamic aligns with the emerging concept of the Silver Economy, which emphasizes the economic potential of an aging yet healthy population. The IMF and related studies suggest that enhanced cognitive and physical health among older individuals enables extended economic participation, thereby mitigating demographic pressures and contributing positively to aggregate productivity (Dormont et al. 2008; Franklin 2018; Giannakis and Mamuneas 2022).

Conclusion and policy recommendations

This study provides a comprehensive understanding of the macroeconomic and demographic determinants of labor productivity across 23 EU countries, revealing both persistent challenges and potential areas for policy intervention. The findings indicate that productivity growth in Europe is shaped by the interplay between macroeconomic stability, demographic dynamics, innovation, and institutional quality. Among the determinants, inflation emerges as a key constraint, exerting a markedly negative effect on productivity by eroding real incomes, increasing production costs, and discouraging firms from investing in efficiency-enhancing innovations. Persistent inflationary pressures also compel monetary authorities, particularly the European Central Bank, to adopt restrictive policies that raise borrowing costs and tighten credit access – conditions that disproportionately burden small and medium-sized enterprises (SMEs), which constitute the backbone of European industry.

Conversely, GDP per capita exhibits a significant positive association with productivity, underscoring the virtuous cycle between higher income levels, technological diffusion, and efficiency improvements. Similarly, research and development (R&D) investment continues to play a vital role in fostering productivity gains. However, the European Union still

lags behind major global competitors – most notably the United States – in research efficiency, innovation output, and the commercialization of new technologies. These results highlight the importance of developing robust innovation ecosystems that not only expand R&D spending but also enhance the quality, diffusion, and economic returns of research investments.

Demographic pressures, particularly increasing life expectancy and the rising old-age dependency ratio, represent a significant constraint on labor productivity. While extended lifespan reflects societal advancement, it can negatively affect productivity in the EU by reducing workforce participation, increasing fiscal burdens from pensions and healthcare, and diverting resources toward lower-productivity sectors such as care services. The adverse impact of unmanaged aging is especially pronounced in Southern and Eastern European countries, where demographic shifts are more rapid and technological adoption is slower. However, research indicates that proactive adaptation can turn aging into a driver of positive transformation. Investments in lifelong learning, digital skills, and active labor market programs can extend the productive contribution of older workers, while migration and higher female labor force participation can help mitigate demographic pressures. Sustaining productivity growth in the coming decades will therefore depend heavily on implementing these measures as Europe's demographic profile continues to evolve.

Labor market dynamics remain a critical factor in shaping productivity outcomes. Although unemployment is often perceived as detrimental, evidence from certain EU contexts shows a positive association with productivity, likely reflecting structural adjustments such as labor reallocation and automation that increase output per worker. However, this relationship is context-specific: persistent unemployment can erode human capital, weaken social cohesion, and limit long-term growth potential. European policymakers must therefore strike a careful balance between labor market flexibility and inclusiveness, ensuring that structural adjustments are supported by retraining programs and institutional mechanisms that facilitate mobility while minimizing the prevalence of precarious employment. Similarly, the findings indicate that gross fixed capital formation (GFCF) does not yield substantial short-term productivity gains, suggesting that capital accumulation alone is insufficient. Sustainable improvements in productivity require complementary investments in innovation, skills development, and institutional efficiency to fully leverage capital inputs.

Taken together, these results underscore the need for a comprehensive, multi-dimensional policy framework to sustain productivity growth across the EU-23. First, macroeconomic stability should be a central priority: fiscal and monetary authorities must coordinate efforts to control inflation while preserving conditions conducive to investment, ensuring that price stability supports both short-term resilience and long-term growth. Second, demographic challenges demand urgent attention. Pension reforms, incentives for extended working lives, and policies that integrate older workers, women, and migrants into the labor force are critical to mitigating the productivity impacts of aging populations. Third, fostering human capital development is essential. Broad access to high-quality education, vocational training, and lifelong learning will equip workers to adapt to technological, digital, and green transitions. Simultaneously, increased investment in R&D will ensure that innovation translates into tangible productivity gains.

Achieving a balance between flexibility and security is essential for effective labor market reforms. Well-designed institutions should promote labor mobility and adaptability while simultaneously preventing excessive precariousness and preserving social cohesion. At the same time, the European Union must address its “intangibles gap” with global competitors

by increasing investment in ICT, automation, and knowledge-intensive sectors. Cohesion funds and public investments should be strategically directed toward areas that foster innovation, digital infrastructure, and green technologies, rather than being dispersed across low-productivity sectors.

Overall, sustaining productivity growth in the EU-23 requires an integrated, multi-dimensional strategy that combines macroeconomic stability, demographic adaptation, human capital development, labor market reform, and innovation-driven structural transformation. By coordinating fiscal, social, and technological policies within a cohesive framework, the EU can transform demographic and digital challenges into long-term opportunities for competitiveness, resilience, and inclusive economic development.

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Supplementary Material

EU-23 Productivity

Dataset

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