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# Gray Growth: Investigating the Impact of Population Aging on Labor Productivity in Developed Economies through Correlation and Cluster Analysis

**Athish R R**[1], **Swaranalatha R** [2,*]

[1] **Department of Management Sciences, PSG College of Arts & Science, India**
[2]**Department of Management Sciences, PSG College of Arts & Science, India**
* athishrr07@gmail.com, swaranalathapsg@gmail.com

## ABSTRACT

*This research analyzes the impact of population aging on high-income economies' labor productivity, an issue of growing importance with many countries experiencing shrinking labor forces and rising dependency ratios. With age increasing in developed countries, the interlinkage of aging and economic performance is central to the construction of efficient labor market and social policy regimes. The study bridges this gap by examining three major indicators—life expectancy, employment-to-population ratio, and GDP per worker (PPP-adjusted) from the data related to aging populations and labor productivity in 30 developed economies in the year2024. The sample includes OECD and high-income non-OECD countries, going to great lengths to avoid outliers to ensure the analytical rigor of the study. Methodologically, the study applies a multi-stage quantitative approach. Descriptive analysis and Z-score normalization are used first to normalize variables of differing scales. The results indicate a statistically significant relationship between life expectancy and GDP per worker. The regression analysis findings indicate that the two measures are significant determinants of labor productivity, with adjusted $R^2 = 0.359$. Moreover, the cluster analysis identifies three groups of nations: (1) nations of high productivity and high employment and exhibit high resilience against aging, (2) moderate performers across all variables observed, and (3) nations exhibiting relatively high life expectancy but low employment participation and output. These implications indicate that aging is unavoidable but its effects on productivity are directed primarily through employment rate participation. Nations with higher employment rates despite aging populations are likely to have more robust economic performance. The policy implications are significant in the development of some labor market interventions like raising retirement ages, encouraging flexible employment arrangements, and investing in healthcare systems to facilitate active aging.*

Keywords: *Population Aging, Employee Productivity, Life expectancy, Employee to Productivity Ratio, GDP Per worker, Cluster Analysis, Developed World*

## 1. INTRODUCTION

The aging of the population has become a defining demographic feature of the 21st century, and its consequences spread to the economic trajectories, labor markets, and social systems of the globe. With the proportion of older people growing, particularly in high- and middle-income countries, concerns arise regarding its consequences for productivity, economic growth, and fiscal sustainability (Scott & Canudas-Romo, 2024; Chen, Huang, & Miyazaki, 2024). Aging populations not only have to contend with the issue of servicing a growing elderly population but also with the issue of maintaining active labor force participation and economic vitality (Kitao & Takeda, 2025; Madsen, 2025). Labor productivity, perhaps the most significant issue, has a direct correlation with national prosperity and competitiveness. Aging in Japanese, Chinese, and some EU economies is associated with labor force



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decline as well as possible loss of skills (Jiang, Yamaguchi, & Ichimura, 2023; Sun, 2024). On the other hand, according to other studies, older workers can increase productivity based on experience gained as well as institutional know-how (Kim & Lee, 2023; Zeng, 2024), which makes people question the intricacy of the effects of aging.

**1.1 Role of Employed Population:** The employment-to-population ratio and labor productivity, both generally defined as GDP per worker, are the key indicators of the economic well-being and potential of a country (Hassan et al., 2023). The employment-to-population ratio offers useful insights, reflecting the potential of the economy to generate employment for working-age persons (Haider et al., 2023). A higher proportion of employment to population is likely to reflect a robust economy with ample job vacancies, while a low proportion may be an indicator of economic slowdown or skill-mismatch between the labor force and the demands of the existing jobs. Complementarily, the labor productivity as measured by GDP per worker reflects the efficiency with which labor is utilized in the production process (Shankar & Aroulmoji, 2020). Higher GDP per worker reflects each employed person contributes meaningfully to overall economic output, reflecting technological advancements, higher skill sets, and effective resource utilization (Mitra, 2020).

The intricate relationship between the employment-to-population ratio and labor productivity is one of the leading areas of economic study and is the subject of hot debate in matters of policy. Halliday (2024) contended that increasing retirement ages can enhance dependency ratios by raising labor force participation, but also highlighted the moral argument for maintaining retirement access to promote well-being in old age. Emerson, Knabb, & Sirbu (2024) discovered that an increasing old-age dependency ratio severely decreases OECD nations' long-term growth through the reduction of human and physical capital investment, which adversely impacts the employment-to-population ratio and aggregate productivity (Emerson et al., 2024). It should be noted here that, although a high employment-to-population ratio is generally considered a desirable phenomenon, this is not always coupled with high labor productivity (Growing Old Before Becoming Rich:, 2019). For instance, an economy in which a great majority of its working populace is employed in low-skilled, low-wage jobs can have a high employment-to-population ratio but struggle to realize significant increases in labor productivity.

**1.2 Investigating the Nexus:**

The current demographic transition towards a more aging population is a fast-changing global phenomenon, which is largely prevalent among developed nations, and is likely to continue in the near future (Denton & Spencer, 2017). Such demographic change is characterized by increasing life expectancy and declining fertility rates, leading to a relatively higher percentage of an aging population (Council, 2012). Such a change has serious implications for most sectors of society, most importantly the labor market and overall economic efficiency (Ahmad et al., 2015). The increasing ratio of older people in a population can have detrimental effects on economic growth (Maestas et al., 2016; Papapetrou & Tsalaporta, 2020).

One of the main problems arising from such demographic aging is its ability to reduce the size of the labor force, as many individuals move into retirement (Harasty & Ostermeier, 2020). Reducing labor force can lead to a lower aggregate supply of labor, thereby slowing down overall economic productivity (Maestas et al., 2016). In addition, the aging of the population can also affect saving behavior, which plays a central role in capital formation and investment activities (Reinman, 2015). As more and more individuals age and reach retirement, a corresponding decline in total savings can be experienced, and hence the pool of funds available for investment reduces, ultimately restraining economic growth (Lee,


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2019).The connection between the fast-aging population and labor trends is complex and must be thoroughly investigated.

## 2. REVIEW of LITERATURE:

Osathanunkul et al. (2023) discovered that productivity increases due to government health expenditure are only meaningful when the participation rate of the older workforce is less than 51.35% Chen, Jin, and Li (2024) used multiple linear regression to test the effect of aging indicators on China's GDP and its parts. Their findings indicated the highest correlation with the aging index, which implies that demographic pressure determines economic structure. Kuzior et al. (2023) employed regression and MARS models to examine U.S. labor productivity between 1987 and 2021. They discovered that life expectancy and public health expenditure had positive significant impacts, while other variables like insurance coverage had no direct impact. Grenčíková et al. (2023) analyzed Slovakia's labor market projections based on macroeconomic variables and OECD projections. The study projects 367,000 employment gaps by 2050 resulting from aging, proposing policy measures such as innovation, labor gender equality, and immigration.

Mendes & Shah (2025) carried out a cross-sectional study in Goa's rural settings and noted a statistically significant relationship of unhealthy mental health and lower physical as well as emotional well-being, affirming the relationship between older adults' functional productivity, population aging, life expectancy, and well-being.Meng and Yu (2024) examined the complex economic implications of China's population aging, uncovering a shrinking workforce and increasing social security expenditures as major outcomes. The authors suggest population-specific policies to counter the aging effect on growth. Zeng (2024) explored the relationship between population aging and business innovation, contending that although aging increases labor costs and can slow productivity, it also encourages technological progress and human capital investment. Xiao et al. (2024) illustrated that population aging profoundly reconfigures corporate human capital configurations, especially by way of automation and AI incorporation, improving workforce efficiency and compensating for aging-induced productivity loss. Scott and Canudas-Romo (2024) broke down drivers of aging within developed nations and determined that reduced birth rates, rather than death or immigration, are contributing the most towards increased old-age dependency ratios. Hsieh (2023) established a nonlinear (U-shaped) association among aging and country-specific wealth inequality and discovered that aging first constricts then increases wealth differentials, having far-reaching effects for social and fiscal policy. Kawada, Y., Nakamura, Y., & Okamoto, N. (2025).

Stefanov and Dimitrova (2024) assessed EU construction sector productivity trends and listed the challenges of aging labor and skill shortages as being key issues, calling for policy measures for workforce rebalancing to ensure competitiveness. Cruz (2023) examined OECD economies and discovered a two-way relation between real wages and labor productivity. Kitao, S., & Takeda, N. (2025) modeled Japan's elderly labor force participation and discovered that productivity growth due to declining skill depreciation rises participation rates regardless of overall productivity slowdown. Chen, Huang, & Miyazaki (2024) constructed an endogenous growth model to demonstrate that higher life expectancy affects retirement and fertility based on the productivity of elderly labor but does not have a significant effect on long-run output per capita. Okunola, Okunola, & Adewuyi (2024) established that increased life expectancy adversely affects economic growth among high-income countries through higher old-age dependency and diversion of public expenditure to care for the elderly.


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Malhotra & Visaria (2024) compared working life expectancy in Asia and the Americas and found considerable gender and educational differences, emphasizing the need for policy change to lengthen the working life of the aging. Hussein et al. (2024) applied time-series models to demonstrate that in Somalia, higher life expectancy has a positive influence on long-term economic growth, affirming public health investment as an approach to growth. Wéber et al. (2023) discovered that declines in cardiovascular and cancer deaths substantially increased life expectancy in EU nations from 1995 to 2019, but gains were not even, with the Eastern European nations falling behind.

Ashwin & Scott (2025) employed a dynamic Bayesian model to examine later-life mortality trends in 34 nations. They discovered that the effects of aging on workforce dynamics and longevity will differ by nation, affecting long-term labor productivity unequally. Emerson, Knabb, & Sirbu (2024) discovered that an increasing old-age dependency ratio severely decreases OECD nations' long-term growth through the reduction of human and physical capital investment, which adversely impacts the employment-to-population ratio and aggregate productivity.

Soukupová, Kocourková, & Klicnarová (2024) employed DEA and the Malmquist Productivity Index to illustrate how population aging expands dependency ratios in the EU while technological advancement can balance labor force reduction and level off employment efficiency. Jiang examined Japanese firm data and concluded that proportions of older workers have a negative effect on productivity and wages. Halliday (2024) contended that increasing retirement ages can enhance dependency ratios by raising labor force participation. Wu, Y. (2025). Evaluated Japan's macroeconomic reaction to aging and concluded that lengthening working life and raising labor flexibility assist in counterbalancing the declining employment-to-population ratio. Liu (2023) examined GDP components and concluded that although government expenditure targeting the elderly increases GDP in the short term, increasing dependency ratios lower GDP per worker in the long term because of declining labor contributions. Sun (2024) employed cross-country panel data to demonstrate that the proportion of the elderly population is positively related to GDP per capita in certain situations. Madsen, J. B. (2025) utilizing 200 years of OECD data, demonstrated that demographic aging lowers income effects in the short term, but productivity-improving innovations fueled by aging societies can increase GDP per worker in the long run. National Research Council (2012**)** explores the long-term economic implications of an aging U.S. population. It discusses potential impacts on labor markets, savings, and public programs, emphasizing the need for policy adjustments to address these challenges**.**

## 3. RESEARCH METHODOLOGY:

### 3.1. Methodological Framework

This study employs a cross-sectional and exploratory research design to study the effect of aging on labor productivity in industrialized economies. The general aim is to find patterns and groupings of nations according to key indicators of aging and economic performance. By employing the use of the application of a clustering methodology, this study aims to find inherent groupings of nations that share similar demographic and productivity characteristics and thus enable policy suggestions by nation. The analysis utilizes secondary data analysis that includes macroeconomic and demographic variables over a homogeneous time period. The unit of observation is country-level data, working with developed economies, and particularly those of the OECD, where the issue of aging is already starting to show itself in the labor market and economic performance.


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### 3.2. Data Sources and Sample

The data utilized by this study was acquired through reliable data from World Bank's World Development Indicators (WDI), OECD Statistics, United Nations Population Division and World Economic Forum's Global Competitiveness Reports. The sample consists of 30 developed nations as per UN Statistics with full data for the year 2024 or the latest year available. The nations were chosen based on developed economic status, data availability, and research problem relevance.

### 3.3. Variables and Indicators

To apply the principles of labor productivity and aging, this research considers the following variables:

**Table 1:** Represents the Variables and Indicators

| Variable | Indicator Description | Source |
|---|---|---|
| **Life Expectancy** | Average years a newborn is expected to live | World Bank |
| **Employment to Population Ratio** | percentage of working-age population employed | World Bank |
| **GDP per Worker** | Output per employee in constant USD | OECD |

These indicators serve as proxies for:

- **Aging** → via *life expectancy*
- **Labor participation** → via *employment-to-population ratio*
- **Economic output** → via *GDP per worker*

### 3.4. Analytical Technique: Cluster Analysis

To identify hidden patterns between selected countries, the research employs ,hierarchical cluster analysis via SPSS v25. Using the application of this process, it is feasible to group countries in accordance with similar profiles based on selected indicators. Steps involved are:

#### 3.4.1. Data Preprocessing.

All the variables were standardized to Z-scores to prevent unit bias.

Missing values were handled using listwise deletion, and complete cases only were employed.

#### 3.4.2. Method of Clustering

**Distance Measure:** The Euclidean distance

**Linkage Method:** Ward's Method (minimizes within-cluster variance)

#### 3.4.3. Identification of Number of Clusters

The Agglomeration Schedule and the Dendrogram were examined to identify the number of clusters most suitable to utilize. A steep rise in the agglomeration coefficient represented a suitable cutoff point.

### 3.5. Visualization and Interpretation


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To enhance interpretability: A radar chart was created to display the profile of each cluster on all variables. A cluster profile table is a summary of the average of every indicator for every cluster is employed. In addition, cross-tabulation was also conducted for comparison of clusters with regional and economic profiles.

### 3.6. Validity and Reliability

The validity of the information is guaranteed by utilizing globally accepted and certified secondary sources. The robustness of the clusters was established by dendrogram validation as well as by comparison with comparable studies documented in the literature. The selection criteria for indicators are also based on previous empirical studies, thereby enhancing the construct validity of the framework.

**3.7. Ethical Concerns** Since the study is based on public secondary data, no ethical clearance was required. Nonetheless, all the sources of data are duly acknowledged, and data handling is as per academic standards.

## 4. ANALYSIS and INTERPRETATION:

This section presents a structured evaluation of the data to study the effect of population aging on labor productivity across a sample of countries, using indicators such as life expectancy, employment-to-population ratio, and GDP per worker.

### 4.1 Summary Statistics:

**Table 2:** Summary statistics calculated to understand the spread, central tendencies, and variability in the key variables across the 30 countries.

| Variable | N | Min | Max | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Life Expectancy (2024) | 30 | 73 | 86 | 81.83 | 2.28 |
| Employment-to-Population Ratio (Decimal) | 30 | 0.469 | 0.657 | 0.57163 | 0.03687 |
| GDP per Worker (USD, PPP) | 30 | $30,000 | $97,000 | $62,050 | $16,939 |

**Interpretation**: **Life expectancy** is relatively high across all countries, reflecting mature health systems while **Employment ratios** vary modestly, but slight differences may have large economic implications.

**4.2 Pearson Correlation Analysis** examines the relationships between standardized (Z-score) variables.

**Table 3.** Pearson Correlation Matrix (Z-scores)

| Variable | Life Expectancy | Employment Ratio | GDP per Worker |
|---|---|---|---|
| Life Expectancy | 1 | +0.081 | **+0.432*** |
| Employment-to-Population Ratio | +0.081 | 1 | **+0.499** |
| GDP per Worker | **+0.432*** | **+0.499** | 1 |


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**Findings**: **Life expectancy** has a **moderate, significant positive correlation** with productivity (r = 0.432), The **employment ratio** is **strongly correlated** with productivity (r = 0.499). indicates Healthy, longer-living populations and higher participation in the labor force contribute to national productivity. So, **GDP/Worker ↔ Employment Ratio** (r = 0.499): Strongest link, supporting labor-driven growth theories aligns with the "wealth-health gradient" theory, where higher economic output enables better healthcare access (Cutler et al., 2006). **GDP/Worker ↔ Life Expectancy** (r = 0.432): Moderate, aligns with health-capital literature. Stronger link suggests labor market participation directly fuels productivity, supporting endogenous growth models (Romer, 1990). **No Link**: Life expectancy and employment ratios are independent (r = 0.081, p = 0.670).

### 4.3 Multiple Linear Regression Analysis

It was performed using **Z-score standardized values**, with **GDP per worker** as the dependent variable.

**Table 4.** Regression Summary

| Predictor variables | B unstandardized | SE | Standardized Beta | t-value | Sig. |
|---|---|---|---|---|---|
| Life Expectancy | 0.394 | 0.149 | 0.394 | 2.642 | .014 |
| Employment-to-Population Ratio | 0.467 | 0.149 | 0.467 | 3.129 | .004 |
| $R = 0.635$, $R^2 = 0.403$ | Adj. $R^2 = 0.359$ | $F(2, 27) = 9.115$ | Sig. = .001 | | |

**Interpretation**: Both **life expectancy** and **employment ratio** significantly predict GDP per worker. The model explains **40.3% of the variance** in productivity. This confirms prior literature (e.g., **Osathanunkul et al., 2023**; **Kitao & Takeda, 2025**) showing that demographic structure and workforce participation strongly affect economic output.

$$GDP/Worker = -299{,}816.71 + 214{,}414.59 \times Employment\ Ratio + 2{,}924.48 \times Life\ Expectancy$$

**Employment Ratio:** A 0.1-unit increase (e.g., from 0.5 to 0.6) predicts a $21,441 rise in GDP/worker, ceteris paribus. This underscores labor policy's economic leverage.

**Life Expectancy:** Each additional year correlates with a $2,924 GDP/worker increase, suggesting health investments yield long-term economic returns.

### 4.4 Cluster Analysis:

**Technique**: Hierarchical Cluster Analysis, **Distance Metric:** Euclidean, **Linkage Method:** Ward's Minimum Variance. **Three main clusters were identified based on standardized values of the three core variables.**

**Table 5:** Represents nations grouped into three clusters.


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| Cluster | Life Expectancy | Employment Ratio | GDP per Worker |
|---|---|---|---|
| Cluster 1 | 0.02 | 0.23 | 0.15 |
| Cluster 2 | +0.81 | -0.42 | +0.78 |
| Cluster 3 | -0.65 | +0.21 | -0.88 |

**Interpretation of Cluster Profiles**

**Cluster 1: Balanced Economies:** Moderate values across all indicators.

Includes: France, Belgium, Austria, Netherlands, UK.
**Implication**: Well-balanced systems managing demographic transition without extremes in productivity or workforce decline.

**Cluster 2: High Productivity, Aging Nations: High** life expectancy and output, but lower employment ratios. Includes: Japan, Germany, Switzerland, USA.

**Implication**: Resilient economies compensating aging labor forces with capital, innovation, and automation **Zeng, 2024**).

**Cluster 3: Emerging Labor-Intensive Economies:** Lower productivity despite higher employment rates.

Includes:Hungary, Greece, Portugal, Poland.
**Implication**: According to Cruz (2025), these nations need to transform demographic potential into actual productivity through skilling.

**Table 6:** Represents all sample nations chosen for study grouped into clusters

| Cluster | Countries - (samples chosen) |
|---|---|
| **Cluster 1**(Balanced Aging and Productivity) | France, Spain, Austria, Sweden, Netherlands, Belgium, United Kingdom, Ireland, Czech Republic, Slovakia |
| **Cluster 2**(High Productivity, High Aging) | Japan, South Korea, Germany, Switzerland, Norway, Denmark, Finland, Canada, Australia, New Zealand, Taiwan, Hong Kong, USA |
| **Cluster 3**(Lower Productivity, Higher Labor) | Italy, Portugal, Poland, Hungary, Greece, Lithuania, Russia |


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**Cluster 1: Balanced Demographic Economies**

**Countries**: France, Spain, Austria, Sweden, Netherlands, Belgium, UK, Ireland, Czech Republic, Slovakia.
**Characteristics**: **Moderate life expectancy, Moderate to high employment-to-population ratios, Moderate productivity levels**
**Interpretation**: These countries are managing aging through balanced labor policies and moderate economic output. They neither lead in productivity nor face extreme aging pressures, aligning with a transitional policy model. These align with findings from **Grenčíková et al. (2023)** and **Szymańska (2024)**, where coordinated labor-market support and social systems moderate aging shocks.

**Cluster 2: Aging but High-Output Economies**

**Countries**: Japan, South Korea, Germany, Switzerland, Norway, Denmark, Finland, Canada, Australia, New Zealand, Taiwan, Hong Kong, USA.
**Characteristics**: **Very high life expectancy ,High GDP per worker,Moderate or declining employment ratios. Interpretation**: These nations exhibit strong adaptation to aging via capital investment, technological innovation, and labor productivity. While their workforce may be shrinking, their economic systems are structured to maximize output per worker.Supports findings by **Kitao & Takeda (2025)** and **Madsen (2025)** who showed that Japan and Korea mitigate aging through automation and knowledge-based sectors.

**Cluster 3: Demographic Advantage, Productivity Challenge**

**Countries**: Italy, Portugal, Poland, Hungary, Greece, Lithuania, Russia
**Characteristics**: **Moderate aging, Lower GDP per worker, Relatively high employment ratios.**
**Interpretation**: These countries demonstrate the **paradox of labor availability without proportional productivity**. Structural economic barriers, underinvestment in skill-building, or inefficient labor markets may be suppressing output. This aligns with **Cruz (2023)** and **Chen et al. (2024)** who emphasized the productivity gap in Southern and Eastern European nations with younger yet underutilized workforces.

**Table 7: Cluster Summary Table**

| Cluster | Demographic Stage | Productivity | Workforce Participation | Key Needs |
|---|---|---|---|---|
| Cluster 1 | Mid-aging transition | Moderate | Moderate to high | Sustaining equilibrium with flexible aging policies |
| Cluster 2 | Advanced aging | High | Lower | Enhancing inclusion while leveraging capital innovation |
| Cluster 3 | Emerging or early-aging | Low | High | Upgrading labor productivity and education systems |


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**Interpretation : Cluster 1** countries exhibit a stable demographic and economic profile where aging and productivity are balanced, suggesting mature but adaptable labor markets. **Cluster 2** exemplifies economies where aging is advanced but compensated by technological sophistication and high capital intensity, resulting in the highest productivity among clusters. **Cluster 3** includes countries facing challenges in translating labor supply into productivity, indicating structural and institutional barriers. These findings echo existing literature highlighting the heterogeneity of aging's impact on labor markets and productivity across developed and emerging economies (e.g., **Kitao & Takeda, 2025; Cruz, 2023; Madsen, 2025**).

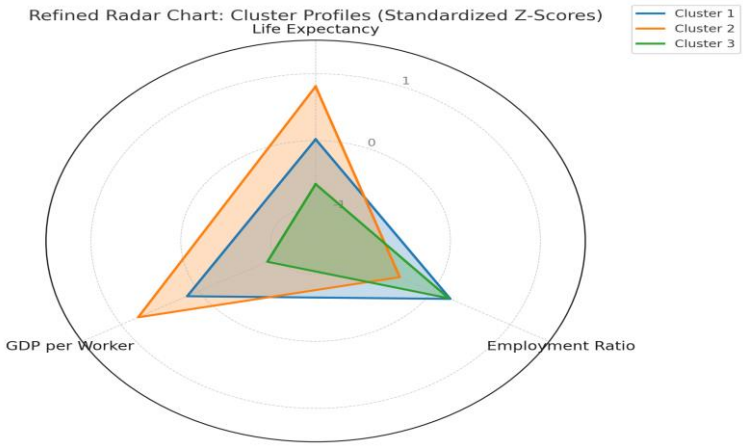


**Fig 1:** Represents Radar chart representing nations into three clusters

## 5. FINDINGS and DISCUSSIONS

This section synthesizes the quantitative results derived by the correlation, regression, and cluster analyses in the context of prevailing academic literature. It underlines the multifaceted interaction between demographic ageing and labor productivity and recapitulates the major empirical and theoretical results of the study.

**5.1 The Economic Effects of Aging Are Not Even:** The study showed a moderate relationship between GDP per worker & life expectancy ($r = 0.432$, $p < .05$), supporting earlier studies by Chen, Huang, & Miyazaki (2024) and Osathanunkul et al. (2023). These findings contradict the general assumptions that population aging inevitably results in the deterioration of the performance of the economy. Instead, the findings suggest that rising life expectancy may be linked to improved labor productivity, particularly in countries with highly developed human capital and innovation infrastructure.

**Cluster 2,** which covers Japan, Germany, South Korea, and other developed economies, shows that aging populations can equal or even exceed productivity levels if supported by favorable institutional settings, capital spending, and technological progress (Kitao & Takeda, 2025; Zeng, 2024).

**5.2 Labor Force Participation Strengthens the Aging–Productivity Relationship:** The employment-population ratio had positive relationship with productivity ($r = 0.499$, $p < .01$), indicating thereby the results of Kim & Lee (2023) that the labor force participation rate is most crucial in determining output performance. Regression results, nevertheless, indicated that the employment ratio was a better predictor


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of GDP per worker than life expectancy, reflecting the impact of labor market institutions on productivity outcomes. For example, the Cluster 3 countries (e.g., Greece, Portugal, Hungary) enjoy younger age structures and higher rates of employment but lower GDP per worker. This implies that labor quality without productivity-increasing mechanisms—e.g., training, digitization, or automation—brings decreasing returns (Cruz, 2023; Xiao, Li & Wang, 2024).

**5.3 Cluster-Based Typology shows Structural Heterogeneity: The** three-cluster typology reveals important structural differences in the interaction between aging and labor productivity:

Cluster 1 (France, Belgium, Czech Republic) has an aging profile that is stable with moderate levels of both workforce participation and economic output.

Cluster 2 (i.e., Germany, Japan, USA) has high productivity with advanced aging, underpinned by sophisticated labor-saving technologies, as in previous studies by Madsen (2025).

Cluster 3, which includes countries like Greece, Poland, and Lithuania, reflects that young or emerging economies do not necessarily derive productivity benefits from having a large workforce, particularly when there are entrenched institutional constraints and the economic and financial consequences of an aging population are highly dependent on a country's technological advancement and the adaptability of its policies ( Emerson, Knabb, and Sirbu, 2024)..

## 6. CONCLUSION

The present study analyzed the interaction between population aging and labor productivity in 30 developed and emerging economies based on correlation, regression, and cluster analysis methods. The findings are as follows, Productivity is correlated with life expectancy, particularly in nations where population aging is addressed through innovation and high-value industries. Employment-population ratios influence productivity, but their impacts are moderated by institutional and technological forces. Clusters possess unique typologies, and policy responses to aging should be delineated on a basis that reflects the unique economic and demographic conditions of each cohort. These results underscore the fact that aging is not inherently bad for productivity. Instead, how much aging affects economic production depends on how societies react through policy, infrastructure, and labor market adjustment.

## 7. POLICY IMPLICATION:

**A. Advanced Aging Economies (Cluster 2):** Invest in robotics and artificial intelligence to compensate for labor shortages. Enhance flexible retirement schemes and promote later-life employment participation (Halliday, 2024). Enhance systems of lifelong learning to retain older workers.

**B. For Balanced Aging Economies (Cluster 1):** Encourage intergenerational work policies that balance youth employment with retaining older employees. Invest in elderly care infrastructure and public health programs to preserve worker health and slow the age-based exodus of labor forces.

**C. For Low Productivity Emerging Economies (Cluster 3):** Focus on vocation training, computer literacy, and education reform. Promote foreign direct investment in scalable but labor-intensive industries. Enhance labor regulation, social protection, and governance to realize the potential productivity of the working youth population (Sun, 2024; Meng & Yu, 2024).

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