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The Differential Impact of Aging on Structural Change: Insights from Cross-Country Analysis Based on Income Levels

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Abstract

This paper examines the heterogeneous effects of population aging on sectoral employment reallocation across countries at varying stages of economic development. Using an unbalanced panel dataset of 59 countries spanning 1960–2018, we estimate a panel fixed-effects model in which the old-age dependency ratio serves as the primary explanatory variable for employment shares across agriculture, manufacturing, and services. To rationalize the empirical findings, we develop an extended overlapping generations (OLG) model incorporating hierarchical consumption preferences differentiated by age cohort, building on the non-homothetic utility frameworks of Matsuyama (2002) and Foellmi and Zweimüller (2008). The model generates age-specific demand structures in which older cohorts systematically shift consumption expenditure toward services, particularly health-related services, inducing labor reallocation away from industry. Empirical results confirm that aging accelerates tertiarization — the expansion of service-sector employment share — most prominently in high-income economies, consistent with the demand-side channel of structural transformation. In low-income countries, however, binding

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income constraints prevent full materialization of preference-driven sectoral reallocation, resulting in persistent agricultural employment retention. Middle-income countries exhibit ambiguous dynamics, suggestive of a structural transformation puzzle. These findings highlight that the demographic transition interacts with the level of economic development to shape the trajectory of deindustrialization and de-agriculturalization, with important implications for development policy and long-run labor productivity growth.
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1 Introduction

A structural transformation process can indicate different levels of development across countries. One can observe the labor productivity level as a factor showing a change in development. As workers move from one sector to another, they carry their productivity there. The aggregate labor productivity can be calculated using the average of all sectoral labor productivity weighted by the share of labor devoted to those sectors. That is why studying workers' movement can also tell us about the difference in income levels across countries.

During the process of structural transformation, secular reallocation of employment across heterogeneous sectors over time occurs. The first phase starts by working primarily in the agricultural-based sectors. Then, this flow of productive workers moves from the agricultural sector to other sectors, for example, from the agricultural sector toward industry, enhancing aggregate labor productivity [Rodrik, 2013].

The empirical results show that structural change has contributed to growth significantly by reallocating resources from low-productivity sectors to high-productivity sectors [Fan et al., 2003]. Although this process may work as it is, there are differences across countries due to several factors which lead to two separated paths for the second phase; either laborer move from the agricultural sector toward manufacturing (positive growth effect since higher productivity usually stems from the industrials) or labor move directly to the services sector (growth hindrance). Whether countries' structural transformation follows the first or second path, factors and mechanisms that cause productive workers' reallocation across sectors must be justified.

A shift in the demographic structure toward an aging society may be one of the main factors pushing a different pattern in structural transformation. The aging phenomenon has become more challenging in many parts of the world. Over the past 70 years, the old-age population has rapidly increased, especially from the year 2000. An increasing trend in the projection of the old-age dependency ratio (OADR) in advanced countries and developing economies such as Southeast Asia. For selected advanced countries such as Europe and Japan, OADR has reached 20 percent since 2000, and this ratio will reach 50 and 70 percent by 2050, respectively. Turning to look at emerging economies like China and Thailand, the OADR will reach 50 and 45 percent by 2050, respectively. This demographic shift pace is relatively fast compared to the advanced economies.

Siliverstovs et al. [2011] are the first to state that aging positively affects employment share in service-related sectors such as personal services, community, and financial services while negatively impacting agricultural and manufacturing employment shares. More recent research also finds that an increase in the aging population directly pushes the country's demand for more services and goods, such as healthcare support, thus shifting the share of workers working in the agricultural sector toward services [Cravino et al., 2022].

Therefore, this paper aims to examine the impact of an aging population on a country's structural transformation. We followed Herrendorf et al. [2022] and Cravino et al. [2022] and gathered an updated panel dataset on sectoral employment share and productivity level of 59 countries from 1960 to 2018. We study how the aging population affects a change in the structural transformation patterns, precisely the sectoral employment share across agricultural sectors, industry, and services. Furthermore, this paper investigates the mechanism of structural transformation through labor movement across industries in each country's income level.

Our study unveils three key findings. Firstly, as the population ages, we observe a shift from traditional (agriculture) to modern sectors (industry and services), aligning with the established pattern of structural transformation—secondly, human capital curbs de-agriculturalization and de-industrialization among middle-income nations in aging scenarios. As the countries develop, structural change exists within agriculture. In particular, workers move from the labor-intensive to the capital-intensive agricultural sector. Thirdly, the impact of aging on low-income countries' structural transformation remains uncertain. Although their agricultural employment share rises, the modern sector's status is unclear. This is possible because many low-income countries still face a modest aging population.

The remainder of this paper is organized as follows. Section II reviews previous literature. Section III presents extended OLG model with structured hierarchically preferences across the variety of consumption goods reflecting an ordered prioritization in consumption decisions. Competitive Equilibrium is Characterized in Section IV. Data and Empirical Study are presented in section IV. Then, we present the results and discuss them in Section VI.

2 Literature Review

Our topic relates to the main branches of literature: First, it is the process and factors observed during structural transformation, and the second is how aging may affect the structural transformation process. Previous research on structural transformation tries to understand the root cause and process of structural transformation. Święcki [2017] reveals that two main patterns occur during the structural transformation process using the data of 45 countries from 1970 to 2005. Those are "de-agriculturalization," where the workers move out of the agricultural sector, and "de-industrialization," where sectoral productivity bias pushes workers to move out of manufacturing towards the services sector.

The process of de-agriculturalization can also be called "non-homothetic preference." As a country's income level increases, people consume fewer agricultural products than goods from other sectors. This means that once the labor productivity in the agricultural sector has been increased, the employment share in the agricultural sector starts to decline. After that, the "technological bias" across sectors creates the productivity differential between sectors through the high relative price of industrial products compared to agricultural products. The reallocation of labor from the agricultural sector to industry enhances the country's aggregate labor productivity and, thus, income level. [Sáenz, 2019].

Researchers usually observe a decline in the share of people working in agriculture. The share of people in an industry increases until it reaches its peak and then declines to support the service sector in developed countries (See more in Herrendorf et al. [2022]; Rodrik [2016]). However, empirical evidence from Rodrik [2016] shows that many developing countries turn to service economies without passing through the process of industrialization, the so-called "premature de-industrialization." Premature de-industrialization can be caused by manufacturing size and productivity that has shrunk too fast or the formation of the industrial needs to be faster and build larger manufacturing sectors (Rodrik [2013]; Rodrik [2016]).

Trade shock, globalization, and policy distortion[1] are considered factors affecting the different patterns of structural transformation in developing countries. In contrast, a

[1]See Fajgelbaum and Redding [2022], Dessy et al. [2010], Uy et al. [2013], and Teignier [2018] for the role of trade and globalization in affecting structural change in developing countries. See more in Feldman et al. [1987]. Dennis and İşcan [2011], Anderson et al. [2013], and Temsumrit and Sriket [2023] for the impact of policy distortion on structural transformation.

different rate of technological change plays a significant role in the developed world[2].

Apart from those factors, Siliverstovs et al. [2011] estimate 51 selected developing and developed economies datasets and show that aging has statistical significance to a change in sectoral employment share. They suggest that aging affects the employment share after controlling for trade, income, and other relevant factors. Aging positively affects employment share in service-related sectors such as personal, community, and financial services while negatively affecting agricultural and manufacturing employment shares.

The fact that the aging population demands more services, primarily related to health and life after retirement, pushes a shift of labor share from agricultural directly towards service-related sectors. Similarly, Cravino et al. [2022] finds that an increase in the share of the old-age population raises the proportion of services consumption. They investigate the relationship between structural transformation patterns and the proportion of the aging population using household-level data from the U.S. Consumer Expenditure Survey (CES).

Evidence on the relationship between population aging and structural transformation remains inconclusive and may vary across countries at different income levels. This paper therefore extends the overlapping generations (OLG) model by incorporating structured hierarchical preferences across varieties of consumption goods, reflecting an ordered prioritization in household consumption decisions. We further investigates empirically the effect of population aging on structural transformation using an updated dataset of 59 countries from 1960 to 2018. The analysis distinguishes between developing and developed economies and further examines how aging affects the sectoral decomposition of labor productivity and labor shares, and consequently, countries' income levels.

This paper contributes to the literature by linking a theoretical model of population aging and structural transformation with empirical evidence from an updated panel dataset of 59 countries and compiled from multiple sources, including the GGDC, ETD, and AFD databases. The model accounts not only for the effect of aging on structural transformation, but also for the way in which countries' income levels shape the hierarchical structure of demand for consumption goods.

[2] See more in Lawrence and Edwards [2013] and Rodrik [2016].

3 The Model

We consider a closed, overlapping generations economy with $I \in \mathbb{N}$ production sectors. Each sector produces a pure consumption good using only labor as input. The economy includes a representative household, where each individual lives for at most two periods: as young and as old. When young, individuals supply labor inelastically to earn wage income, which they allocate between current and future consumption. Consumption goods are ranked by preference, although these rankings may differ between the young and the old. All markets are perfectly competitive. Time is discrete and indexed by $t = 0, 1, 2, 3, \ldots$

3.1 Households

We consider a representative household whose members live for at most two periods. In each period t, L_t identical young individuals are born. We assume that the size of young individuals evolves according to $L_{t+1} = (1 + n_t)L_t$, where n_t is the (potentially time-varying) population growth rate. Given the initial size of the young L_0, the time path of the young generation is:

$$L_t = L_0 \prod_{\tau=0}^{t-1} (1 + n_\tau).$$

In the special case where $n_{t+1} = n_t = n > -1$, we have:

$$L_t = (1 + n)^t L_0.$$

Unless otherwise stated, we assume constant population growth.

Each young individual lives with certainty during their first period and supplies one unit of labor inelastically, earning wage income w_t. This income is used to consume goods and/or save for old age. The budget constraint for a young individual born in period t is:

$$\sum_{i=1}^{I} p_{i,t} c^y_{i,t} + s_t = w_t, \tag{1}$$

where $p_{i,t}$ is the price of good i in period t, $c^y_{i,t}$ is consumption of good i when young, and s_t is savings.

In the second period, only a fraction $\pi \in (0, 1]$ of individuals survive. The budget constraint for the surviving old individuals is:

$$\sum_{i=1}^{I} p_{i,t+1} c^o_{i,t+1} = \frac{R_{t+1}}{\pi} s_t, \tag{2}$$

where $c^o_{i,t+1}$ is consumption of good i when old and R_{t+1} is the gross rate of return on savings. Note that when $\pi < 1$, the effective return on savings, $\frac{R_{t+1}}{\pi}$, is higher than R_{t+1}, because the interest income of deceased individuals is redistributed among survivors. This is a standard feature in overlapping generations models with uncertain lifespans.[3]

Preferences across the variety of consumption goods are structured hierarchically, reflecting an ordered prioritization in consumption decisions. Similar to Matsuyama [2002] and Foellmi and Zweimüller [2008], individuals prioritize which goods to consume based on fixed rankings. Let $\text{Index}_Q \equiv \{1, 2, 3, \ldots, I\}$ denote the set indexing all consumption goods, where each good is labeled by an index $i \in \text{Index}_Q$. The priority ranking of goods when young is given by a bijective function:

$$\sigma_y : \text{Index}_Q \to \text{Permutation}(\text{Index}_Q),$$

and when old by

$$\sigma_o : \text{Index}_Q \to \text{Permutation}(\text{Index}_Q).$$

The ranking functions σ_y and σ_o are assumed to be common across all individuals: σ_y is identical for all young individuals across time, and σ_o is likewise identical for all old individuals.

As a concrete example, suppose the economy consists of four sectors: agriculture (1), manufacturing (2), non-health services (3), and health services (4), so that $\text{Index}_Q = \{1, 2, 3, 4\}$. We may assume:

$$\sigma_y(1) = 1, \quad \sigma_y(2) = 2, \quad \sigma_y(3) = 3, \quad \sigma_y(4) = 4,$$

$$\sigma_o(1) = 1, \quad \sigma_o(2) = 3, \quad \sigma_o(3) = 4, \quad \sigma_o(4) = 2.$$

This reflects the idea that health services are of lower priority when young but become more essential with age.

To model preferences under such prioritization, we follow Foellmi and Zweimüller

[3]See Cipriani [2014], among many others.

(2008). For each life stage $j \in \{y, o\}$, the utility weight function assigned to good i is given by:

$$\xi_j(i) = \sigma_j(i)^{-\gamma}, \quad \gamma > 0,$$

where a lower rank $\sigma_j(i)$ indicates higher priority, and hence a higher utility weight.

The utility from consuming good i follows a quadratic form:

$$u_i(c^j_{i,t}) = \mu_i c^j_{i,t} - \frac{1}{2}(c^j_{i,t})^2,$$

where $\mu_i \geq 0$ is a good-specific bliss point, denoting the consumption level at which utility from good i is maximized. Unlike Foellmi and Zweimüller [2008], who assume a common bliss point μ, we allow μ_i to vary across goods. In principle, μ_i could also differ across life stages, but for simplicity, we abstract from this.

Suppose that the instantaneous utility in each life stage is given by the weighted sum:

$$\sum_{i=1}^{I} \xi_j(i) u_i(c^j_{i,t}) \quad \text{for } j \in \{y, o\}.$$

Because utility is quadratic, consuming a good in unbounded quantities is never optimal—even with unlimited income—as marginal utility becomes negative beyond the bliss point μ_i.

Now, we turn to the individual optimization problem. The representative young agent born in period t solves:

$$\max_{\{c^y_{i,t}\}_{i=1}^I, \{c^o_{i,t+1}\}_{i=1}^I} \left\{ \sum_{i=1}^{I} \xi_y(i) u_i(c^y_{i,t}) + \pi\beta \sum_{i=1}^{I} \xi_o(i) u_i(c^o_{i,t+1}) \right\}, \tag{3}$$

subject to the budget constraints (1) and (2).

Let λ_t and θ_{t+1} denote the Lagrange multipliers. The Lagrangian becomes:

$$\begin{aligned}
\mathcal{L} = &\sum_{i=1}^{I} \sigma_y(i)^{-\gamma} u_i(c^y_{i,t}) + \pi\beta \sum_{i=1}^{I} \sigma_o(i)^{-\gamma} u_i(c^o_{i,t+1}) \\
&+ \lambda_t \left(w_t - \sum_{i=1}^{I} p_{i,t} c^y_{i,t} - s_t \right) + \theta_{t+1} \left(\frac{R_{t+1}}{\pi} s_t - \sum_{i=1}^{I} p_{i,t+1} c^o_{i,t+1} \right).
\end{aligned}$$

The first-order conditions (FOCs) are:

$$c_{i,t}^y \ : \quad \sigma_y(i)^{-\gamma}(\mu_i - c_{i,t}^y) - \lambda_t p_{i,t} \leq 0, \quad c_{i,t}^y \geq 0, \quad \text{complementary slackness,} \tag{4}$$

$$c_{i,t+1}^o \ : \ \pi\beta\sigma_o(i)^{-\gamma}(\mu_i - c_{i,t+1}^o) - \theta_{t+1}p_{i,t+1} \leq 0, \quad c_{i,t+1}^o \geq 0, \quad \text{complementary slackness,} \tag{5}$$

$$s_t \ : \quad -\lambda_t + \theta_{t+1}\frac{R_{t+1}}{\pi} \leq 0, \quad s_t \geq 0, \quad \text{complementary slackness.} \tag{6}$$

From the FOCs, the optimal consumption profiles are:

$$c_{i,t}^y = \max\left\{0, \mu_i - \lambda_t p_{i,t}\sigma_y(i)^\gamma\right\}, \tag{7}$$

$$c_{i,t+1}^o = \max\left\{0, \mu_i - \frac{\lambda_t}{\beta R_{t+1}} p_{i,t+1}\sigma_o(i)^\gamma\right\}. \tag{8}$$

Intuitively, consumption of any given good - either when young or old - can be positive or zero, but never exceeds the bliss point μ_i. The expressions in (7) and (8) capture how price, priority rank, and intertemporal trade-offs shape the consumption allocation.

The optimal savings can be derived using equation (1) and (7):

$$s_t = w_t - \sum_{i=1}^{I} p_{i,t} \max\left\{0, \mu_i - \lambda_t p_{i,t}\sigma_y(i)^\gamma\right\}. \tag{9}$$

Alternatively, combining (2) with (8) gives an alternative expression for savings::

$$s_t = \frac{\pi}{R_{t+1}} \sum_{i=1}^{I} p_{i,t+1} \max\left\{0, \mu_i - \frac{\lambda_t}{\beta R_{t+1}} p_{i,t+1}\sigma_o(i)^\gamma\right\}. \tag{10}$$

3.2 Technologies

There are $I \geq 1$ sectors, each producing a distinct good using a linear production technology:

$$Q_{i,t} = A_{i,t}\, l_{i,t} L_t, \quad i = 1, 2, \ldots, I. \tag{11}$$

Here, $l_{i,t} \in [0, 1]$ denotes the fraction of the total labor force L_t allocated to sector i. Thus, $l_{i,t}L_t$ represents the quantity of labor employed in that sector. The term $A_{i,t}$ denotes sector-specific productivity, assumed to evolve exogenously as $A_{i,t} = A_{i,0}(1+g_{i,t})^t$, where $A_{i,0}$ is the initial productivity level, and $g_{i,t} \geq 0$ is the sector-specific growth rate.

The profit maximization problem for sector i is:

$$\max_{l_{i,t}L_t} \{p_{i,t}A_{i,t}l_{i,t}L_t - w_t l_{i,t}L_t\}. \tag{12}$$

The first-order condition for this problem implies:

$$p_{i,t} = \frac{w_t}{A_{i,t}}. \tag{13}$$

4 Competitive Equilibrium Characterization

4.1 Labor Market

We begin by characterizing the labor market. In each period t, the representative household supplies L_t units of labor inelastically. Labor input is allocated across I sectors, where each sector i may or may not demand labor depending on profitability conditions. In equilibrium, some sectors may be inactive, implying $l_{i,t} = 0$, while active sectors employ a positive share of labor, i.e., $l_{i,t} \in (0,1]$. The labor market clearing condition requires that the total labor employed across all sectors equals the total labor supply:

$$\sum_{i=1}^{I} l_{i,t} = 1. \tag{14}$$

4.2 Loanable Fund Market

Next, we consider the equilibrium condition in the loanable funds market. In each period, the young save a portion of their income, which is then used to finance consumption by the surviving old in the next period. In equilibrium, the total savings of the young must equal the total interest income received by the old. Formally, this requires:

$$s_t L_t = \frac{R_t}{\pi} s_{t-1} \cdot \pi L_{t-1} \quad \Rightarrow \quad s_t = \frac{R_t}{1+n} s_{t-1} \quad \Rightarrow \quad s_t = \frac{\prod_{\tau=0}^{t} R_\tau}{(1+n)^t} s_{-1}.$$

Given the initial old's savings $s_{-1} > 0$ and a sequence of interest rates $\{R_t\}_{t=0}^{\infty}$, the sequence of savings $\{s_t\}_{t=0}^{\infty}$ is recursively determined. We focus on a stationary equilibrium in which the interest rate is constant over time: $R_t = R_{t+1} = R$. Then, the savings dynamics follow:

$$s_t = \left(\frac{R}{1+n}\right)^t s_{-1}.$$

If $R > 1+n$, savings grow without bound: $\lim_{t\to\infty} s_t = \infty$. If $R < 1+n$, savings decline over time: $\lim_{t\to\infty} s_t = 0$. If $R = 1+n$, then savings remain constant over time: $s_t = s_{-1}$ for all t.

We assume the government provides a bond market that serves as a saving device for individuals. The government offers a perfectly elastic supply of one-period risk-free bonds at a fixed gross interest rate:

$$R_t = R^* \tag{15}$$

for all t. This allows the young to transfer resources across time for old-age consumption.[4]

4.3 Output Market

We now turn to the output market clearing condition. For each sector i, total output is entirely consumed by the current young and surviving old individuals. In any period t, the size of the young generation is L_t, while the number of surviving old individuals is πL_{t-1}. Therefore, the goods market clearing condition for sector i is:

$$Y_{i,t} = c^y_{i,t} L_t + c^o_{i,t} \pi L_{t-1}.$$

Using this, together with equations (7), (8), and (11), we obtain the following expression for the labor share allocated to sector i:

$$l_{i,t} = \frac{1}{A_{i,t}} \left[\max\left\{0, \mu_i - \lambda_t p_{i,t} \sigma_y(i)^\gamma\right\} + \frac{\pi}{1+n} \max\left\{0, \mu_i - \frac{\lambda_{t-1}}{\beta R_t} p_{i,t} \sigma_o(i)^\gamma\right\}\right]. \tag{16}$$

[4]Notably, each young individual can purchase one-period annuities that pay a fixed gross return R^* in the next period only if they survive. However, only a fraction $\pi \in (0,1]$of the population survives into old age, and the government redistributes the assets of those who die equally among survivors, the effective return on individual savings becomes $\tilde{R} = \frac{R^*}{\pi}$. This implies that the expected payoff conditional on survival is higher than the market return R^*, because the interest income of the deceased is fully transferred to the survivors. The young still save s_t in period t, but the old who survive receive $\frac{R^*}{\pi} s_t$ in period $t+1$. This standard annuity structure is consistent with models like Yaari [1965] and Blanchard [1985], and allows tractable intertemporal consumption smoothing while capturing mortality risk.

4.4 Equilibrium Dynamics

To proceed further, we normalize the price of good 1 to unity, i.e., $p_{1,t} = 1$. From equation (13), this normalization implies that the wage rate is:

$$w_t = A_{1,t} \quad \text{for all } t. \tag{17}$$

Substituting (13), (15), and (17) into equation (16), we can express the labor share more compactly as:

$$l_{i,t} = \frac{1}{A_{i,t}} \left[\max\left\{0, \mu_i - \lambda_t \frac{A_{1,t}}{A_{i,t}} \sigma_y(i)^\gamma \right\} + \frac{\pi}{1+n} \max\left\{0, \mu_i - \frac{\lambda_{t-1}}{\beta R^*} \frac{A_{1,t}}{A_{i,t}} \sigma_o(i)^\gamma \right\} \right]. \tag{18}$$

Equation (18) implies that, given the sequence $\{\lambda_t\}_{t=-1}^{\infty}$, we can characterize the entire path of labor shares $\{l_{i,t}\}_{t=0}^{\infty}$ in each sector. To do so, we begin by determining λ_{-1}, which is pinned down by the consistency between the initial old generation's savings and their optimal consumption. Specifically, λ_{-1} solves:

$$s_{-1} \cdot \frac{R^*}{\pi} = \sum_{i=1}^{I} \frac{A_{1,0}}{A_{i,0}} \max\left\{0, \mu_i - \lambda_{-1} \cdot \frac{1}{\beta R^*} \cdot \frac{A_{1,0}}{A_{i,0}} \cdot \sigma_o(i)^\gamma \right\}. \tag{19}$$

Given λ_{-1}, we can solve for λ_0 using the labor market clearing condition at $t = 0$:

$$\sum_{i=1}^{I} l_{i,0} = 1,$$

where each $l_{i,0}$ is determined by:

$$l_{i,0} = \frac{1}{A_{i,0}} \left[\max\left\{0, \mu_i - \lambda_0 \frac{A_{1,0}}{A_{i,0}} \sigma_y(i)^\gamma \right\} + \frac{\pi}{1+n} \max\left\{0, \mu_i - \frac{\lambda_{-1}}{\beta R^*} \frac{A_{1,0}}{A_{i,0}} \sigma_o(i)^\gamma \right\} \right]. \tag{20}$$

Subsequently, for each $t \geq 1$, we can compute λ_t recursively from:

$$1 = \sum_{i=1}^{I} \left[\frac{1}{A_{i,t}} \left(\max\left\{0, \mu_i - \lambda_t \frac{A_{1,t}}{A_{i,t}} \sigma_y(i)^\gamma \right\} + \frac{\pi}{1+n} \max\left\{0, \mu_i - \frac{\lambda_{t-1}}{\beta R^*} \frac{A_{1,t}}{A_{i,t}} \sigma_o(i)^\gamma \right\} \right) \right]. \tag{21}$$

This recursive procedure allows us to characterize the full equilibrium path of allocation and prices across all sectors and time periods.

The competitive equilibrium can now be summarized as follows:

Proposition 1. *Given the exogenous rate of return on savings R^*, the structural parameters $\{\beta, \pi, \mu, \gamma, n\}$, the preference rankings $\sigma_y(i)$ and $\sigma_o(i)$, the initial old-age savings $s_{-1} > 0$, and the exogenous processes $\{A_{i,t}\}_{i=1}^I$ for all $t \geq 0$, a dynamic competitive equilibrium is characterized by sequences of prices $\{p_{i,t}, w_t, R_t\}_{i=1,\ldots,I;\,t\geq 0}$, a sequence of shadow prices $\{\lambda_t\}_{t=-1}^\infty$, sequences of labor shares $\{l_{i,t}\}_{i=1,\ldots,I;\,t\geq 0}$, and a sequence of individual savings $\{s_t\}_{t=0}^\infty$, such that the following conditions hold:*

(i) ***Price normalization and factor prices:***

$$
\begin{aligned}
R_t &= R^* \quad \textit{for all } t \geq 0, \\
p_{1,t} &= 1 \quad \textit{for all } t \geq 0, \\
w_t &= A_{1,t} \quad \textit{for all } t \geq 0, \\
p_{i,t} &= \frac{w_t}{A_{i,t}} = \frac{A_{1,t}}{A_{i,t}} \quad \textit{for all } i = 1, \ldots, I \textit{ and } t \geq 0.
\end{aligned}
$$

(ii) ***Initial shadow price:***

$$
s_{-1} \cdot \frac{R^*}{\pi} = \sum_{i=1}^{I} \frac{A_{1,0}}{A_{i,0}} \max\left\{0, \mu_i - \lambda_{-1} \cdot \frac{1}{\beta R^*} \cdot \frac{A_{1,0}}{A_{i,0}} \cdot \sigma_o(i)^\gamma\right\}.
$$

(iii) ***Recursive law of motion for shadow prices λ_t:***

$$
1 = \sum_{i=1}^{I} \frac{1}{A_{i,t}} \left[\max\left\{0, \mu_i - \lambda_t \cdot \frac{A_{1,t}}{A_{i,t}} \cdot \sigma_y(i)^\gamma\right\} + \frac{\pi}{1+n} \max\left\{0, \mu_i - \frac{\lambda_{t-1}}{\beta R^*} \cdot \frac{A_{1,t}}{A_{i,t}} \cdot \sigma_o(i)^\gamma\right\}\right],
$$

for all $t \geq 0$.

(iv) ***Labor allocation across sectors:***

$$
l_{i,t} = \frac{1}{A_{i,t}} \left[\max\left\{0, \mu_i - \lambda_t \cdot \frac{A_{1,t}}{A_{i,t}} \cdot \sigma_y(i)^\gamma\right\} + \frac{\pi}{1+n} \max\left\{0, \mu_i - \frac{\lambda_{t-1}}{\beta R^*} \cdot \frac{A_{1,t}}{A_{i,t}} \cdot \sigma_o(i)^\gamma\right\}\right],
$$

for all $i = 1, \ldots, I$ and $t \geq 0$.

(v) ***Individual savings:***

$$s_t = \left(\frac{R^*}{1+n}\right)^t s_{-1}, \quad \textit{for all } t \geq 0.$$

Technically, Proposition 1 highlights the central role of the shadow price sequence $\{\lambda_t\}_{t=-1}^{\infty}$ in determining the equilibrium dynamics. In fact, this proposition defines a non-linear mapping $\lambda_{t-1} \mapsto \lambda_t$ via the recursive conditions stated in parts (ii) and (iii). Once this sequence is determined, all other equilibrium variables — including prices, allocations, and sectoral labor shares — can be recovered recursively. Moreover, the structure of the optimal consumption rules implies that the equilibrium allocations are piecewise linear in λ_t, due to the presence of the $\max\{0, \cdot\}$ operator. This structure introduces the possibility of corner solutions, where some sectors may become non-participating in certain periods depending on relative productivity and preference rankings.

Part (iv) shows that as $\sigma_y(i)^\gamma \uparrow$ increases, the number of ranks the young give to a certain good i is high, which indicates less priority in their consumption, thus **few labour** is reallocated to certain sector i. Meanwhile, an increase in $\sigma_o(i)^\gamma \uparrow$ means that the number of ranks the old give to a certain good i is high, which indicates less priority in their consumption, thus **few labour** is reallocated to sector i. For the probability to survive, $\pi \uparrow$, or population growth drop, $n \downarrow$, the higher the weight to the aging situation and preference for goods consumed by the old $\Rightarrow$, the more labour shifts toward health/services sector. Lastly, the bliss point, $\mu_i = 0$, where economy chooses not to eat good i at all $\Rightarrow$ no labor will be reallocated to that sector i.

5 Data and Empirical Study

5.1 Data

To empirically investigate the effect of the aging population on structural transformation, we extended the sectoral labor productivity database from various sources, followed Herrendorf et al. [2022] and Cravino et al. [2022].

The level of income per capita and the aggregate labor productivity dataset are taken from the Penn World Table (PWT) Version 10 [Feenstra et al., 2015] and the Groningen Growth and Development Centre (GGDC) [Inklaar and Timmer, 2014], respectively. These databases will help us capture the development paths and aggregate productivity in more detail.

To analyze at the sectoral level, we collected the value added at constant and current prices and also persons employed in each sector from the Economic Transformation Database (ETD)[5]. This dataset contains the economic growth and labor inputs for 51 economies in Africa, Asia, and Latin America, and they have already been classified into 12 sectors. Twelve sectors include agriculture, mining, manufacturing, construction, utilities, trade, transportation, financial services, business services, real estate, personal services, and government services.

Although the ETD provides a database in 12 sectors, the previous database on sectoral productivity and employment share provided by GGDC only classified into ten sectors. We then follow Herrendorf et al. [2022] and reclassify and categorize the disaggregated production activities from the ETD into the following ten categories: (A) agriculture, (1) mining, (2) manufacturing, (3) utilities, (4) construction, (5) wholesale, (6) transport, (7) finance, (8) government services, and (9) personal services. We include trade and other services in the personal services sector, business services, and real estate in the financial service sector.

To analyze the three sectors model, we group these ten sectors as agricultural, industry, and services. The Agricultural sector contains only (A) agricultural sector; the Industry sector contains (1) mining, (2) manufacturing, (3) utilities, (4) construction, (5) wholesale sectors; the Service sector contains (6) transport, (7) finance, (8) government services and (9) personal services.

Moreover, the ETD dataset only includes the economic growth and labor inputs from 1990 to 2018. We then expanded this dataset by merging it with the Groningen Growth and Development Centre (GGDC) from De Vries et al. [2015] since the GGDC dataset covers the period from 1950 to 2013. Therefore, our data currently covers a more extended period than the usual ETD dataset. Another problem is that the ETD dataset does not allow for sectoral comparison across countries as they do not have the sectoral PPP (purchasing power parity). So, we cannot calculate the productivity levels at constant international prices. On the other hand, the GGDC does provide productivity levels at continuous international prices. Therefore, we followed Herrendorf et al.(2022) and acquired two more datasets, the Africa sector database (ASD)[6] and the Productivity

[5]See De Vries et al. [2021] for more information on Economic Transformation Database (ETD).
[6]See more in De Vries et al. [2015].

Level Database (PLD)[7] to get the sectoral PPPs of 11 Sub-Saharan African countries and 42 developing countries, respectively. After combining these two datasets with the extended ETD, we get the international price of sectoral productivity in 53 countries. Sectoral productivity can be calculated as follows:

$$SLP(currentprice) = \frac{SVA(currentprice)}{SEM} \tag{22}$$

Where SLP represents sectoral labor productivity at the current price, which is the ratio of sectoral value-added (SVA) to sectoral employment (SEM), we will use the sectoral PPPs to transform the sectoral labor productivity at the current price into an international price. This will allow us to compare sectoral labor productivity across countries.

$$SLP(internationalprice) = \frac{SVA(currentprice)}{sectoralPPPs} \tag{23}$$

Another point of concern is that the ETD dataset covers mainly developing countries and includes only a few developed nations. We then extend the dataset by adding the dataset of selected advanced countries as follows: the U.S., Denmark, France, Germany, Italy, Netherlands, Spain, Sweden, and the U.K. We combine the dataset from EUKLEMS productivity database to expand the sectoral productivity and employment share of our samples. After combining this dataset, we obtained observations in 62 countries from 1960 to 2018.

Next, we follow Üngör [2017] and use the data from PWT Version 10 to obtain the real GDP per employed person, approximating these countries' aggregate labor productivity levels starting in 1963.

All data related to demographic structure, such as old-age dependency ratio, percentage of the old-age population, total population, birth rate, mortality rate, and life expectancy at birth, are acquired from the World Bank Databank. Some other control variables such as GDP per capita, trade as a percentage of GDP, government final consumption as a percentage of GDP, human capital index, control of corruption, and other

[7]See more in Timmer et al. [2014].

related control variables are taken from the World Bank Databank and the World Governance Index (WDI). We have about 3,481 observations with 59 countries (44 developing countries and 15 developed countries)[8].

The dataset covers the period from 1960 to 2018. So far, our dataset has covered most countries worldwide longer than previous research. The total GDP of our selected samples accounts for 70.25 percent of world GDP in 2018[9]. It helps us better understand the dynamic of worker reallocation across sectors over a long period. Since we analyze the aging effect and structural transformation, an extended period will present more apparent dynamics of worker movement, the development of countries, and how economies move towards an aging society. Our dataset is not yet open to the public as we still need to clarify the rights over this dataset with the sponsor. However, once it is published, the dataset will be available upon request[10].

Before statistically testing the relationship between structural transformation and the old-age population, we use the data to illustrate the comparison of employment share in the industry to the non-agricultural sector by the level of income (Figure 1). Note also that employment share in the non-agricultural sector consists of the share in the industry and service sectors. For low-income and lower-middle-income countries, employment share in the industry is still on the rise compared to non-agricultural sectors.

At the same time, the picture is different for upper-middle-income and high-income countries. We see the returning point of industry employment share. Employment share in industry decreases when countries become more developed. This pattern is consistent with literature suggesting the development process starts from "de-agriculturalization" toward "de-industrialization." In other words, due to development, high productivity in the agricultural sector induces labor to move from the agricultural sector to industry. Then, from industry to the service sector. One more important message from this figure is that the structural transformation process happens differently across countries' levels of development [Huneeus and Rogerson, 2023].

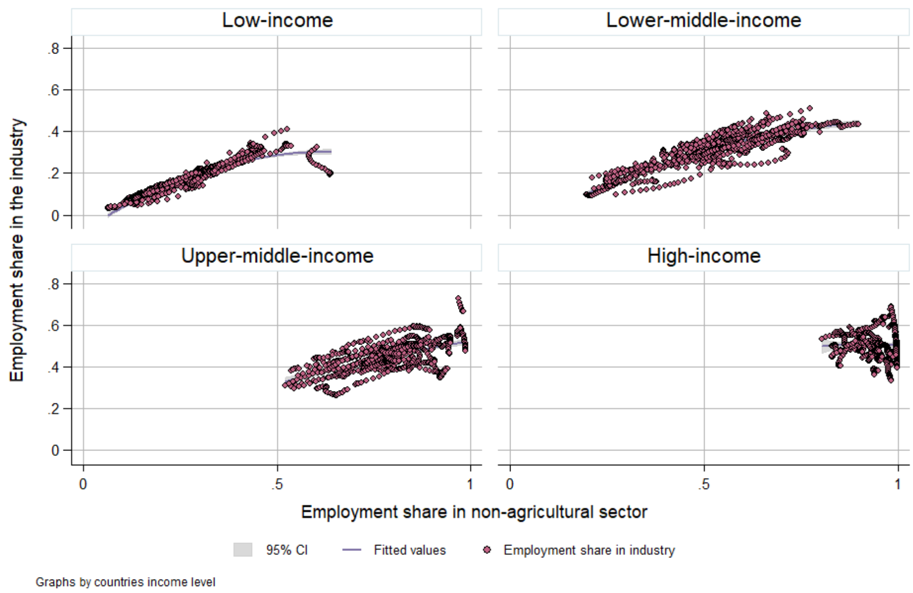
Although we see the pattern of structural transformation moving from agriculture

[8]We must remove some countries where the series contains massive breaks, or their countries are small islands. This left us with about 59 countries in total. See the Appendix for the list of studied countries.

[9](67.8 trillion USD/96.5 trillion USD)*100=70.25 percent

[10]Contact the authors

Fig. 1. The comparison of employment share in the industry to the non-agricultural sector



Source: The authors' calculation, modified from Huneeus and Rogerson [2023].
Notes: The figure presents the comparison of employment share in the industry to the non-agricultural sector—data sourced extended by the authors.

toward industry (industrialization) at the beginning of development, we also observe a slowdown in industry employment share as the country develops (as we can see from the bottom right panel in Figure 1). It raises the question of what causes such a pattern.

There are many conjectures about the hump-shaped industry sector. One of them is trade and globalization. Uy et al. [2013] highlight the linkage between globalization and structural change. There shows a hump-shaped pattern in manufacturing employment shares for middle and upper-income countries using a multi-sector open economy model to calibrate South Korea's structural change from 1971 to 2005. A country's comparative advantage in manufacturing becomes more pronounced as trade costs decrease.

Agriculture and manufacturing are impacted by changing trade costs and total factor productivity (TFP). In contrast, TFP changes mainly influence the services sector over time as it is treated as non-tradable goods. Others genuinely mention the demographic transition toward an aging society as the main cause of the de-industrialization pattern, especially in developed economies.

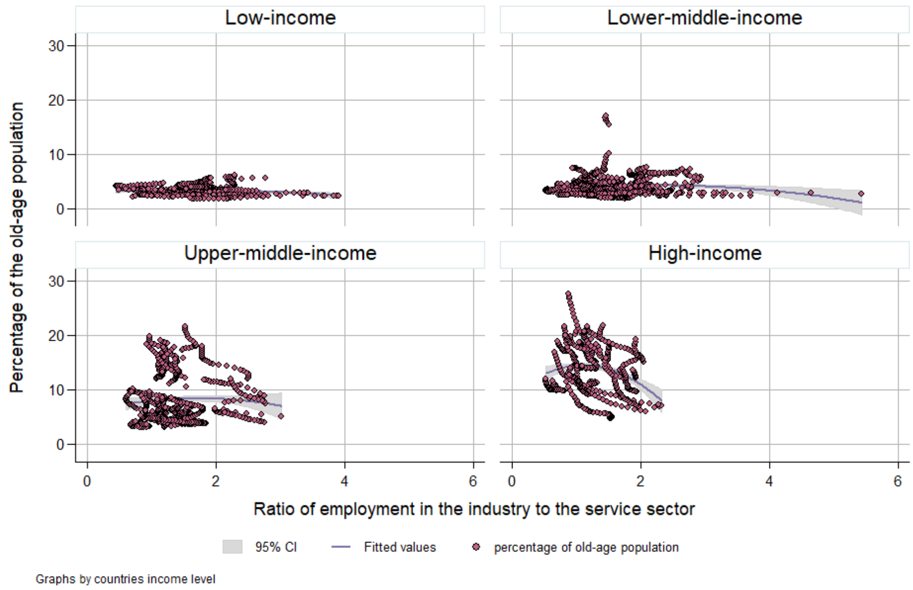
Siliverstovs et al. [2011] employ dynamic panel data analysis on datasets of 51 developing and developed economies. Their study reveals that aging remains a significant factor affecting sectoral employment share.

Aging positively impacts worker share in service-related sectors, particularly in personal services, community, and financial services. On the other hand, aging induces a decline in agricultural and manufacturing employment shares. More recent work from Cravino et al. [2022] also suggests that a higher proportion of the old-age population induces higher demand for goods and services from the service sector.

Does demographic shift take any responsibility for countries' structural transformation process? Although there are some explanations for this issue, it still needs to be more conclusive whether the aging population impacts structural transformation and how it might affect economic growth. Therefore, we start by looking at the data to test this hypothesis.

Figure 2 depicts the relationship between the percentage of the old-age population and the ratio of employment in the industry to the service sector by income level. It can be seen that for low-income and lower-middle-income countries, their proportion of the old-age population is still low, below ten percent of the total population, and the ratio of employment in industry to service sector spread around 1.5 to 5 (on the top-left and

Fig. 2. Relationship between the percentage of the old-age population and the ratio of employment in the industry to the service sector



Source: The authors' calculation.
Notes: The figure presents the comparison of employment share in the industry to the non-agricultural sector—data sourced extended by the authors.

top-right panels of Figure 2). It means the proportion of workers in the industry still is higher than in the service sector.

On the other hand, for upper-middle-income and high-income countries, where the proportion of the aging population becomes more significant than that of those counterparts, the number of workers in the industry and service sector spreads between 1 and 3 (on the bottom-left and bottom-right panels of Figure 2). As the country becomes aged[11] , employment share in the industry and the service sector is likely to be indifferent.

5.2 Empirical Strategy

We construct the baseline model specification for an unbalanced panel data of 60 developing and developed countries from 1960 to 2018. Our model is modified from Cravino et al. [2022] to test how aging may affect a change in the sectoral labor share and sectoral labor productivity, in particular in agricultural, industry, and services sectors as Equation (3):

$$\begin{gathered} share_{i,m,t} = \alpha + \beta_1 OADR_{i,t} + \beta_2 share_{i,m,t-1} + \beta_3 Y_{i,t} + \\ \beta_4 Ysq_{i,t} + \beta_5 \mathbf{X}_{i,t} + \mu_i + \lambda_t + \epsilon_{i,t} \end{gathered} \tag{24}$$

Where $share_{i,m,t}$ is the employment share of country i at time t in sector m. Sector m includes (A) agriculture, (I) Industry, and (S) service. $share_{i,m,t-1}$ represents each employment share of country i in sector m of the previous period. $OADR_{i,t}$ is an indicator related to the aging population, that is, the ratio of the old-age population to the total population (percentage of old-age population). It is the factor of interest here. $Y_{i,t}$represents GDP per capita of the contemporaneous period in natural logarithmic form, and $Ysq_{i,t}$ represents the squared natural logarithm of GDP per capita. This is to capture the non-linear relationship between the level of development and employment share of interested sectors. For the baseline model, we only include GDP per capita and squared GDP per capita as the control variable, followed [Cravino et al., 2022]. Then, we will include $\mathbf{X}_{i,t}$, the set of control variables, such as trade share, government final consumption to GDP, and human capital index, into the extended model. μ_i captures the country-specific effect. λ_t is a time dummy, and $\epsilon_{i,t}$ is the shock for each period.

[11]The country is considered an altogether aging society when the percentage of the old-age population is above 20 percent of the total population.

For the model specification, our dataset is unbalanced panel data. So, we perform the panel data with multi-way fixed-effect (syntax: reghdfe). Our models try to control individual specific effects that do not vary across the time of each entity. They also account for heteroskedasticity and serial correlation within an entity by conducting the robust error term. Regarding the issue of endogeneity, we consider demographic variables to be exogenous, meaning they are not affected by other variables in our model.

Once again, we are interested in the coefficient β_1, which represents the marginal effect of the old-age population on the employment share of each sector. We expect an increase in the old-age population to induce a higher employment share in the sector related to services, especially for the sample of developed countries.

6 Results and Discussion

We begin to analyze how aging may affect structural transformation, the allocation of employment from one sector to another, for each income group. Columns 2 to 4 from Table 1 present the testing results for the whole sample, showing how the percentage of the old-age population correlated to employment share in the agricultural, industry, and service sectors, respectively. We observe that an increase of 1 percent in the aging population significantly induces lower employment share in agriculture and industry by 0.003 and 0.005, respectively. In contrast, as the old-age population has increased, employment share in the service sector is raised by 0.009 at a 99 percent confidence interval level. For the baseline model, we include only GDP per capita and GDP per capita squared as control variables following Cravino et al. [2022].

Having a look at each level of development[12], the results from columns 5 to 7 of Table 1 suggest a positive trend of employment share in the service sector as the proportion of the old age population has increased in developed economies. In contrast, the employment share in agriculture and industry declined as the countries aged. The results of developed economies are consistent with the previous study by [Cravino et al., 2022]. However, the effects of an aging population on sectoral employment share in developing economies still need to be investigated. Although we find that the aging population tends to lessen the share of workers in the agricultural sector and increase worker share in the service sector, we cannot say anything about industry employment share as the coefficient of

[12]See the Appendix for more detail on the definition.

Table 1

Regression Results Using Baseline Model

	(em_agri_all)	(em_manu_all)	(em_serv_all)	(em_agri_h)	(em_manu_h)	(em_serv_h)	(em_agri_l)	(em_manu_l)	(em_serv_l)
old-age pop	-0.003***	-0.006***	0.009***	-0.005***	-0.004***	0.009***	-0.007***	-0.002	0.009***
	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.000)	(0.002)	(0.002)	(0.002)
ln_GDPsq 005	-0.336***	0.412***	-0.076***	0.047	0.087	-0.134	0.020	0.140***	-0.159***
	(0.028)	(0.021)	(0.015)	(0.157)	(0.245)	(0.170)	(0.031)	(0.023)	(0.019)
ln_GDPsq	0.011***	-0.020***	0.009***	-0.003	-0.008	0.011	-0.014***	-0.001	0.015***
	(0.002)	(0.001)	(0.001)	(0.008)	(0.012)	(0.008)	(0.002)	(0.002)	(0.001)
Constant	2.420***	-1.626***	0.206***	-0.021	0.532	0.489	1.173***	-0.686***	0.513***
	(0.110)	(0.082)	(0.056)	(0.799)	(1.263)	(0.880)	(0.113)	(0.084)	(0.068)
N	2606	2606	2606	542	542	542	2063	2063	2063
r2	0.956	0.914	0.940	0.934	0.884	0.943	0.943	0.906	0.912
r2_a	0.955	0.912	0.938	0.930	0.878	0.940	0.941	0.903	0.910

Source: Author's calculation.
Note: For the baseline model, we test the relationship between the percentage of the old-age population and employment share in three main sectors; agriculture, industry, and service. The main dependent variables are employment share in agricultural, industry, and service sectors. This table presents the results of developing (with subscription "l") separately, developed (with subscription "h") countries, and the whole samples (with subscription "all"). The main dependent variable is the percentage of the old-age population (percentage). We add two control variables, GDP per capita and GDP per capita squared. Standard errors in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

'percentold' in column 9 is insignificant.

We further examine the model classified by country income level, shown in Table 2. The results from high-income countries (columns 2 to 4) are consistent with those of developed economies in Table 1. This implies that employment share in the service sector will increase as the countries age, while workers usually move out of the agricultural and industry sectors. This phenomenon happens when countries' income levels rise.

Table 2

Regression Results Using Baseline Model for Each Income Group

	(em_agri_h)	(em_manu_h)	(em_serv_h)	(em_agri_m)	(em_manu_m)	(em_serv_m)	(em_agri_l)	(em_manu_l)	(em_serv_l)
old-age pop	-0.005***	-0.004***	0.009***	-0.016***	-0.001	0.016***	0.012+	0.003	-0.015***
	(0.000)	(0.001)	(0.000)	(0.002)	(0.001)	(0.002)	(0.007)	(0.006)	(0.002)
ln_GDP	0.047	0.087	-0.134	-0.642***	0.758***	-0.116+	0.023	-0.106	0.083
	(0.157)	(0.245)	(0.170)	(0.089)	(0.064)	(0.059)	(0.140)	(0.101)	(0.073)
ln_GDPsq	-0.003	-0.008	0.011	0.027***	-0.038***	0.011**	-0.016	0.019*	-0.002
	(0.008)	(0.012)	(0.008)	(0.006)	(0.004)	(0.004)	(0.012)	(0.008)	(0.006)
Constant	-0.021	0.532	0.489	3.886***	-3.258***	0.372	1.184**	0.088	-0.272
	(0.799)	(1.263)	(0.880)	(0.364)	(0.257)	(0.240)	(0.430)	(0.310)	(0.222)
N	542	542	542	1509	1509	1509	553	553	553
r2	0.934	0.884	0.943	0.906	0.857	0.879	0.895	0.836	0.909
r2_a	0.930	0.878	0.940	0.903	0.851	0.874	0.890	0.828	0.904

Source: Author's calculation.
Note: For the baseline model, we test the relationship between the percentage of the old-age population and employment share in three main sectors; agriculture, industry, and service. The main dependent variables are employment share in agricultural, industry, and service sectors. This table presents the results of developing (with subscription "l") separately, developed (with subscription "h") countries, and the whole samples (with subscription "all"). The main dependent variable is the percentage of the old-age population (percentage). We add two control variables, GDP per capita and GDP per capita squared. Standard errors in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Looking at the middle-income countries in columns 5 to 7, we observe the same pattern as the results for developing countries from Table 1. Old-age population pushes workers to move out of the agricultural sector, as we can see in the coefficient of 'percentold' in column 5 of Table 2. Daymard [2020] found empirically that for small closed-economy countries, people reallocated towards the industry once they had a higher productivity growth in the agricultural sector. As the productivity of the agricultural sector increases, inelastic demand cannot absorb all the excess supply in the agricultural sector, thus pushing workers to move from the traditional economy towards modern activities.

While the effect of the old-age population on the industry share of workers is unclear, we observe a significant increase in the share of workers in the service sector, around 0.016 percent, as the old-age population increased by 1 percent. The reason for an unclear industry employment share pattern is that middle-income countries usually have various development patterns. Huneeus and Rogerson [2023] find that some developing economies have already passed the cycle of an increase in the share of industry workers ('premature de-industrialization), while some are still moving from agriculture to industry. For the low-income countries, we see a positive correlation between the aging population and workers' share in the agricultural sector (see Columns 8-10 in Table 2). In low-income countries, aging people are stuck in the agricultural sector due to higher migration costs [Cao et al., 2023]. Using a spatial equilibrium model, Cao et al. [2023] suggests that their mobility is less than any other age group, especially in rural areas. Moreover, the employment share in the service sector decreases when countries have a higher proportion of the old-age population. The reason could be that the proportion of the aging population needs to be larger, or the higher demand for service goods needs to match the greater supply, which usually happens in less developed countries.

Table 3 presents extensions of the baseline model, including a related set of control variables. Adding the human capital index as one control variable lowers the employment share in agriculture by around 16 percent while increasing the employment share in industry and service sectors by 7.8 and 8.1 percent, respectively. Columns 8 to 10 and 11 to 13 present the models with two more additional controls: government spending per GDP and share of trade. After controlling variables related to employment share, the regression results still suggest that an increase in the old-age population correlates to a decrease in agriculture and industry employment share while raising the share of workers in services sectors.

Next, we choose Model 4 from Table 3 to test each country's income level. Table 4 illustrates that after controlling related variables and classifying our sample by their income level, an increase in the old-age population induces a change in employment share in the agricultural, industry, and services sectors.

For high-income countries, the share of workers in agricultural and industry sectors significantly decreases when countries age (Columns 2 to 4 Table 4). This means that

Table 3
Regression Results Using Various Extended Models

	(em_agri_1)	(em_manu_1)	(em_serv_1)	(em_agri_2)	(em_manu_2)	(em_serv_2)	(em_agri_3)	(em_manu_3)	(em_serv_3)
old-age pop	0.001	-0.008***	0.007***	-0.003***	-0.005***	0.007***	-0.002*	-0.005***	0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)
ln_GDP	-0.366***	0.427***	-0.061***	-0.541***	0.600***	-0.060**	-0.493***	0.589***	-0.096***
	(0.029)	(0.021)	(0.015)	(0.028)	(0.023)	(0.021)	(0.027)	(0.024)	(0.023)
ln_GDPsq	0.018***	-0.023***	0.005***	0.027***	-0.031***	0.004***	0.024***	-0.031***	0.007***
	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
hc	-0.159***	0.078***	0.081***	-0.094***	0.014^{+}	0.081***	-0.094***	0.014^{+}	0.080***
	(0.007)	(0.005)	(0.004)	(0.012)	(0.008)	(0.009)	(0.012)	(0.008)	(0.009)
govspend_perGDP				-0.002***	0.002***	-0.000	-0.002***	0.002***	-0.000
				(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
trade							-0.166***	0.040*	0.127***
							(0.030)	(0.018)	(0.028)
Constant	2.486***	-1.658***	0.172**	3.175***	-2.409***	0.235**	2.988***	-2.365***	0.377***
	(0.108)	(0.081)	(0.056)	(0.116)	(0.102)	(0.085)	(0.112)	(0.105)	(0.094)
N	2606	2606	2606	1529	1529	1529	1529	1529	1529
r2	0.969	0.924	0.951	0.979	0.942	0.962	0.980	0.942	0.963
r2_a	0.968	0.922	0.950	0.978	0.939	0.960	0.979	0.940	0.962

Source: Author's calculation.
Note: For the extended models, we test the relationship between the percentage of the old-age population and employment share in three main sectors; agriculture, industry, and service. The main dependent variables are employment share in agricultural, industry, and service sectors. The main dependent variable is the percentage of the old-age population (percentold). The control variables are GDP per capita and GDP per capita squared, human capital ("hc"), government spending to GDP ("govspend_perGDP"), and trade share ("trade"). Standard errors in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 4
Regression Results Using Various Extended Models for Each Income Group

	(em_agri_h)	(em_manu_h)	(em_serv_h)	(em_agri_m)	(em_manu_m)	(em_serv_m)	(em_agri_l)	(em_manu_l)	(em_serv_l)
old-age pop	-0.004***	-0.004***	0.008***	-0.003	0.002	0.002	0.106*	-0.095**	-0.011
	(0.000)	(0.000)	(0.000)	(0.002)	(0.002)	(0.001)	(0.042)	(0.030)	(0.016)
ln_GDP	0.384**	-0.091	-0.292^{+}	-0.440***	0.893***	-0.453***	-0.251	-0.090	0.341^{+}
	(0.124)	(0.182)	(0.152)	(0.056)	(0.061)	(0.047)	(0.340)	(0.261)	(0.199)
ln_GDPsq	-0.021***	0.005	0.016*	0.021***	-0.049***	0.028***	0.005	0.017	-0.022
	(0.006)	(0.009)	(0.007)	(0.004)	(0.004)	(0.003)	(0.029)	(0.023)	(0.016)
hc	0.015	-0.057***	0.042***	-0.151***	0.033**	0.119***	-0.173**	0.185***	-0.012
	(0.012)	(0.009)	(0.012)	(0.011)	(0.012)	(0.007)	(0.052)	(0.029)	(0.047)
govspend_perGDP	-0.002***	0.000	0.002**	-0.001^{+}	0.001***	-0.001^{+}	-0.000	0.004***	-0.004***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.002)	(0.001)	(0.001)
trade	0.019**	-0.015	-0.004	-0.063*	0.020	0.043*	0.160*	-0.048	-0.112
	(0.007)	(0.011)	(0.011)	(0.025)	(0.025)	(0.019)	(0.075)	(0.046)	(0.080)
Constant	-1.615**	1.172	1.442^{+}	2.870***	-3.713***	1.843***	1.999^{+}	0.026	-1.025
	(0.619)	(0.930)	(0.786)	(0.227)	(0.234)	(0.189)	(1.067)	(0.818)	(0.620)
N	477	477	477	855	855	855	194	194	194
r2	0.949	0.942	0.963	0.966	0.891	0.945	0.917	0.854	0.939
r2_a	0.945	0.938	0.961	0.964	0.885	0.942	0.906	0.835	0.932

Source: Author's calculation.
Note: For the baseline model, we test the relationship between the percentage of the old-age population and employment share in three main sectors; agriculture, industry, and service. The main dependent variables are employment share in agricultural, industry, and service sectors. This table presents the results of high-income (with subscription "h"), middle-income (with subscription "m"), and low-income (with subscription "l") countries separately. The main dependent variable is the percentage of the old-age population (percentold). The control variables are GDP per capita and GDP per capita squared, human capital ("hc"), government spending to GDP ("govspend_perGDP"), and trade share ("trade"). Standard errors in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

people will move out of agriculture and industry when the level of development is high enough. Workers also move more toward the service sector as countries become old. This is consistent with Cravino et al. [2022], which explains the older-age population's higher demand for service goods, pushing workers to move more to the service sector. However, the significant sign for the middle-income country group is gone, and we observe different patterns for low-income countries once accounting for the level of human capital. For low-income countries, as the aging population increases, more people stay longer in agriculture, and employment share in the industry is reduced.

As we can see from the regression results in Table 3 and Table 4, there is a hump-shaped reduction in manufacturing and a rise in services after saturated development in high-income countries. However, once we include human capital variables in the models, the results for middle- and low-income countries have changed. Buera and Kaboski [2009] argue that the standard structural transformation models fail to explain the process of de-industrialization and why workers move out of the industry. They suggest that human capital is a crucial factor in explaining the reallocation of workers out of manufacturing and the rise in the service sector. The difference in human capital accumulation across sectors and sector-specific factor distortions helps explain the distortion in production and, thus, a decrease in employment share in the industry.

Therefore, we also incorporate human capital into the models to test whether human capital and the aging population affect the reallocation of workers during the structural transformation process. Table 5 presents the results focusing on the primary interest variable: the interaction between human capital and the old-age population in affecting sectoral employment share.

For high-income countries, results show in Columns 2 to 4 and Table 5 that an increase in the old-age population induces workers to stay in the agricultural sector (the marginal effect of the aging population is 0.012+(-0.0045*0.055) = 0.012). However, as human capital increases, population aging reduces the agricultural sector's employment share.

On the other hand, aging reduces the employment share in manufacturing (the marginal effect of the aging population is -0.018+(0.00396*-0.0934) = -0.107), but higher human capital in the aging situation increases the employment share in manufacturing (See Column 3). For the service sector employment share, results turn insignificant once the model includes interaction effect terms between aging and human capital (See Column 4).

For middle-income countries, the results suggest that the employment share in the agricultural sector tends to decrease as the percentage of the old-age population increases. Column 5 of Table 5 presents the marginal effect of an increase in 1 percent of the old-age population:- 0.0387+(0.0114*-0.181) = -0.04. This means that a rise of 1 percent in the old-age population tends to reduce the employment share in the agricultural sector on average by 0.04.

Table 5
Regression Results Using Various Extended Models with Interaction Effect Terms between Old-age Population and Human Capital for Each Income Group

	(em_agri_h)	(em_manu_h)	(em_serv_h)	(em_agri_m)	(em_manu_m)	(em_serv_m)	(em_agri_l)	(em_manu_l)	(em_serv_l)
old-age pop	0.012^{**}	-0.018^{***}	0.006	-0.039^{***}	0.013^{*}	0.026^{***}	-0.153	-0.127^{+}	0.280^{***}
	(0.004)	(0.004)	(0.004)	(0.005)	(0.006)	(0.004)	(0.101)	(0.076)	(0.055)
ln_GDP	0.290^{*}	-0.038	-0.252	-0.262^{***}	0.839^{***}	-0.578^{***}	-0.089	0.006	0.083
	(0.115)	(0.184)	(0.158)	(0.061)	(0.066)	(0.055)	(0.308)	(0.222)	(0.201)
ln_GDPsq	-0.017^{**}	0.003	0.014^{+}	0.010^{**}	-0.046^{***}	0.035^{***}	-0.007	0.010	-0.003
	(0.006)	(0.009)	(0.008)	(0.004)	(0.004)	(0.003)	(0.027)	(0.019)	(0.017)
hc	0.055^{***}	-0.093^{***}	0.039^{*}	-0.181^{***}	0.041^{***}	0.140^{***}	-0.559^{***}	0.119	0.440^{***}
	(0.010)	(0.013)	(0.016)	(0.011)	(0.012)	(0.008)	(0.127)	(0.100)	(0.072)
govspend_perGDP	-0.002^{***}	-0.000	0.002^{**}	-0.000	0.001^{**}	-0.001^{*}	-0.001	0.004^{***}	-0.003^{**}
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.002)	(0.001)	(0.001)
trade	-0.021	-0.003	0.024	-0.065^{+}	0.053^{*}	0.012	-0.038	0.005	0.033
	(0.018)	(0.031)	(0.031)	(0.033)	(0.027)	(0.033)	(0.069)	(0.048)	(0.040)
old-age pop X hc	-0.004^{***}	0.004^{***}	0.001	0.011^{***}	-0.004^{*}	-0.008^{***}	0.124^{**}	0.018	-0.142^{***}
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.038)	(0.028)	(0.024)
Constant	-1.230^{*}	0.990	1.240	2.249^{***}	-3.528^{***}	2.279^{***}	2.280^{*}	-0.169	-1.110^{+}
	(0.576)	(0.945)	(0.820)	(0.242)	(0.252)	(0.218)	(0.995)	(0.738)	(0.577)
N	477	477	477	855	855	855	194	194	194
r2	0.954	0.944	0.963	0.968	0.893	0.947	0.921	0.854	0.954
r2_a	0.951	0.940	0.961	0.966	0.886	0.944	0.910	0.834	0.948

Source: Author's calculation.
Note: For the baseline model, we test the relationship between the percentage of the old-age population and employment share in three main sectors; agriculture, industry, and service. The main dependent variables are employment share in agricultural, industry, and service sectors. This table presents the results of high-income (with subscription "h"), middle-income (with subscription "m"), and low-income (with subscription "l") countries separately. The main dependent variable is the percentage of the old-age population (percentold) and the interaction terms between the old-age population and human capital ("percentold X hc"). The control variables are GDP per capita and GDP per capita squared, human capital ("hc"), government spending to GDP ("govspend_perGDP"), and trade share ("trade"). Standard errors in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

However, since the coefficient of human capital presents the minus sign, it implies that although an increase in the old-age population induces a lower employment share in the agricultural sector, it will be less pronounced when the country has higher human capital. That is because as the country becomes more developed, there is a structural change within the agricultural sector. Blanco and Raurich [2022] find that productivity in the agriculture sector has increased relative to the non-agricultural sector, which implies that agrarian moving toward more capital-intensive technology.

Looking at how the old-age population affects the employment share in industries of middle-income countries (Column 6 Table 5), we find that an increase of 1 percent of the old-age population significantly correlated to the rise in the employment share in the industry around 0.0125+(-0.0036*0.0412) = 0.0123.

However, since the coefficient of human capital presents a plus sign, it implies that more human capital in an aging situation lessens the industry employment share. Column 7 Table 5 presents the results of the relationship between aging and human capital in affecting service sector employment share in middle-income countries.

We observe that an increase in the aging population significantly induces higher employment in the service sector (the marginal effect is 0.026+(-0.0078*0.140) = 0.025). However, once human capital rises, service sector workers decrease.

To sum up for the middle-income group, when we account for human capital in the model, the results suggest that an increase of 1 percent of the aging population tends to reduce the employment share in the agricultural sector by about 0.04, increase industry and service worker share by 0.0123 and 0.025, respectively. However, when the level of human capital increases, it tends to keep workers in the agricultural sector longer and slow the movement to the industry and service sectors. Human capital helps to slow down the transition toward de-industrialization. This may be good for middle-income countries since they are moving too fast toward the industry and service sector associated with fast-growing (industry) and are stuck longer in the less productive sector (service sector) or the so-called 'premature de-industrialization.'

The results of the aging population effect for low-income countries (Columns 8 to 10, Table 5) are still inconclusive. Although we still see an increased agricultural employment share, more clarity is needed in the modern sector.

In a nutshell, we found that for **the high-income countries**, Population aging is associated with a strong movement away from agriculture and industry toward the service sector. As income levels are sufficiently high, older populations can translate their age-related preferences into actual demand, especially for health, care, and personal services. This supports the hierarchical preference mechanism, where aging accelerates service-sector expansion once basic needs are already satisfied. For **the middle-income countries**, the results are less clear, as the coefficients are statistically insignificant across all sectors. This suggests two opposing forces may offset each other: aging increases preferences for services, but income constraints limit the ability to demand age-related services. As a result, aging does not generate a dominant pattern of structural change in this group. As for **the low-income economies**, aging appears to increase retention in agricultural employment while reducing the share of industry. Although older populations may also prefer consuming more services goods, low income levels prevent this demand from being fully realized. Consequently, workers remain in subsistence agriculture rather than moving into service-related activities, leading to a structural pattern that differs sharply from high-income countries.

7 Robustness Checks

In this section, we repeat the same exercises testing the relationship between the aging population and the structural transformation of selected 59 countries (both developing and developed countries) between 1960 and 2017. Firstly, we use the old-age dependency ratio to the total population instead of a percentage of the old-age population as a proxy for an aging population. The old-age dependency ratio is calculated using the percentage of the population above 65 years to the working-age population (age 15-64 years)—data sourced from the World Bank Databank. Then, in the second part, we check whether the aging population is related to the sectoral value added.

Tables 6 and 7 illustrate the effects of the old-age population on employment share in the agricultural, industry, and service sectors. The primary dependent variables are the employment share in the agricultural, industry, and service sectors, respectively. We also classify the countries based on their development (Table 6) and income level (Table 7). The results from Table 6 suggest similar patterns to those in Table 1. Even though we use the different proxies representing our old-age population variable, the results are robust. For developed economies, a higher old-age dependency ratio increases employment share in the service sector while reducing employment share in the agricultural and industry sectors. A rise in demand for health care, social security, and other personal services from older persons can explain this situation.

Table 7 classifies the countries into high-, middle- and low-income countries. The first six columns suggest that an increase in the old-age population induces a decrease in the agricultural sector and industry employment share. In contrast, it increases the employment share in the service sector. However, the results are in comparison to those of the low-income group. Columns 8 to 10 report that an increase in the old-age population increases the employment share in the agricultural sector, though it is only statistically significant at a 90 percent level.

Additionally, an increase of 1 percent of the proportion of the old-age population induces a reduction of about 0.0678 percent in service sector employment share. The results for high-income countries are consistent with Cravino et al. [2022], which men-

Table 6
Regression Results Using Baseline Model with Old-age Dependency Ratio as a Dependent Variable

	(em_agri_all)	(em_manu_all)	(em_serv_all)	(em_agri_h)	(em_manu_h)	(em_serv_h)	(em_agri_l)	(em_manu_l)	(em_serv_l)
old-age dep	-0.000	-0.004***	0.005***	-0.003***	-0.002***	0.005***	0.001	-0.005***	0.004***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
ln_GDP	-0.310***	0.405***	-0.095***	0.025	0.060	-0.085	0.080**	0.103***	-0.183***
	(0.028)	(0.021)	(0.015)	(0.156)	(0.248)	(0.175)	(0.029)	(0.022)	(0.019)
ln_GDPsq	0.008***	-0.019***	0.011***	-0.002	-0.007	0.010	-0.019***	0.002	0.017***
	(0.002)	(0.001)	(0.001)	(0.008)	(0.012)	(0.008)	(0.002)	(0.002)	(0.001)
Constant	2.331***	-1.583***	0.251***	0.120	0.694	0.187	0.964***	-0.540***	0.576***
	(0.110)	(0.082)	(0.057)	(0.791)	(1.278)	(0.907)	(0.111)	(0.082)	(0.068)
N	2606	2606	2606	542	542	542	2063	2063	2063
r2	0.956	0.915	0.939	0.932	0.883	0.940	0.942	0.907	0.911
r2_a	0.955	0.913	0.937	0.929	0.876	0.937	0.941	0.904	0.909

Source: Author's calculation.
Note: For the baseline model, we test the relationship between the old-age dependency ratio and employment share in three main sectors: agriculture, industry, and service. The main dependent variables are employment share in agricultural, industry, and service sectors. This table presents the results of developing (with subscription "l") separately, developed (with subscription "h") countries, and the whole samples (with subscription "all"). The main dependent variable is the old-age dependency ratio(olddepen). We add two control variables, GDP per capita and GDP per capita squared, as suggested in [Cravino et al., 2022]. Standard errors in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 7
Regression Results Using Baseline Model with Old-age Dependency Ratio as a Dependent Variable for Each Income Group

	(em_agri_h)	(em_manu_h)	(em_serv_h)	(em_agri_m)	(em_manu_m)	(em_serv_m)	(em_agri_l)	(em_manu_l)	(em_serv_l)
old-age dep	-0.003***	-0.002***	0.005***	-0.004**	-0.004***	0.008***	0.009+	-0.002	-0.007***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.005)	(0.004)	(0.002)
ln_GDP	0.025	0.060	-0.085	-0.489***	0.671***	-0.182**	0.008	-0.126	0.118
	(0.156)	(0.248)	(0.175)	(0.091)	(0.064)	(0.060)	(0.137)	(0.099)	(0.077)
ln_GDPsq	-0.002	-0.007	0.010	0.016**	-0.032***	0.016***	-0.015	0.020*	-0.006
	(0.008)	(0.012)	(0.008)	(0.006)	(0.004)	(0.004)	(0.011)	(0.008)	(0.006)
Constant	0.120	0.694	0.187	3.331***	-2.909***	0.578*	1.202**	0.165	-0.367
	(0.791)	(1.278)	(0.907)	(0.371)	(0.261)	(0.242)	(0.425)	(0.305)	(0.237)
N	542	542	542	1509	1509	1509	553	553	553
r2	0.932	0.883	0.940	0.904	0.858	0.874	0.896	0.836	0.906
r2_a	0.929	0.876	0.937	0.900	0.853	0.870	0.890	0.828	0.901

Source: Author's calculation.
Note: For the baseline model, we test the relationship between the percentage of the old-age population and employment share in three main sectors; agriculture, industry, and service. The main dependent variables are employment share in agricultural, industry, and service sectors. This table presents the results of high-income (with subscription "h"), middle-income (with subscription "m"), and low-income (with subscription "l") countries separately. The main dependent variable is the old-age dependency ratio(olddepen). We add two control variables, GDP per capita and GDP per capita squared, as suggested in [Cravino et al., 2022]. Standard errors in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

tions a push-up demand for services and goods when countries age. However, we cannot generalize the results from Cravino et al. [2022] to other countries' groups.

We repeat the same exercises as Tables 1 and 2 but use the sectoral value-added instead of employment share as dependent variables. The results are presented in Tables 8 and 9. The results in Table 8 are pretty robust. They confirm that an aging population induces workers to move out of agricultural and industry sectors while pushing them toward the service sector. This is due to the high demand for health care services when countries age.

Table 8

Regression Results Using Baseline Model with Sectoral Value-added as an Independent Variable

	(em_agri_all)	(em_manu_all)	(em_serv_all)	(em_agri_h)	(em_manu_h)	(em_serv_h)	(em_agri_l)	(em_manu_l)	(em_serv_l)
old-age pop	-0.001**	-0.002*	0.003***	-0.001***	-0.005***	0.006***	-0.000	-0.005**	0.005**
	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.002)	(0.002)
ln_GDP	-0.429***	0.370***	0.059**	-0.165**	0.295	-0.130	-0.450***	0.520***	-0.070**
	(0.011)	(0.021)	(0.019)	(0.061)	(0.274)	(0.246)	(0.017)	(0.027)	(0.024)
ln_GDPsq	0.021***	-0.022***	0.001	0.008*	-0.015	0.007	0.022***	-0.032***	0.010***
	(0.001)	(0.001)	(0.001)	(0.003)	(0.013)	(0.012)	(0.001)	(0.002)	(0.002)
Constant	2.230***	-1.033***	-0.197**	0.916**	-0.869	0.953	2.302***	-1.570***	0.269**
	(0.042)	(0.080)	(0.072)	(0.310)	(1.389)	(1.248)	(0.064)	(0.100)	(0.088)
N	2502	2502	2502	538	538	538	1963	1963	1963
r2	0.949	0.797	0.803	0.913	0.968	0.973	0.934	0.761	0.714
r2_a	0.947	0.791	0.797	0.908	0.966	0.972	0.932	0.753	0.706

Source: Author's calculation.
Note: For the baseline model, we test the relationship between the percentage of the old-age population and the sectoral value-added of three main sectors; agricultural, industry, and service. The main dependent variables are sectoral value-added in agricultural, industry, and service sectors. This table presents the results of developing (with subscription "l") separately, developed (with subscription "h") countries, and the whole samples (with subscription "all"). The main dependent variable is the percentage of the old-age population (percentage). We add two control variables, GDP per capita and GDP per capita squared, as suggested in [Cravino et al., 2022]. Standard errors in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Looking at different income levels in Table 9, we observe quite a robust pattern for high-income countries. An increase of 1 percent in the aging population tends to reduce the value-added in agriculture and industry by 0.0012 and 0.0045, respectively, while increasing the value-added in the service sector by 0.0057 (see Columns 2 to 4). These results are all significant at a confidence level of 99 percent.

For middle-income countries, a high proportion of older people tends to increase the value-added in the agricultural and service sectors by 90 percent but reduce the value-added from the industry sector by 0.005 points. This could be because most middle-income countries export and have a comparative advantage in agriculture compared to high-income countries (see Columns 5 to 7).

Low-income countries' value-added in agriculture and industry decreased as there was a larger old-age population. Many workers are stuck in these sectors, reducing their productivity and value-added. As fewer people stay in the service sector, the value added is higher than in counterpart sectors.

Table 9
Regression Results Using Baseline Model with Sectoral Value-added as an Independent Variable for Each Income Group

	(em_agri_h)	(em_manu_h)	(em_serv_h)	(em_agri_m)	(em_manu_m)	(em_serv_m)	(em_agri_l)	(em_manu_l)	(em_serv_l)
old-age pop	-0.001***	-0.005***	0.006***	0.002^{+}	-0.005*	0.003^{+}	-0.006	-0.022***	0.027***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.002)	(0.002)	(0.005)	(0.006)	(0.005)
ln_GDP	-0.165**	0.295	-0.130	-0.404***	0.186**	0.219**	-0.160	-0.009	0.169
	(0.061)	(0.274)	(0.246)	(0.048)	(0.070)	(0.069)	(0.103)	(0.193)	(0.209)
ln_GDPsq	0.008*	-0.015	0.007	0.019***	-0.012**	-0.007	-0.001	0.011	-0.010
	(0.003)	(0.013)	(0.012)	(0.003)	(0.004)	(0.004)	(0.008)	(0.016)	(0.017)
Constant	0.916**	-0.869	0.953	2.127***	-0.144	-0.983***	1.398***	0.069	-0.467
	(0.310)	(1.389)	(1.248)	(0.199)	(0.285)	(0.284)	(0.319)	(0.586)	(0.631)
N	538	538	538	1367	1367	1367	595	595	595
r2	0.913	0.968	0.973	0.854	0.777	0.830	0.913	0.577	0.489
r2_a	0.908	0.966	0.972	0.848	0.769	0.823	0.909	0.556	0.464

Source: Author's calculation.
Note: For the baseline model, we test the relationship between the percentage of the old-age population and employment share in three main sectors; agriculture, industry, and service. The main dependent variables are agricultural, industry, and service value-added. This table presents the results of high-income (with subscription "h"), middle-income (with subscription "m"), and low-income (with subscription "l") countries separately. The main dependent variable is the percentage of the old-age population (percentold). We add two control variables, GDP per capita and GDP per capita squared, as suggested in [Cravino et al., 2022]. Standard errors in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

8 Conclusion

The process of structural transformation can serve as an indicator of varying levels of development among nations. As the labor reallocates across the sector, their productivity is transposed. To understand the mechanism behind the structural transformation process, which is linked to the country's level of development, one must acknowledge the importance of a shift in demographic structure toward an aging society. As countries age, the demand for service goods has increased, pushing the worker share to the service sector. However, this pattern is not consistent once we consider countries' income levels (level of development).

Therefore, we explore the correlation between an aging population and a structural transformation process, particularly regarding changes in sectoral employment share in agriculture, industry, and services, through an extended panel dataset spanning 59 developing and developed countries.

Our study points to 3 key findings. First, we confirm that the pattern of structural transformation starts from the reallocation of employment share from agriculture toward industry. As the aging population becomes more pronounced, a trend exists from the traditional sector (agriculture) to modern sectors (industry and services). Second, in an aging situation, human capital is a tool to slow down the process of de-agriculturalization and de-industrialization for the middle-income group. As the countries develop, structural change exists within agriculture. In particular, workers move from the labor-intensive to the capital-intensive agricultural sector. Third, the aging effect still needs to be more conclusive for low-income countries. We still see increased agricultural employment share and ambiguity in the modern sector. The reason could be that the proportion of the aging population needs to be larger, or the higher demand for service goods needs to match the greater supply, which usually happens in less developed countries.

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