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UNLOCKING THE INVERTED-U: EXPLORING THE THRESHOLD IMPACT OF POPULATION AGING ON INCOME INEQUALITY DYNAMICS

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Abstract. As population aging unfolds at an unprecedented scale worldwide, its impact on income inequality continues to be contentious, with no clear consensus in the literature. Rather than viewing the aging-inequality linkage as solely positive or negative, this paper introduces a modified life cycle with precautionary behavior, indicating that inequality may initially worsen with aging before stabilizing at later stages. The Dynamic Panel Threshold Kink (DPTK) regression method is used to identify the threshold point of aging intensity at which the inequality begins to moderate following a period of intensification. The findings reveal a threshold aging intensity of 1.4%, which supports an inverted-U characterization of the aging-inequality nexus. The results suggest that liberalizing trade and improving government redistribution can assist countries experiencing a rise in inequality. At the same time, the prevalence of precautionary effects due to population aging may offer a natural defense against the detrimental effects of inequality over time.

Keywords: income inequality, population aging, panel data, kink threshold regression.

JEL Classification: O15, J11.

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1. Introduction

Following the twin threat of population aging and rising income inequality, there is a natural tendency to ascertain the inherent implications of the aging-income inequality nexus. However, the ongoing discussions on the impact of aging on income inequality have yet to attain a consensus. For instance, the literature primarily points to a positive relationship between aging and income inequality (see Kang & Rudolf, 2016; Chen et al., 2017; Dong et al., 2018; Hwang et al., 2021; Zhang et al., 2021) while Alimi et al. (2017) report that aging moderates income inequality. Meanwhile, some studies indicate that aging may have either a limited or no impact on income inequality (Andriopoulou et al., 2017; Chong & Ka, 2019). The conflicting evidence could stem from a need for more emphasis on innovative methodology examining the intricate connection between aging and inequality through a nonlinear framework. Thus, the disparities within the body of literature provide a compelling reason to explore the nexus between aging and inequality from a nonlinear perspective.

On top of that, the empirical discourse surrounding the relationship between income inequality and aging becomes even more intricate due to potential reverse causality concerns (Dong et al., 2018). In addition, notable drivers of income inequality, such as aging, economic growth, and inflation, may introduce challenges of reverse causality during estimations. For example, increased economic growth can lead to higher inequality as its benefits may not be equally allocated among the population. Meanwhile, higher inequality impedes growth in the reverse direction, especially in developing nations, as it leads to increasing political instability and declining educational attainment (Shen & Zhao, 2023). Hence, methodologies that quantify and account for potential endogeneity among the covariates is warranted in examining the relationship between aging and income inequality.

As the Asia-Pacific region is poised to experience rapid aging in the coming years, the objective of this study is to uncover a threshold effect between aging and income inequality using balanced panel data from 22 Asia-Pacific[1] (United Nations, n.d.) member states (i.e., Australia, Bangladesh, China, Cyprus, Hong Kong, India, Indonesia, Iran, Japan, Jordan, Kazakhstan, Kyrgyzstan, Malaysia, New Zealand, Pakistan, Philippines, South Korea, Singapore, Sri Lanka, Thailand, Turkey, Vietnam). A panel ranging from 1998 to 2016 is used in this study. Our contribution is three-fold. First, to the best of our knowledge, this is the first nonlinear model that objectively identifies the threshold value of aging at which income inequality is moderated upon intensification. While Shaik et al. (2023) determined that varying aging intensities has a differential impact on income inequality outcomes, this study takes one step further by identifying the exact threshold aging intensity and its consequence on income inequality. This specific nonlinear examination can reconcile potential disparities between high-intensity and low-intensity aging regimes and provide critical insight for old-age policy formulations and income inequality alleviation practices.

Second, this study empirically verifies the modified life cycle model incorporating precautionary savings. This helps to address the limited consensus on the impact of aging on income inequality in numerous countries by proposing an inverted-U curve to represent the Life Cycle hypothesis with precautionary motives. Third, this study addresses possible reverse causality issues using the Dynamic Panel Threshold Kink (DPTK) model that allows for endogenous covariates. This is because past studies have only examined aging and income inequality without considering endogenous covariates; in this case, the causality runs from aging, economic growth, and inflation to income inequality and vice versa.

The DPTK analysis indicates that a threshold aging intensity of 1.4% exists for the association between the elderly dependency ratio and income inequality, whereby an inverted-U curve is identified for the aging-inequality nexus. The results suggest that the aging population leads to the deterioration (stabilization) of the income distribution when aging is below (above) the threshold value. The empirical results further validate the life cycle hypothesis with precautionary motives in the context of the Asia-Pacific.

The structure of this paper is as follows: Section 2 presents the literature on the topic. Section 3 discusses the conceptual framework behind the drivers of income inequality. Section 4 comprises the methodology, including the empirical model, data, and sources. Section 5 presents the results. Section 6 concludes.

[1] The United Nation's (UN) classification of regional Asia-Pacific member states is referred to when choosing the countries used for the relevant estimations.

2. Literature review

Understanding the complex dynamics between demographic changes and income quality is vital for addressing today's social challenges. As inequality manifests concomitantly with population aging, research on the aging-inequality nexus has intensified. However, past research has often focused on mainstream methods, primarily decomposition analysis (Lam, 1992; Jenkins, 1995; Jäntti, 1997; Ohtake & Saito, 1998; Barreti et al., 2000; Cameron, 2000; Zhong, 2011; Hong & Kim, 2012; Alimi et al., 2017). Recent attempts to analyze the aging-inequality nexus using decomposition analysis have incorporated new aspects such as spatial and temporal analysis. For example, Alimi et al. (2017) examine the case of New Zealand for the 1986–2013 period using decomposition analysis that highlights the spatial-temporal effect of different age cohorts on income distribution. More specifically, the authors compare the metropolitan and non-metropolitan areas. Interestingly, the results show that population aging has ameliorated income inequality in New Zealand primarily due to the slowing rate of greying process in metropolitan areas due to a higher prevalence of the youth population.

Since then, researchers have pursued new frontiers in methodological approaches for studying the impact of demographic changes on income inequality. Such measures may have been due to data issues faced by researchers, namely limited availability, heterogeneity, and reverse causality problems that may be less than ideal for traditional methodologies like decomposition analysis (Luo et al., 2018). Chen et al. (2017) use a two-period overlapping-generation (OG) model to determine the effect of aging on income inequality in China. The OG model emphasizes that in the first period, within-cohort inequality is fueled by the difference in productivity among younger workers during their working era. The retirement period (i.e., the second period) sees a divergence between workers of different skill levels – unskilled workers can expect to utilize only their working years' savings accumulated as income, while their skilled counterparts can resume working at discounted wages to supplement their prior savings. The authors posit that within the defined OG model, income inequality rises as population aging progresses.

The use of panel data has also been at the forefront of current examinations of the aging-inequality nexus. For example, Luo et al. (2018) use a panel of 69 countries for the 1975–2015 period to examine the transmission mechanism of the labor share effect in the aging-inequality nexus. The authors posit that aging leads to the deterioration of the income distribution due to a decline in the labor share income influenced by the fall in productivity. Meanwhile, Dong et al. (2018) adopt the dynamic panel data methodology to address endogeneity concerns in the context of aging and income inequality. To remedy this, the authors add a one-order time lag of the inequality index and infer empirically that an increase in the older age group has been driving inequality in China. Even though their study also addresses endogeneity concerns by adding a lagged dependent variable, it does not address the reverse causality between aging and other determinants of income inequality, which remains lacking in empirical research.

Another stream of research focuses on the aging-inequality nexus, using simulation methods. Dolls et al. (2019) utilize reweighting and microsimulation methods to obtain projections of the aging population in 2030 and attempt to uncover the resulting impacts on income inequality for European Union countries (EU-27). The analysis predicts that almost two percent of the increase in the Gini coefficient can be attributed to changes in the demography. Similarly, Zhang et al. (2021) examine simulation data from a dynamic computable general equilibrium model featuring China's population. The results suggest that the working population is expected to decrease as the aging population problem becomes prominent in the region, intensifying inequality. Here, inequality rises due to the decline in the adequate labor quantity needed to sustain the economy. Moreover, aging has been found to drive the migration of older workers from East China to the West, further increasing the income discrepancy between regions.

Meanwhile, Hwang et al. (2021) employ the novel recentered influence function (RIF) approach for the case of South Korea using the year 2017 longitudinal panel dataset. The motivation behind the pursuit of this research is due to South Korea's recent surge in the aging population. The RIF regression analysis involves simulating the effect of the economically active group replacing the elderly age group, whereby the results suggest that such a replacement results in worsening income inequality. Despite the unique results of this study, the authors note that the RIF approach cannot accommodate the dynamics of population change and reflects only a static change in demographic structure.

Lastly, Shaik et al. (2023) utilize time series analysis for a group of Asia-Pacific countries with various aging experiences. The authors use the augmented autoregressive distributed lag (A-ARDL) bounds test to test for the long-run stability of the aging-inequality nexus and find that countries with low growth in elderly dependency ratio yield no long-run relationship between aging and income inequality. In contrast, those countries with a greater degree of the aging population show significant cointegrating relationship. Interestingly, the authors identify an expected stabilization of income inequality with aging in Hong Kong and attribute the results to a possible reform of the elderly retirement savings fund that may have helped counter the adverse effects of the greying process.

The current methodological efforts in examining the impact of aging on income inequality have centered around monotonic linear approaches, i.e. spatial analysis, panel models, simulations, the recentered influence function, and a time series approach. However, the literature has yet to explore the aging-inequality nexus in terms of non-linear threshold effects. The empirical evidence of aged and super-aged society yielding a significant long-run aging-inequality nexus while early aging transition countries show no cointegrating relationship (see Shaik et al., 2023) may indicate that threshold effects are likely present. Thus, a nonlinear threshold framework is warranted to characterize the aging-inequality nexus.

The evolution of threshold models has been rooted in short panel data, which features a shorter time dimension (i.e., short *T*) compared to its cross-sectional counterpart (*N*) (Tsionas, 2019). For example, Steiner (2001) focuses on a sample of 19 OECD countries for the 1986–1996 period, while Zhang et al. (2005) utilize a short panel of 25 developing economies (1985–2001) to uncover the associated threshold effects of reforms in electricity production. More recently, Ferjani et al. (2023) attempt to capture the threshold kink effect in the US-China trade flows caused by the misalignment of the real dollar-renminbi exchange rate. The authors find evidence of a threshold effect that indicates significant differential effects on the exchange rate. The authors further point out that the common assumption that the relationship between economic variables is linear must be amended to incorporate nonlinearity to improve alignment with the real world (Ferjani et al., 2023). To that effect, this paper addresses such concerns and aims to shed light on the nonlinear aspects of the aging-inequality nexus.

Thus, the use of the DPTK approach is an essential methodological contribution to the existing body of the aging-inequality literature as it helps reconcile real-world contradictions on the impact of aging on income inequality and addresses the lack of threshold analysis in the literature and potential reverse causality issues.

3. Conceptual frameworks

This section examines the conceptual frameworks to explain the rationale behind the nonlinear relationship between aging and income inequality, followed by theories that link aging with the explanatory variables of interest, namely aging, and selected control variables, i.e., economic growth, inflation, trade openness, and government expenditure, incorporated in the model as control variables. Discussions on reverse causality for aging, economic growth, and inflation in relation to income inequality are included.

The traditional life cycle hypothesis (LCH) dictates that aging and inequality are positively related because individuals accumulate income over time at different rates. Hence, the discrepancy between and across individuals of different age groups results in the intensification of inequality. However, with the increased prevalence of aging, the elderly may adopt precautionary behavior in anticipation of increased longevity[2] and future uncertainty (Boar, 2020). As a result, the wealth decumulation process occurs more gradually or much later in life (Danziger et al., 1982). Some older individuals may even resume working beyond their retirement age. Hence, aging may have resulted in slower old-age consumption due to longevity and uncertainty, which fuels altruistic motives such as bequests (Bloom et al., 2010). Such a response may help stabilize income inequality via intergenerational transfers and inheritances (Westerheide, 2005; Elinder et al., 2018).

Based on the argument above, the LCH becomes more applicable when aging is below some threshold level, while at higher intensities, the effects of precautionary motives and longevity become more pronounced. Therefore, the modified LCH with precautionary behavior is proposed in this study to reconcile the underlying ambiguity empirical findings behind the relationship between aging intensity and income inequality. More importantly, since the linkages between aging and income inequality occurs in either an increasing or decreasing manner, the support for the threshold kink model is economically and theoretically sound. This paper attempts to determine if such a threshold level or kink exists above which the intensification of income inequality is reversed due to the dominance of precautionary motives. Therefore, a linear regression model may not be informative or justified as opposed to the kink regression approach. The modified LCH model can best be presented as an inverted-U curve, as shown in Figure 1 below.

[2] Longevity can be defined as the improvements or a shift in the life-length of individuals in a population (Scott, 2021).

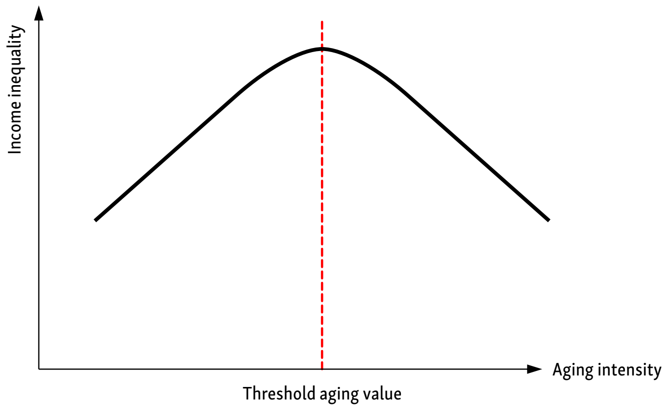

Figure 1. The modified life cycle model with precautionary motives

It is important to understand that the relationship can run the other way too, i.e. from income inequality to aging. For instance, countries with lower (higher) instances of income inequality experience a fertility reduction (gaining) effect (Luo et al., 2018). As these nations experience improvements (decline) in the standards of living and improved (reduced) educational attainment, which drives (slows) the aging population problem (Bhattacharyya, 2011; Lee et al., 2011; Lee & Mason, 2014).

On the other hand, the growth-inequality nexus has often been associated with the inverted-U Kuznets curve, whereby high inequality prevails in the early stages of development (Kuznets, 1955). With further expansion in development and urbanization, employment level improvements help stabilize inequality, especially among the poor and the middle-class (Nord, 1980). Alternatively, income inequality can affect growth in reverse, as it tends to impede growth among low-income countries for three reasons: increased political instability, declining human capital investment, and rising fertility rates. In addition, inequality is found to have a negligible impact on growth among wealthy nations (Shen & Zhao, 2023). Therefore, causality can run in both directions, from growth to income inequality and, conversely, from income inequality to growth.

Higher inflation has often worsened income inequality, as the more significant proportion of those holding liquid assets, such as cash, tend to be people with low incomes. In fact, inflation intensifies income inequality by eroding the value of such assets. As a result, the share of wealth is more likely to be transferred from the poor to the rich (Jain-Chandra et al., 2016). On the other hand, reverse causality may be possible between inflation and income inequality – countries facing higher levels of income inequality face higher incentives to opt for high inflation (Crowe, 2004). Inflation can be seen as a regressive tax, affecting the poor more than the rich. As a result, countries with the highest inequality levels consist of wealthier individuals who prefer inflation over income taxes, which are more progressive. Consequently, the rich could lobby for inflation-inducing policies at the national level (Crowe, 2004). Hence, there may be issues of reverse causality between inflation and income inequality.

Improvements in trade openness can help integrate economies and increase returns to skilled labor (Antonelli & Gehringer, 2017). Increased integration of trade rewards high-skill workers and helps drive economic growth, allowing skill-intensive jobs to flourish and prop up demand for skilled labor. The skill premia effect fuels income inequality. Lastly, government expenditure primarily involves spending on education, health, subsidies, and transfers. Transfers and subsidies have typically been aimed at reducing poverty and aiding the poor and vulnerable groups at the bottom decile of the income ladder. Therefore, government spending can be seen as a safety net, which is expected to reduce income inequality. However, it has been argued that the beneficial impacts of such spending have been restricted as the targeted poor fail to receive it; instead, the higher-income groups become the dominant recipients (Anderson et al., 2017). The preceding conceptual framework discussing the bidirectional linkages (where applicable) between i.e., population aging, economic growth, inflation, trade, and government expenditure and income inequality is illustrated in Figure 2 below[3]:

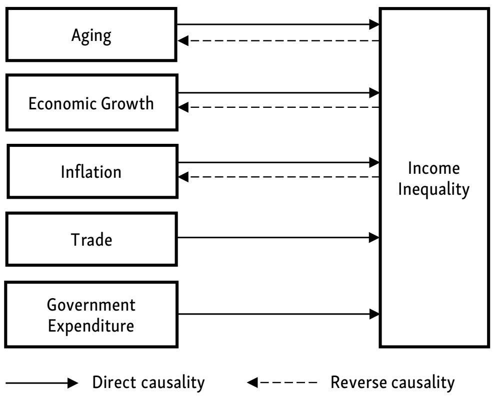

Figure 2. The aging-inequality nexus

4. Data and methodology

The present study examines the effect of the elderly dependency ratio on income inequality for a sample of 22 Asia-Pacific countries during 1998 to 2016[4]. For the dependent variable, the Gini index of inequality (GINI) is used to measure income inequality. The following are included as the independent variables: elderly dependency ratio (DEP65), real GDP per capita (RGDPPC), inflation based on the consumer price index (CPI), trade openness (TRADE), and government expenditure (EXP). It is important to note here that RGDPPC and EXP data were transformed on a logarithmic scale to enable easier coefficient interpretation. The corresponding LRGDPPC and LEXP variables generated are subsequently used in the preliminary tests and estimations. The annual data were extracted from the World Development Indicators (WDI) via the World Bank (n.d.) and the Standardized World Income Inequality Index (SWIID) based on Solt (2020); refer to Table 1 for detailed source descriptions.

[3] Direct and reverse causality directions are indicated by solid and dotted arrows, respectively.

[4] The cutoff point at year 2016 is due to the balanced panel requirement of the DPTK model (i.e., each country needs to have the same time dimension). As the latest data available for all 22 countries used in the sample is only up to 2016, this incidentally restricts the investigation period. However, the model's results remain valid as the threshold value generated based on historical data can function as a regional benchmark in the short-term.

Table 1. Variable definitions and sources

Variable	Definition	Source
GINI	The equivalized household disposable income (pre-tax and pre-transfer) estimate of the Gini inequality index using the Luxembourg Income Study data standard	Solt (2020)
DEP65	The ratio of people older than 64 (considered as older dependents) to the group of people aged 15–64 (assumed as the working-age population).	World bank (n.d.)
RGDPPC	Real GDP per capita in constant 2010 US$	World bank (n.d.)
CPI	Inflation using the annual percentage change in the consumer price index	World bank (n.d.)
TRADE	Trade openness, which is the sum of exports and imports of goods and services measured as a percentage share of GDP	World bank (n.d.)
EXP	General government final consumption expenditure in constant 2010 US$	World bank, (n.d.)

4.1. Cross-sectional dependence and panel unit root tests

Traditional panel data analysis has typically assumed cross-sectional independence. However, this may not be the case, as cross-sectionally dependent disturbances are relatively common and can lead to invalid and unreliable estimates (Pesaran, 2004). Hence, the Lagrange Multiplier (LM) test, scaled LM test, and the Pesaran cross-sectional dependence (CD) test are used to determine the presence of CD in the panel dataset. Under the null hypothesis, cross-sectional independence is assumed. The presence or absence of CD in the dataset will inform the choice of panel unit root tests employed to determine the stationarity of the variables. In other words, panel unit root tests that account for some form of cross-sectional dependence will be needed if CD is present (Tsionas, 2019).

If CD is not present in the panel dataset, the first-generation panel unit root tests such as Im, Pesaran, and Shin (IPS) and Levin, Lin, and Chu (LLC) are sufficient to identify the order of integration. Alternatively, the stationarity of variables needs to be tested with the second-generation panel unit root tests if CD is present in the data. In essence, the cross-sectionally augmented IPS (CIPS) test and the cross-sectionally augmented Dicky-Fuller (CADF) that assume heterogeneous slopes and account for CD are applied. The CIPS test statistic is constructed based on modifications to the IPS test (Im et al., 2003) and the Fisher type test (Choi, 2001) to overcome the CD problem in the unit root panel framework to ensure reliable results. Meanwhile, the CADF method extends the traditional Augmented Dickey regression equation by including the cross-sectional (mean) difference and level variables (Yu et al., 2022). The specific panel unit root tests are conducted to confirm that the necessary stationarity conditions are satisfied (i.e., all variables are integrated of order one or lower). If variables are stationary at level or become stationary after first-differencing, these conditions are deemed fulfilled. In such cases, the panel threshold analysis will utilize the variables in their levels form. However, if a variable is determined to be integrated of order two (i.e., I (2)), its first-differenced version must be employed in the panel threshold analysis to ensure consistency with the integration order of the other independent variables that are I (0) and I (1). This particular treatment of I (2) variables allows for the variables to be integrated in the long run, consistent with established practices in the literature (Goh et al., 2020; Shaik et al., 2023; Saffarudin et al., 2024).

4.2. Dynamic Panel Threshold Kink Model (DPTK)

Before examining the specifics of the DPTK methodology, consider the non-threshold panel model presented in Equation (1) as a starting point to understand the evolution of threshold analysis (Okunade, 2022), in the context of the Gini index and the relevant independent variables used in this study. Equation (1) is represented below:

$$GINI_{it} = \mu_i + \sum_{j=1}^{q} \theta X_{i,t} + \varepsilon_{it}, \tag{1}$$

where i represents countries $(i = 1,\ldots,N)$ and t indicates the time dimension for each unit $(t = 1,\ldots,T)$; the inequality index, $GINI_{it}$ is a function of $X_{i,t}$, which represents the independent variables that include the lagged dependent variable, μ_i is the country fixed effect, and $\varepsilon_{it} \approx (0,\sigma^2)$ is the error term. The above non-threshold model is then developed into a static panel threshold model as proposed by Aydin and Esen (2018), which is shown in Equation (2) below:

$$GINI_{it} = \mu_i + \rho X_{it} I(DEP65_{it} \le \gamma) + \varphi X_{it} I(DEP65_{it} > \gamma) + \varepsilon_{it}, \tag{2}$$

where $DEP65_{it}$ is the elderly dependency ratio, I (.) is the regime specifying indicator function, γ is the threshold parameter that separates the Equation into low and high-regime slope coefficients, denoted as ρ and φ, respectively (Aydin & Esen, 2018). Specifically, if X_{it} adds the lagged dependent variable, the dynamic panel threshold (DPT) model can be expressed as Equation (3) below (Kremer et al., 2013):

$$\begin{aligned} GINI_{it} = {} & \mu_i + \rho_1 DEP65_{it} I(DEP65_{it} \le \gamma) + \delta_1 I(DEP65_{it} \le \gamma) + \\ & \varphi_1 DEP65_{it} I(DEP65_{it} > \gamma) + \phi X_{it} + \varepsilon_{it}, \end{aligned} \tag{3}$$

where ρ_1, δ_1, and φ_1 are the regime fixed coefficients. The coefficients of the slopes in the DPT model are estimated using the generalized method of moments (GMM) once the threshold level (γ) is determined.

In the estimation, the instruments used in the DPT model are the lagged dependent variable values, which allows the estimated coefficients to be consistent and free of serial correlation (Arellano & Bover, 1995). However, the DPT model proposed by Kremer et al. (2013) suffers from possible panel heterogeneity caused by the endogeneity of threshold variables and the discontinuity assumption no longer being applicable. To address the latter, Seo et al. (2019) argued that while the standard threshold model indicates a discontinuity in the regression, there remains a possibility that a kink may be the case instead of the implied jump or discontinuity. Hence, Seo and Shin (2016) propose the imposition of a kink restriction on the DPT model, which allows for lagged dependent variables and endogenous covariates that can include the threshold variable. This dynamic panel threshold kink (DPTK) model is based on the first-differenced GMM estimators and includes the bootstrap linearity test for threshold effect (Okunade, 2022). Equation (3) is then written in consideration of the modified restrictions and assumptions and can be presented as Equation (4) below:

$$GINI_{it} = \mu_i + \alpha_i + \beta X'_{it} + (1, X'_{it}) \delta I\{\psi_{DEP65_{it}} > \gamma\} + \varepsilon_{it}, \tag{4}$$

where $\psi_{DEP65_{it}}$ is the threshold variable (aging). Then, the first difference transformation removes both the individual effects (α_i) and the incidental parameter (δ). The DPTK model is finally formulated as Equation (5) below, which includes the lagged dependent, independent variables, and the kink restriction:

$$GINI_{it} = \mu_i + \beta X_{it}^{'} + k\left(\psi_{DEP65_{it}} - \gamma\right) I\{\psi_{DEP65_{it}} > \gamma\} + \varepsilon_{it}, \tag{5}$$

where $k(\cdot)$ is the notation for the kink constraint. Equation (5) is used to investigate the threshold effect between aging and income inequality in this study. The DPTK methodology is crucial because it helps to uncover the actual pattern of the variables in the model by assuming a kink instead of the conventional discontinuity assumption applied in nonlinear methodology (Seo & Shin, 2016). Another benefit of the DPTK method is that it addresses reverse causality concerns via endogenous covariates that can include the threshold variable itself, which is ideal for our study of the aging-inequality nexus due to the potentially endogenous relationship between aging and income inequality and other control variables such as economic growth and inflation.

Concerning the research strategy, the necessary preliminary tests mentioned in Section 4.1 must be applied before deploying the DPTK method. Once the preliminary tests have been conducted, three important checks for threshold effects are conducted. First, bootstrap linearity testing is used to confirm whether nonlinearity is present; the null hypothesis is that no threshold effect exists. Second, the threshold level (γ) and the kink slope (k) estimated in the model must be significant. Third, the kink slope must have a sign that is different from the DEP65 coefficient in the low regime. Lastly, five specifications of the aging-inequality model are estimated to ensure the results of the threshold model are robust (i.e., coefficient estimates do not change much with different modifications) and structurally valid. The robustness check helps to ensure the coefficient estimates does not drastically change when variables are added or dropped. This can be evidence of structural validity and remains necessary for further causal inferential purposes (Lu & White, 2014).

5. Results and discussion

The main results in this Section are introduced in the following manner. First, the panel cross-section dependence test results, followed by the unit root tests for the variables, are presented. Lastly, the Dynamic Panel Threshold Kink (DPTK) model results are rendered with some further discussions regarding the estimations.

5.1. Panel cross-sectional dependence (CD) test

The LM test, the scaled LM test, and the Pesaran cross-section dependence (CD) test presented in Table 2 suggest that CD is present at a one percent level of significance since the null hypothesis of cross-sectional independence is rejected at 1% significance level. Hence, the presence of CD necessitates the use of the second-generation panel unit root tests to check the integration order of all variables.

Table 2. Cross-section dependence tests

Variable	LM test	Scaled LM test	Pesaran CD test
GINI	2063.881***	85.273***	2.540***
DEP65	2827.558***	120.803***	37.995***
LRGDPPC	3312.970***	143.386***	55.975***
CPI	731.834***	23.301***	19.284***
TRADE	1278.276***	48.724***	8.090***
LEXP	3975.086***	174.191***	62.707***

Notes: *** represent 1% level of statistical significance. The null hypothesis of the cross-section dependence test is cross-sectional independence. The EViews 12.0 application is used to obtain estimates of the CD tests above.

5.2. Second-generation panel unit root test

The results of the cross-sectionally augmented Dicky-Fuller (CADF) and the cross-sectionally augmented IPS (CIPS) unit root tests are presented in Table 3. The tests show that CPI is stationary at level. On the other hand, GINI, LRGDPPC, TRADE, and LEXP only become stationary after first-differencing. Since DEP65 is found to be integrated at order two, the I (1) first differenced version of the variable (i.e., DDEP65) is employed. This approach ensures consistency with the other independent variables, since only I (0) and I (1) variables can be integrated in the long run. The use of the growth version of demographic variables is similar to the approach by Shaik et al. (2023), Saffarudin et al. (2024), and Goh et al. (2020).

Table 3. Second-generation panel unit root tests

Variable	CADF test			CIPS test		
	Level	First diff.	Second diff.	Level	First diff.	Second diff.
GINI	2.918	−3.578***		−1.428	−2.823***	
DEP65	6.934	1.779	−1.763**	−0.797	−1.907	−2.123*
LRGDPPC	3.367	−3.571***		−1.565	−2.517***	
CPI	−3.585***			−3.062***		
TRADE	−0.872	−5.680***		−2.102	−3.513***	
LEXP	−1.203	−8.729**		−2.549	−3.638***	

Notes: ***, **, and * represent statistical significance at 1%, 5%, and 10% level, respectively. Intercepts and trends are included in estimations at level. Selection of lag length is based on the AIC criterion. The Stata commands "pescadf" and "xtcips" are used to obtain the results for the CADF and CIPS panel unit root tests, respectively.

5.3. Dynamic Panel Threshold Kink regression

Table 4 indicates that the threshold variable is significant for all five models, suggesting the null of no threshold effects of aging on income inequality is rejected. The significance of the bootstrap linearity test provides additional confirmation of the presence of a threshold and establishes the nonlinear nature of the relationship between aging and income inequality in the Asia-Pacific region.

Table 4. Dynamic Panel Threshold Kink Regression Model

Threshold variable: DDEP65		Model 1	Model 2	Model 3	Model 4	Model 5
Coefficients in the low regime	$GINI_{t-1}$	0.797*** (0.030)	0.701*** (0.087)	0.797*** (0.048)	0.854*** (0.070)	0.731*** (0.106)
	DDEP65	0.877*** (0.194)	1.108*** (0.293)	1.067*** (0.149)	1.003*** (0.231)	1.320*** (0.379)
	LRGDPPC		−0.151** (0.077)	−0.344*** (0.119)	−0.178* (0.117)	−0.265 (0.208)
	CPI			0.003* (0.001)	0.010** (0.005)	0.010*** (0.003)
	TRADE				−0.001* (0.001)	−0.001** (0.001)
	LEXP					−0.443** (0.175)
Kink_Slope		−1.250*** (0.253)	−1.565*** (0.456)	−1.138*** (0.271)	−1.397*** (0.380)	−1.931*** (0.594)
Threshold (γ)		0.137** (0.045)	0.158*** (0.046)	0.119** (0.056)	0.133*** (0.015)	0.093*** (0.020)
Bootstrap p-value for linearity test		0.000	0.000	0.000	0.000	0.000
Number of moment conditions		357	510	663	816	833
Year		19	19	19	19	19
Cross-section		22	22	22	22	22

Notes: DDEP65 is the growth version of DEP65. DDEP65, LRGDPPC, and CPI are included as endogenous regressors in the estimation. Standard errors of estimated coefficients are reported in parentheses. ***, **, and * represent statistical significance at the levels of 1%, 5%, and 10%, respectively. A bootstrap algorithm with 100 replications and trim rate setting of 0.4 is used to test for presence of threshold effect. Grid search with scope set at 85% of the threshold variable distribution and 100 search steps.

The results of the dynamic panel threshold kink model show that the lagged value of GINI ($GINI_{t-1}$) has a positive and statistically significant effect on the current GINI in the Asia-Pacific at the one percent level of significance for all estimated models. The implication here is twofold; first, the past level of GINI plays a vital role in determining the present status of inequality in the Asia-Pacific. Second, the statistical significance of the lagged dependent variable confirms that the dynamic panel threshold model is justified and invalidates Hansen's (1999) static threshold approach (Maddah et al., 2022).

Row 7 of Table 4 also shows that the kink slope coefficient is negative and significant at the one percent level and has a different sign than the coefficient of DDEP65 in the low regime, substantiating the nonlinear relationship hypothesized between aging and income inequality. The statistical significance of the kink slope further proves that the kink model is justified and represents the most accurate model for the selected sample of countries (Okunade, 2022). To ensure the reliability of our threshold estimates, we conducted extensive robustness checks by testing multiple model specifications. Across these specifications, the threshold coefficient estimates remained stable, and the kink slope consistently showed a negative value above the threshold, reinforcing the robustness of the threshold effect. This stability across models underscores that the observed threshold effect is not sensitive to minor model modifications, which is essential for valid causal interpretation of the results (Lu & White, 2014). The five specifications of the model shown in Table 4 indicate the coefficient estimates do not experience volatile fluctuations – thus, the core variables are not sensitive to the adding of new variables, enabling valid causal inferencing. Moreover, the threshold values calculated remain consistent within a range of 1.2–1.4%[5] and do not show evidence of distortion being present.

As indicated in the modified Life Cycle Hypothesis (LCH) with precautionary savings (see Section 3), we posit that the relationship between aging and income inequality follows a nonlinear, inverted-U pattern. This hypothesis suggests that, at lower levels of aging intensity, income inequality may increase due to savings decumulation among the elderly. However, as the intensity of aging surpasses a certain threshold, precautionary savings behavior becomes more prominent. This behavior is driven by heightened awareness of longevity risks, where individuals delay consumption and retain wealth longer in life, potentially contributing to a moderation in income inequality. Prior research supports this framework, suggesting that precautionary motives lead to greater wealth retention and reduced consumption among aging populations, ultimately stabilizing income inequality (Bloom et al., 2010; Westerheide, 2005). The threshold effect captured by our Dynamic Panel Threshold Kink (DPTK) model empirically validates this theoretical expectation, showing that as aging intensity grows, its impact on inequality shifts direction from positive to negative in an inverted-U pattern.

Furthermore, the positive relationship between aging and income inequality in the low regime (see Row 2), in contrast to the negative slope of the kink (refer to Row 7), indicates that the relationship between aging and income inequality in the Asia-Pacific follows a concave-up or inverted-U shape. The concave-up relationship implies that the early aging transition is accompanied by an increase in income inequality (i.e., positive relationship in the low regime).

This result is consistent with the implications of the life cycle hypothesis, whereby aging fuels income inequality due to heavy decumulation of savings by the elderly. Meanwhile, further increases in the growth of the elderly dependency ratio beyond the threshold level then help moderate income inequality (i.e., negative relationship in the high regime). This is because matured aging societies eventually become aware of living longer and factor this into their expectations of the future. As a result, the continuous wealth accumulation effect occurs instead, whereby the elderly continue to work past retirement, spending their savings much later in life, and are heavily motivated by altruism (Bloom et al., 2010).

The following discussion encompasses the relevant control variables reported in Table 4. The coefficient of CPI is positive and significant for the lower regime, which implies that higher inflation leads to greater inequality. This supports a rise in inflation, eroding the value of assets, typically held in cash by those at the lower end of the income distribution, further fueling income inequality. Next, the coefficient of TRADE is negative and significant in Model 4, which

[5] The calculation of threshold levels obtained in the models are as follows: Model 1 ($10^{0.137} = 1.37$, since γ = 0.137); Model 2 ($10^{0.158} = 1.44$, since γ = 0.158) Model 3 ($10^{0.119} = 1.32$, since γ = 0.119); Model 4 ($10^{0.133} = 1.36$, since γ = 0.133); Model 5 ($10^{0.093} = 1.24$, since γ = 0.0.093).

indicates in favor of trade integration in the low regime, helping to promote economic growth and allowing for the equalization of the income distribution (Haq et al., 2016). Lastly, the coefficient of government expenditure is negative and significant in Model 5 for the low aging regime, which implies that LEXP may be a vital instrument in mitigating the effects of income inequality. In other words, improvements in social welfare spending may be more progressive and better able to target vulnerable population segments, such as the poor and the elderly (Anderson et al., 2017).

5.4. Further discussion

Table 5 shows the mean levels of income inequality and the growth in the elderly dependency ratio by country for the 1998–2016 period. The results indicate that Japan has the highest average growth in the aging population at 1.24%, consistent with the country being of super-aged status. On the other hand, Cyprus, Australia, and India yield the highest average income inequality levels for the chosen time period.

Table 5. The average levels of income inequality and growth in the elderly dependency ratio (by country)

Country	Average growth in the elderly dependency ratio	Average levels of income inequality
Australia	0.26	47.94
Bangladesh	0.07	38.11
China	0.28	45.91
Cyprus	0.20	48.83
Hong Kong	0.37	46.64
India	0.08	47.65
Indonesia	0.10	39.88
Iran	0.10	43.53
Japan	1.24	46.23
Jordan	0.04	39.29
Kazakhstan	0.04	37.53
Kyrgyzstan	–0.15	43.38
Malaysia	0.12	44.17
New Zealand	0.26	46.43
Pakistan	0.01	35.29
Philippines	0.10	45.12
South Korea	0.50	34.53
Singapore	0.22	43.94
Sri Lanka	0.28	43.49
Thailand	0.44	44.40
Turkey	0.12	45.55
Vietnam	0.03	38.23

Note: The average values are computed by country for the entirety of the observed period in this paper.

In the context of the prior threshold analysis, it can be said that aging has thus far led to rising inequality in the Asia-Pacific because most countries in the region have been consistently experiencing growth in the aging population below the threshold value (see Table 5). For example, despite being a super-aged country, Japan has only recorded an elderly population growth average of 1.24%[6] (see Row 9 of Table 5), which remains at the precipice of the threshold value range of 1.2–1.4% determined in Section 5.3. As such, Japan may continue to experience exacerbation of income inequality up until it crosses the threshold range and expectations of longevity begins to induce continuous wealth accumulation strategy among the elderly population.

To further enhance the discussion, a scatter plot of the average values of aging and income inequality of each country (see Table 5) is presented in Figure 3, with the inverted-U curve superimposed in the same diagram alongside the upper bound threshold value of 1.4%.

Figure 3 indicates that most countries in the sample remain far below the upper bound threshold value and will continue to experience worsening income inequality as their aging population grows. To counter this, the results of the DPTK model provides some avenues for temporary income inequality relief via improved government redistribution efforts and liberalization of trade. In addition, Figure 3 highlights that the twin occurrence of high inequality paired with increased aging population will remain in existence for the foreseeable future up until the expectations of longevity awareness develop among the Asia-Pacific populace, which is expected when countries begin exceeding the threshold level (i.e., 1.2–1.4%). Once the threshold is reached, countries can expect income inequality to stabilize (see the trajectory of the inverted-U curve beyond the threshold value displayed in Figure 3) as the population shifts its focus to deal with the consequences of aging.

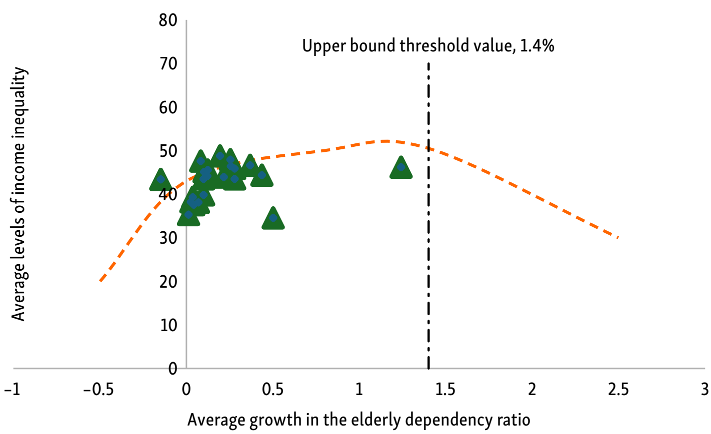

Figure 3. The inverted-U aging-inequality nexus (by country)

[6] This is the average value of the growth in elderly dependency ratio (DDEP65) data for Japan during the observed period in this paper.

6. Conclusions

This study applies the dynamic panel threshold kink (DPTK) analysis to examine the aging-inequality nexus, which accounts for endogeneity (Seo & Shin, 2016; Seo et al., 2019). The study reveals an upper bound threshold point of 1.4% in the relationship between the growth in the elderly dependency ratio and income inequality. The DPTK analysis suggests that for modest increases in the elderly dependency ratio, aging worsens income inequality. Meanwhile, once countries cross the threshold level, income inequality ultimately stabilizes.

Further examination of the data yields that most countries in the sample have not crossed the threshold level of aging and thus, remain susceptible to the adverse twin phenomenon of high aging and inequality levels. Since most countries have not reached the threshold aging level to help stabilize income inequality, potential avenues to ease income distribution pressures can be employed via targeted government redistributive policies – such as enhanced retirement savings plans, targeted social safety nets, and extended employment opportunities for the elderly – to reallocate wealth to vulnerable groups without excessive fiscal strain. In addition, promoting further liberalization of trade may be an alternative course of action to moderate income inequality.

However, as countries approach or surpass the threshold of aging intensity of 1.4%, a natural stabilization of income inequality may emerge as the aging population increasingly prioritizes wealth preservation. Consequently, policymakers in high-aging societies should adopt proactive, long-term saving strategies aimed at supporting wealth retention and facilitating intergenerational transfers, particularly for older adults and other vulnerable groups. Such measures will lay the groundwork for the natural stabilization of income disparities over time.

To conclude, the limitations of the present study and potential directions for future research are discussed. One significant constraint is the absence of continuous macro-level savings or wealth-related data for all countries in our sample over the specified period. While incorporating such data could explicitly establish the role of precautionary saving behavior in the observed kink effect, the DPTK model used requires a continuous and balanced panel, which restricts our ability to include variables with substantial data gaps. Despite this limitation, this study supports its findings via a robust conceptual framework (see Section 3) that draws from existing literature to strengthen the theoretical soundness of the DPTK findings. Future research could address this limitation by including savings or wealth metrics as data availability improves over time to empirically validate the role of precautionary savings behavior in the aging-inequality nexus. This would further refine our understanding of the mechanisms underlying the kink effect and enhance its policy relevance.

Another limitation of this study is the unavailability of alternative Gini indices due to data constraints, particularly for developing and emerging countries where incomplete or missing data is a common challenge. While resources like the Estimated Household Income Inequality (EHII) from the University of Texas at Austin (n.d.) and the World Inequality Database (n.d.) offer valuable insights, their coverage remains limited. Future research could address this by integrating multiple datasets as data availability improves, enabling robustness checks and comparative analyses to uncover deeper insights into income inequality dynamics across diverse contexts.

The final limitation of this study is the selection of 2016 as the endpoint for the analysis. While this decision was driven by the requirement for a balanced panel in the DPTK model, which ensures consistency across the 22 countries in the sample, it restricts the inclusion of more recent years. Extending the period beyond 2016 would result in an unbalanced panel due to data availability constraints, potentially undermining the methodological rigor of the panel threshold analysis. Nonetheless, the threshold value identified remains a robust indicator for understanding the short- to medium-term dynamics between population aging and income inequality. Given the gradual nature of both aging and income inequality, the findings offer insights that are likely to hold relevance beyond the study period. Future research could build on this work by incorporating additional years as more comprehensive and consistent data become available, allowing for a more extensive examination of the aging-inequality nexus.

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