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Understanding Growth Slowdown in Asia and the Way Forward

Title of the paper

*Retirement, work and aging in Korea: understanding the labor pool in
an aging economy*

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**Retirement, work and aging in Korea:
understanding the labor pool in an aging economy**

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Abstract

The research aim of this paper is to explore the long-term as well as the short-term relation between aging and growth in the case of Korea. Design of the study is based on a time series approach, utilizing macro data of Korea over 1970-2013. Analysis framework is largely two-fold: cointegration and the Granger causality test using vector error correction model framework. Major findings of the analysis are: (1) there exists a long run equilibrium between economic growth and aging, each using a proxy of GDP growth and change in old-dependency rate, respectively, (2) regarding the short-run dynamics, the relation between growth and aging is unidirectional where growth Granger causes aging, and (3) there is a negative relationship between growth and change in old-dependency ratio when the state of growth deviates from the equilibrium state.

Keywords: Population Aging; Korea; Growth; Cointegration; Granger Causality; Time Series Analysis

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1. Introduction

Headlines such as ‘growing old before growing rich’ are in line with concerns being shared by economies that are experiencing or projected to experience population aging and how such trend may adversely affect economic growth. What are the policy implications of population aging for economic growth? What is the government’s role? Which policy response should the government adopt to cope with the challenges in the face of population aging? These are some of the questions that are becoming more prevalent to many policymakers in the face of unprecedented rate of population aging and projections that are unlikely to change.

Regarding economic growth, there are indeed various factors that affect growth in an economy such as openness, foreign direct investment, technological advancement, human capital, public and private institutions and total factor productivity that measures how efficiently production inputs such as labor and capital are being used in an economy, to name a few. However, in this paper, in terms of its scope, the focus is on the relation between aging and growth, and labor. Furthermore, by recognizing the policy challenges and concerns of population aging, policy implication is discussed at the end of the paper.

1.1 Growth slowdown and population aging in Asia

As an abundant labor force was a driver for growth in the past to a handful of Asian countries, an argument backed by the demographic dividend literature, aging and shrinking labor force could be disruptive for growth if not prepared for. In fact, the most recent Regional Economic Outlook of Asia and Pacific released by International Monetary Fund (2017, 1) warns the region that “medium-term growth faces secular headwinds, including from population aging and slow productivity catch up,” and in turn calls for structural reforms to address its demographic challenges. Labor market reforms, such as raising labor force

participation and promoting active labor market polices, as well as pension system reforms, closely tied with income support systems of the elderly, are suggested as priority areas of reform in response.

Population aging, a phenomenon where the share of the elderly to the society or the active working population is growing, was of relevance to developed countries in the earlier days (see Table 1). However, it is an important issue in Asia today and for years to come. In fact, the number of persons aged 60 and above is projected to more than double between 2015 and 2050 amounting to 2.1 billion with 66 percent of the increase coming from Asia (United Nations 2015).

Table 1 – Population aging trend and pace in selected countries

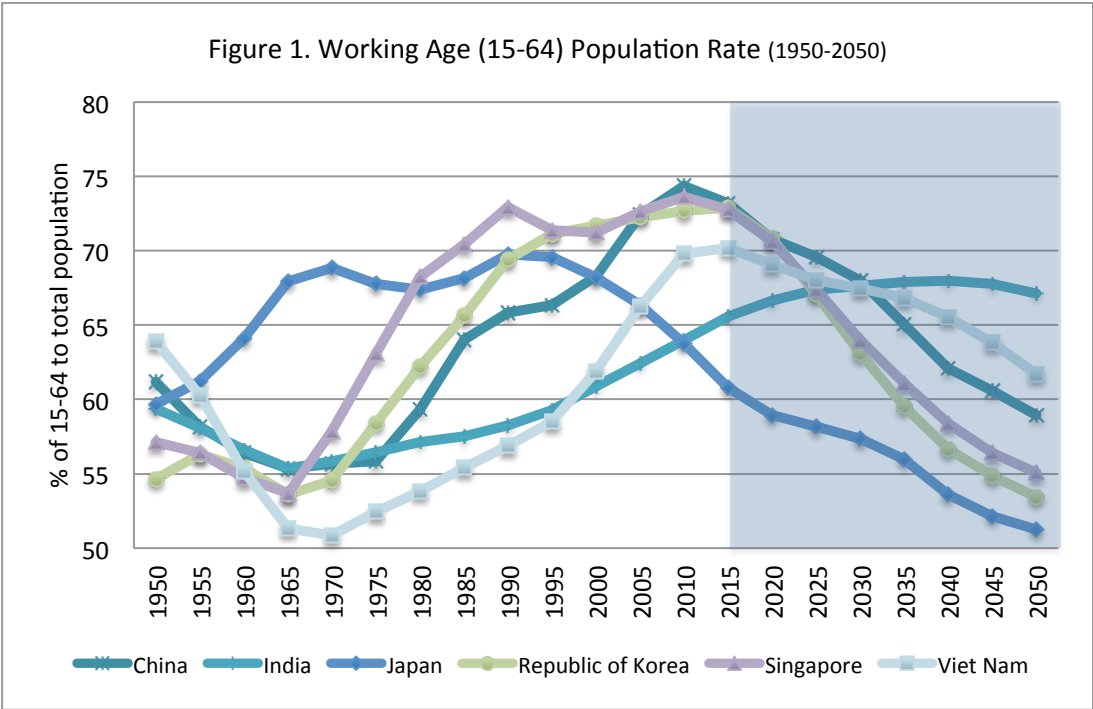
Country	Year reached/ projected to reach the following % of the elderly population			Number of years taken for the population aging transition	
	7%	14%	21%	7% → 14%	14% → 21%
				(aged society)	(super-aged society)
France	1864	1979	2018	115	39
Germany	1932	1972	2009	40	37
Italy	1927	1988	2006	61	18
Japan	1970	1994	2006	24	12
Korea	2000	2017	2027	17	10
Sweden	1887	1972	2014	85	42
U.S.	1942	2015	2036	73	21

Notes: Korea statistics reflect the 2010 estimate and the projection, while the others reflect the 2005 estimate adopted from Kim and Kim (2006). Population projection by Statistics Korea is carried out every 5 years. Elderly is defined as population aged 65 and over.

Sources: Statistics Korea; adopted from Kim and Kim(2006) based on 2005 estimate

By taking the elderly group to be those aged 65 and over, aging has three phases as commonly referred to in the literature: ‘aging society’ is a society with proportion of the elderly in the population

to be 7-14 percent. Similarly the proportions indicative of ‘aged society’ and ‘super-aged society’ are 14-20 percent and over 20 percent, respectively. According a recent population report by the UN (2015)², there will be more than 30 super-aged countries by 2030, in which three of the four Asian Tigers, Hong Kong (26.3 percent), Korea (23.7 percent), and Singapore (23.3 percent) are included. Such form of change in the age structure of the society affect growth through labor market in two-fold: greying of labor force with higher proportion of older workers, and shrinking of labor force with many older workers retiring.



Note: Population projected between 2015-2050 in the shaded area is based on ‘medium variant’ scenario.

Source: World Population Prospects, United Nations (2015)

As shown in Figure 1, great variation can be found across countries regarding the evolution of working age population rising and falling, reflected in the inverted-U shape. Japan leading the transition is followed by Singapore and Korea first, then China and Vietnam. According to a recent

² Details to the methodology underlying the population projection presented in the UN World Population prospects can be found at <http://esa.un.org/wpp/index.htm>. The statistics referenced in this essay follows the ‘medium variant’ scenario, which is most recommended, encompassing medium fertility, normal mortality, and normal immigration scenario projections.

report by World Bank (2016), between 2010-2040, working-age population is projected to shrink by 15 to 20 percent in Hong Kong and Korea, around 10 to 15 percent in Singapore, Thailand, Japan and China, and less than five percent in Vietnam.

1.2 Study rationale and filling in the gap

Not only growth and population aging important issues for Asia, but also a review of previous literatures on both the relationship between aging and economic growth and the application of time series method seemed to signal room for contribution in both regards. There are a handful of studies examining a direct relationship between aging and growth primarily from the production perspective (see Futagami and Nakajima (2001) for an in-depth theoretical explanation), and taking an indirect approach exploring the relation between aging and savings mostly from the consumptions side (Hu 2015; Hviding and Mérette 1998; Kim and Kim 2006; Curtis, Lugauer, and Mark 2015). Implication drawn on the relation between growth and aging from the latter set of literature is often discussed based on theory but in many cases not explicitly tested. This paper is an attempt to do so with empirical data.

In terms of the method, most of the studies were cross-sectional using panel data (Hu 2015; Curtis, Lugauer, and Mark 2015; Li, Zhang, and Zhang 2007), exploring aging as independent variable. On the contrary, time series approach was not utilized as much in examining population aging: Horioka (1997) and Thornton (2001), and Kim and Kim (2006) are country case studies applying the method in the context of Japan, U.S. and Korea, respectively, examining aging and savings relation. Also, using time series approach, Hu (2015) conducted a panel granger causality analysis on China, Japan and Korea examining the relation between aging and savings rate. However, I am cautious of the Hu (2015)'s pooled-panel approach given that the three countries have different institutions.

On that note, this paper will address two research questions: i) will population aging have a long-term equilibrium relationship with economic growth and ii) if so, is there any granger causality that could be identified in the short run.

1.3 *Why Korea*

Korea is widely known to be one of the Four Asian Tigers, achieving an “East Asian Miracle” with impressive economic growth especially in the 1960s-1980s. While achieving a great deal in economic development, the country also tried to pursue development in welfare policies. However, the consensus is that it remains in an immature form, which is likely to yield difficulty in accommodating the rising demands of a society faced with the demographic transition. Balancing sustainable economic growth as well as raising the welfare standard remains a challenge for the country. On that note a study understanding the relationship between aging and growth for Korea could potentially have implications for those countries that achieved or achieve compressed growth but is also looking to prepare for graying society.

Moreover, the rate of aging is fast-paced as shown in Table 1; such trend is favorable in the analysis of assessing aging’s impact on growth as its effect, if any, and would be more visible in the result than the case otherwise. Korea became an aging society in 2000 reaching 7.2% and is rapidly heading towards the state of aged society.

Lastly, Korea is one of the countries with high gross savings rate, with a 32% average over the period of 1970-2013. Gross savings include both private savings and government savings where household savings is included in the former basket. If the channel for impact of aging on growth is savings, then this also offers a favorable setting for the question of interest.

In sum, the aim of the paper is to explore the relation between aging and growth in both long run and short run. More specifically speaking, the existence of such relationship(s), either in the long-term or short-term or both, and the direction of the effect are explored in the estimation.

The rest of the article is structured as follows. The next section presents the hypotheses along with the theoretical ties. The third section explains the estimation strategy,

which will then be followed by the fourth section discussing the results. Lastly, the final section discusses policy implications, and explores relevant labor institutions in Korea in an effort to understand one of the ways the state could respond to the challenge.

2. Research Hypotheses and Theoretical Ties

Key hypotheses addressed in the paper are the followings: (H1) there exists a long-run equilibrium linkage among aging and economic growth; (H2) [if so,] the relationship between aging and growth is bidirectional in the short run; (H2-1) aging will negatively affect economic growth.

Literature that examines the relationship between aging and growth has at least two strands: the dominant theory points such change in age-structure to the direction of growth 'inhibitor'; however, some argue this phenomenon can be a 'booster' for growth, with the right policies in place. In ties with the hypotheses, often times it seems to be considered as a given that there exists a long run relationship between aging and growth [H1].

Demographic dividend literature provides a central theoretical framework for arguing that population aging restricts economic growth. It is an important framework recognized in late 1990s from the perspective that it highlighted the importance of incorporating the change in age distribution (i.e. age-structure of the population). One of the primary reasons for it stemmed from the fact that each age group has different behaviors as actors in the economy: "the young require intensive investment in health and education, prime-age adults supply labor and savings, and the aged require health care and retirement income" (D. E. Bloom, Canning, and Sevilla 2003, 20–21). Such varying needs and behavior by age groups imply that changing age structure affects national economic performance.

Bloom, Canning, and Sevilla (2003, xi) had specified that in the case the proportion of the population is greatest in the working ages, "the added productivity of this group can produce a 'demographic dividend' of economic growth, assuming that policies to take advantage of this are in place". A number of empirical evidence followed such as attributing the East Asian economic miracle

with this demographic dividend (Williamson 2013; Mason and Kinugasa 2008; D. Bloom and Williamson 1998; D. E. Bloom, Canning, and Sevilla 2003). However, in the face of aging, what these evidence imply is rather a pessimistic view on future economic growth [H2-1]. Considering that labor is one of the important factors in production, shrinking labor force participation would mean less economic output created on a per-person basis. Also, as the number of retirees grows in size, the fiscal pressure to the state in terms of age-related expenditure such as pension and healthcare spending will rise.

On a similar note to the demographic dividend literature but perhaps not so direct, is theoretical explanation of the relationship between aging and growth in an indirect manner, combining life-cycle hypothesis and endogenous growth model. According to the life-cycle hypothesis (Modigliani 1970), people would save more when working (i.e. part of the labor force), and would de-save or save less when they grow older especially after retirement as consumption rises under limited income. Edwards (1996) also asks a similar question where the conclusion is such that aging (with old-age dependency ratio (ODR) as a proxy) is negatively linked to both household and national savings. These theoretical explanation linking aging and savings implicitly claim that they affect growth, as saving affects growth in the endogenous growth models. The general consensus is that aging negatively affects economic growth primarily through the channels of reduced savings after retirement [H2-1].

On the contrary, some argue population aging may not necessarily threaten economic growth. In fact, it may even promote economic growth, with the right policies in place. Proponents of this view used the term “second demographic dividend” (Mason and Lee 2006) and “longevity dividend” (BlackRock 2015) in support of the view. The main idea lies on the possibility that working adults may save more and accumulate greater capital in anticipation of the wave of population aging (Mason and Lee 2006; Williamson 2013). This is driven by factors such as increasing longevity, less uncertain mortality, and a fall in the expectation of receiving support from children during old age. Also, BlackRock, an asset management firm, argues that the elderly could bring valuable work experience and management skills to the workforce (especially in times of crisis when in need of insight) enhancing productivity under the term, “longevity dividend”.

Mason and Lee (2006, 14) notes however that realization of the second demographic dividend could be in its full potential, contributing to favorable economic performance “only to the extent that consumers and policymakers are forward-looking and respond effectively to the demographic changes that are coming”. A caveat here is that institutional arrangement and policy matters. One can accumulate assets for old age not only through greater savings and investment, but also by transfers through government program such as pay-as-you-go (PAYG) pension scheme and through families. However, the latter option does not result in capital formation at the national level; in turn realization of the second dividend would be unlikely under such setting. The following script explains it further (Mason and Lee 2006, 15):

“Transfer wealth and assets are close substitutes as a means of reallocating resources across the lifecycle. Either can be used to sustain consumption of low productive age groups. Transfer wealth and assets differ, however, in that accumulating transfer wealth has no effect on economic growth or per capita income. Accumulating transfer wealth does not yield a second demographic dividend.”

In addition to the proponents of “second demographic dividend”, Li et al (2007) argues even the way one operationalizes ‘aging’ could give different results. In other words, the relation between aging and savings could depend on which indicator is used as a proxy for aging: for instance, rise in life expectancy is positive and the dependency ratio is negative in its relation with savings. As life expectancy extends, people plan for longer retirement period after exiting the labor force, thus tend to save more; in turn the increase in saving rate would “accelerate the output growth through faster capital formulation” (Futagami and Nakajima 2001, 38).

Thus, for hypothesis [H2-1], literature seems to offer mixed evidence. So the Granger causality direction if any is not clear. After checking for H1 and H2 through time series analysis techniques, which is essentially checking the existence of relationship in long run and short run, the primarily interest would be along the lines of [H2-1] to understand the direction of the effect better. In

regards to operationalization of key terms in the paper, the elderly in this paper is defined as people aged 65 years and over³.

3. Data and Estimation Strategy

3.1 Data

Data being used in the paper for the analysis is three-fold at large: population data from Statistics Korea and economic indicators including GDP and savings rate from the Bank of Korea. Given that this paper is a country study, statistics are primarily retrieved from the national statistics bureaus in order to be consistent with the source to ensure any adjustment methodologies applied are consistent across variables. If the study were to be extended to a comparison study involving multiple countries, then it would be advisable to retrieve the data from an international source.

Key variables are the three measures of aging specified below, and GDP growth. As a proxy for GDP growth rate the first difference in log form is used. Also, savings rate is incorporated at the later part of the analysis as a possible factor influencing the causal relationship between aging and economic growth. For savings, three variables are explored: household savings rate as a share of GDP and at its nominal value (i.e. level), and gross savings as a share of GDP. See Table 2 for the overall trend and descriptive statistics of the key variables.

Measures of aging: three measures of aging are considered in this paper, mostly due to the common usage in the literature: proportion of the elderly (aged 65 and over) in the society, the old-age dependency ratio⁴, and life expectancy. For all measures of aging, their first difference is used for

³ This is the most commonly used cutoff based on statistics reports and the literature; however, some foresee the bar being raised as both the proportion of the elderly in a society and life expectancy rises

⁴ Old-age dependency ratio (ODR) is by definition the ratio of population aged 65 and over to population aged 15-64 (i.e. indicative of the labor force).

analysis in this paper instead for stationarity purposes⁵ – and doing so provides us with a better insight in terms of the rate of change.

Table 2 – Descriptive statistics on indicators of population aging, economy and saving

Year	Population share, age 65+ (%)	Old-age dependency ratio	Life expectancy at birth (year)	GDP (KRW, trillion)	Real GDP growth rate (%)	Gross savings (% of GDP)	Household savings (% of GDP)
1970	3.1	5.6	61.9	2.8	10.0	18.9	-
1980	3.8	6.1	65.7	39.5	-1.7 [#]	25.4	7.8
1990	5.1	7.4	71.3	197.7	9.8	39.3	17.0
2000	7.2	10.1	76.0	635.2	8.9	34.2	8.7
2010	11.0	15.2	80.8	1265.3	6.5	34.8	5.7
2013	12.2	16.7	81.9	1428.3	3.0	34.5	6.4
Mean	6.1	9.0	71.8	439.1	7.4	32.0	11.1
Obs.	44	44	44	44	44	44	39
Std. Dev.	2.8	3.4	6.3	455.8	4.1	6.4	4.8
Min.	3.1	5.6	61.9	2.8	-5.5	15.8	3.9
Max.	12.1	16.7	81.9	1428.3	14.8	41.8	18.9

Notes: The time period of the data is from 1970 to 2013; however, some variables have later start year due to data availability. Negative growth rate is reflective of the oil crisis in 1980: real GDP growth rates the year before (8.6%) and after (7.2%) show that such event was an external shock. Household savings nominal value is examined for the analysis but is excluded from the table mainly because it wasn't yielding significant result and it is self-evident from GDP and household savings share.

Sources: Statistics Korea, Bank of Korea

Time-series properties of the data: Before moving forward with the estimation, however, it is necessary to ensure the time-series properties of the data. In other words, variables necessarily need to be integrated of order 1 (i.e. I(1)), which means a variable contains unit root in its level but is

⁵ Both variables – proportion of the elderly (aged 65 and over) in the society, the old-age dependency ratio – were tested directly for the unit root test but resulted to be non-stationary (i.e. I(2)).

stationary in its first difference. Such practice is done primarily because estimation of a variable containing unit root could yield spurious results. Estimation strategy on this is elaborated in the section below.

3.2 *Estimation strategy*

In regards to assessing the impact of population aging (or the pace thereof) addressed in the research question, the estimation strategy of the paper is to use econometric specification with a time series approach utilizing macro data covering more than one generational period⁶ - over 40-year period from 1970 to 2013. The baseline specification of the time series analysis framework is largely two-fold: cointegration⁷ and the Granger causality test using vector error correction model (VECM) framework. These two analyses go hand-in-hand because of two reasons: i) the former is the condition to the latter analysis, and ii) the former gives the long run relationship while the latter depicts the short run dynamic, thus it allows for a more holistic understanding of the relationship between the variables of interest.

Unit root test: In order to ensure the variables meet the time series properties, augmented Dickey-Fuller (ADF) test is used for unit root test. See Table 3 for results.

Cointegration test: Engle-Granger methodology, a residual-based test, is mainly utilized in this paper to test for cointegration on each of the measures for aging with GDP growth. An alternative methodology called Johansen cointegration likelihood ratio methodology is used also but only when Engle-Granger result shows that variables are cointegrating for robustness check purposes. If the variables cointegrate, this means there exists an equilibrium relation between the variables in the long run. In the case the two test results differ, more weight was given towards Engle-Granger test result as it is considered more robust (Gonzalo and Lee 1998).

⁶ One generation in terms of years is roughly 30 among human beings, accepted as the average period between the birth of parents and the birth of their offspring.
(<http://dictionary.reference.com/browse/generation>)

⁷ By definition, if variables X_t and Y_t are $I(1)$, and there exists a linear combination, $Z_t = m + a X_t + b Y_t$ where Z_t is $I(0)$, then X_t and Y_t are said to be cointegrated.

Under *VECM framework*, we have the following sets of specification:

$$(1) \quad \Delta Aging_t = c_1 + \sum_{i=1}^n \alpha_{2i} \Delta Growth_{t-i} + \sum_{i=1}^n \alpha_{1i} \Delta Aging_{t-i} + \rho_1 ECT_{t-1} + u_{1t},$$

$$(2) \quad \Delta Growth_t = c_2 + \sum_{i=1}^n \beta_{1i} \Delta Aging_{t-i} + \sum_{i=1}^n \beta_{2i} \Delta Growth_{t-i} + \rho_2 ECT_{t-1} + u_{2t},$$

where $Aging_t$ is either of the three measures specified above in the data section⁸ at year t ; $Growth_t$ is the first difference in log GDP, used as a proxy for GDP growth rate, in year t ; for $t = 1970, \dots, 2013$. Also, c_1 and c_2 are constants in the equation, which are intercepts; first subscripts written to α_{*i} and β_{*i} (i.e. *) is respective to the dependent variable of the regression equation (1) and (2)⁹; ECT_{t-1} is the Error Correction Term (ECT) at year $t-1$ (i.e. residuals generated by the cointegrating regressions (1) and (2) respectively) that reflect the long-term equilibrium relation between the variables; and ρ_1 and ρ_2 are coefficients of the ECT denoting the speed of adjustment back to the long-term equilibrium relation when a variable deviates from it. u_{1t} , and u_{2t} are error terms that are serially uncorrelated. Using the VECM result, Granger causality will be tested.

In addition, other determinants of the two variables tested under VECM framework can be included in the ECM equation (1) and (2) (Panas and Vamvoukas 2002). On that note, this paper attempts to include the ‘change in life expectancy’ and ‘(household/ gross) savings rate¹⁰’ as additional variables, since some literature suggest they could potentially affect the pattern of causality between $Aging_t$ and $Growth_t$. Thus, at the end of this paper series of ECM tests are generated adding each and both of the variable to (1), primarily due to time constraint and greater interest on the impact of aging on growth, to see if it adds any significant explanations to the granger causal relationship.

⁸ VECM framework is applied only if a variable is found to cointegrate with GDP growth.

⁹ For instance, regression (1) has $Aging$ as a dependent variable, thus any variable related to $Aging$, the first subscript would be noted as 1 for its respective coefficient.

¹⁰ For savings the data availability varies: household savings (1975-2013) and gross savings (1970-2013).

4. Results and Analysis

4.1 Main findings

Unit root test: Key variables of interest satisfy the time series properties in its first difference: all are found to be stationary (i.e. I(1)) at significance level 1% as in Table 3.

Table 3 – ADF test for unit root

	Aging			GDP growth	Savings	
	Δ Elderly share in pop.	Δ Old-age dependency ratio (())	Δ Life expectancy		Gross savings	Household savings
Level	0.138 (4)	0.248 (4)	-2.586 (1)	-0.962 (2)	-2.025 (3)	-1.529 (1)
First difference	-5.828 (2)***	-4.981 (3)***	-6.130 (1)***	-5.845 (1)***	-3.894 (2)***	-5.385 (0)***

*Notes: The figures are t-statistics in the ADF test result. Δ is a difference operator, indicating the first difference of the term. The figures in parentheses are the number of lags for the ADF test was determined by the Akaike Information Criterion (AIC) where AIC is the criterion for lag specification. Details described under 'data' section apply, if not already mentioned. For more details, reference Dickey and Fuller (1981). * indicates significance at 10% level, ** at 5% level, and *** at 1% level*

Long run equilibrium relationship

Cointegration test: The relevant estimation results are as shown in Table 4. According to the result, it appears that there exists long run equilibrium between change in ODR and GDP growth. Relatively high R^2 value (0.5956) from the regression between two variables and statistically significant result of ADF (at significance level 1%) indicate that the variation of the change in ODR has some explanatory power in the variation in GDP growth.

Table 4 – Summary of cointegration test results

(a) Engle-Granger methodology					
GDP growth (<i>dep. var. for the regression</i>)					
Δ Elderly % in pop.	0.237	constant	- 0.437	Δ Elderly % in pop.	$R^2 = 0.5478$ ADF = -2.469
Δ ODR	0.227	constant	- 0.317	Δ ODR	$R^2 = 0.5956$ ADF = -3.082**
Δ Life expectancy	0.248	constant	- 0.222	Δ Life expectancy	$R^2 = 0.0829$ ADF = -0.893
(b) Johansen methodology (<i>on 'GDP growth – AODR' relations</i>)					
No. of lag(s) used	H_0	H_a	Trace statistics	Critical value (Trace _{95%})	Critical value (Trace _{99%})
1 (SBIC)	r=0	r>0	15.34	15.41	20.04
4 (AIC)			12.47		

Notes: The time period of the data is from 1970 to 2013. Johansen test was carried out for robustness check purposes and was only conducted in the case Engle-Granger methodology results show that variables are cointegrating. SBIC stands for Schwarz Bayesian information criterion. ADF is reflective of ADF test statistics of the equation residuals. Reference Johansen (1988) for further theoretical details.

** indicates significance at 10% level, ** at 5% level, and *** at 1% level*

Short run dynamics

Granger causality test using VECM: Short run dynamics depict the movements in the short run modeled in the ECM guiding the variable towards the long run equilibrium. On that note, estimation is carried out on equations (1) and (2) specified under estimation strategy, and the results can be found in Table 5 and Table 6. Table 5 presents the key VECM results, and Table 6 explicitly examines the joint significance of the lag terms used for drawing conclusions on Granger causality relation, if any.

Table 5 – VECM test results, 1970-2013

Dependent variable	Regressor	Variable	Coef.	Std. Err.	t-value	p-value	Diagnostic statistics
$\Delta\text{GDP growth}_t$ (i.e. Δgr) ^a	Constant	c	- 0.017**	0.008	-2.27	0.023	
	ECT	ECT _{t-1}	- 0.192	0.162	-1.18	0.238	$R^2=0.4291$
	Lagged regressors	Δgr_{t-1}	- 0.267	0.208	-1.28	0.200	$\chi^2=23.296,$ Prob.> χ^2 =0.0030
		Δgr_{t-2}	- 0.076	0.187	-0.41	0.684	
		Δgr_{t-3}	0.027	0.171	0.16	0.874	
		ΔODR_{t-1}	0.140*	0.073	1.91	0.056	
		ΔODR_{t-2}	- 0.039	0.080	-0.48	0.629	
	ΔODR_{t-3}	0.049	0.066	0.75	0.454		
$\Delta(\Delta\text{ODR})_t$ ^b	Constant	c	0.004	0.013	0.30	0.762	
	ECT	ECT _{t-1}	- 0.803***	0.291	-2.76	0.006	$R^2=0.5829$
	Lagged regressors	ΔODR_{t-1}	- 0.308**	0.131	-2.35	0.019	
		ΔODR_{t-2}	- 0.087	0.144	-0.60	0.545	$\chi^2=43.325,$ Prob.> χ^2 =0.0000
		ΔODR_{t-3}	- 0.467***	0.117	-3.98	0.000	
		Δgr_{t-1}	0.220	0.373	0.59	0.554	
		Δgr_{t-2}	0.901***	0.334	2.70	0.007	
	Δgr_{t-3}	- 0.010	0.306	-0.03	0.973		

Cointegrating equation: $u_t = gr_t + 0.336 \Delta\text{ODR}_t - 0.260$

(5.40***)

Notes: The time period applied for the estimation is 1975-2013 considering lag terms. Δ is a difference operator, indicating the first difference of the term. ECT is error correction term. Details described under 'data' section apply, if not already mentioned. The number of lags is chosen based on AIC; in this case 4 lags were used for the VECM estimation. The figure in the parentheses within the cointegrating equation is t-statistics.

* indicates significance at 10% level, ** at 5% level, and *** at 1% level

The coefficient on ECT is statistically significant for the equation with change in ODR as dependent variable (i.e. equation (1)). The coefficient of the ECT is statistically significant at 1% level meaning that the VECM is valid. Also, the fact that the sign is negative and size is significant implies that there is a conservative force towards the long run equilibrium state. This result implies that if the economic growth rate were too high compared to the equilibrium state then the change in ODR would fall in the short run to adjust. Likewise, if growth were too low, then the change in ODR would rise in the short run to adjust. Potential explanation to this will be explored in the following section.

Cointegration equation specified in Table 5 specifies the long run equilibrium between the two variables, GDP growth and change in ODR. The size of the coefficient imply the speed of adjustment, which in this case it means the adjustment (towards an equilibrium state) occurs at a rate of 33.6% each time period whenever the variable deviates from the equilibrium. Also, the coefficient is significant at 1% level, which confirms that the long run equilibrium state is valid.

After conducting joint significant test on the lag terms, potential Granger causality relations were explored. The only Granger causality seems to be working in the general direction from *Growth* to *Aging*, but not the other way around. In other words, the short run dynamics is unidirectional.

Having established a general relation both in long term and short term between *Growth* and *Aging*, additional variables were added to see if the results could make additional insights as shown in Table 6¹¹. Change in life expectancy (Δ *Life expectancy*) was added and tested together with the two variables for *Growth* and *Aging* using VECM¹² in order to account for the seemingly positive relation between *Growth* and *Life expectancy* alluded to in the literature.

¹¹ Note that household savings rate (as % of GDP) was added as the third variable as well separately, but did not result in any significant finding in terms of short run dynamics; thus, the result is not incorporated in Table 6.

¹² Cointegration equation: $u_t = gr_t + 0.393 \Delta ODR_t + 0.388 \Delta LifeExpectancy_t - 0.440$.

Table 6 – Granger causality tests, 1970-2013

	<i>Growth</i> Granger causes <i>Aging</i>		<i>Aging</i> Granger causes <i>Growth</i>	
	Joint significance test result [#] (χ^2)	p-value	Joint significance test result [#] (χ^2)	p-value
Two variable case				
	12.41	0.006	5.61	0.132
Obs.	39		39	
Three variable case (<i>third variable added is specified below</i>)				
Δ Life expectancy	17.34	0.0002	14.63	0.0007
Obs.	40		40	

Notes: The time period for the estimation is 1970-2010. The Wald F-statistics test that all the coefficients of the lagged values of the independent variable are jointly significant. The number in parentheses after the criterion reflects the number of lags used for estimation. Details described under 'data' section apply, if not already mentioned. [#] Joint significance test result here implies that applied to the lag terms specified in Table 5.

* indicates significance at 10% level, ** at 5% level, and *** at 1% level.

After adding the life expectancy variable, the Granger causality between *Growth* and *Aging* seem bidirectional. Also, life expectancy variable was found to be jointly significant with its lag terms on Granger causing *Aging* variable, which is not surprising: by definition of ODR, as life expectancy increase and the elderly live longer, ODR would increase, holding fertility rate and else constant.

4.2 Robustness checks

Post-estimation tests were carried out on the VECM output with two key variables of interest: serial correlation test and normality test (on the error term). For both diagnostic tests, that the VECM examined on the two key variables of interest passes the test for serial correlation and normality (see Table 7 for details).

Table 7 – Robustness check: Diagnostic test on serial correlation and normality of residuals

Test	H ₀	Test statistics
Serial correlation ($\chi^2(2)$)	No correlation at lag order	1.373
Normality ($\chi^2(2)$)	Normal distribution (i.e. skewness=0 & excess kurtosis=0)	6.905

Notes: The diagnostic tests for serial correlation is Lagrange multiplier test of residual serial correlation. Normality test is a goodness-of-fit test, based on Jarque-Bera test. See Jarque and Bera (1987) for details.

** indicates significance at 10% level, ** at 5% level, and *** at 1% level*

5. Conclusion and Discussion

Key results in this paper are as follows with potential explanations for them in relation to the background, theory and hypotheses:

There exists long run equilibrium between economic growth and aging, each using a proxy of GDP growth (i.e. log difference of GDP) and change in ODR, respectively. This is in line with the previous literature, and is rather confirmatory. Regarding the short run dynamics, it appears to be that the long run relation is mainly channeled through economic growth to aging and is unidirectional in terms of Granger causality.

In particular, in the case of short run effect, the aging (i.e. roughly the rate of change in ODR) equation (1) result show that the coefficient of ECT is statistically significant at 1% level, with a negative sign, and large magnitude. This result implies that if the economic growth rate were too high compared to the equilibrium state then the change in ODR would fall in the short run to adjust. Possible explanation for this may be the increasing elderly mortality in times of rapid economic growth. If elderly mortality rises and shrinks the size of the population aged 65 and above, it is possible for ODR to drop if the elderly mortality drops quicker than the rate of decrease in the size of working age group. In fact, as a country experiences rapid economic growth, there is a tendency to put more weight on work; thus, working long hours could yield to overlook the elderly who may need care.

Likewise, if growth were too low from the equilibrium state, then change in ODR would rise in the short run to adjust. Increasing change in ODR implies either a rise of the elderly population or a drop in the working labor force, or both. While the relationship other way around is widely accepted in the literature, not much about low growth raising the change in ODR. It could be taken as a possible existence of a feedback loop.

In the growth equation (2), the coefficient of ECT is statistically insignificant. This could possibly mean that the change in ODR is not a significant determinant of growth, or there are other variables not accounted for in the equation, among many other possible reasons. Also, inclusion of life expectancy variable in exploring the Granger causality between *Growth* and *Aging* seem to yield result where the effect is bidirectional. As noted by Li et al (2007), life expectancy variable may have offset the aging effect.

In sum, aging (using change in ODR as a proxy) and economic growth cointegrate; in other words, two variables of interest in this paper indeed have a long-run equilibrium where deviation from it would adjust itself to an equilibrium state. Also, the negative relationship between aging and growth is unidirectional in the short run with growth Granger causing change in ODR.

5.1 *Limitations*

Limitation of the analysis stems from the probable effect from the financial crises, 1997 Asian financial crisis and 2008 global financial crisis. These incidences had a detrimental effect on GDP resulting in real GDP growth rate of -5.5% in 1998 and 0.7% in 2009. Also, the negative effect was visible on household savings rate as well with spillover effect over a period of roughly 5 years: savings rate (as a percentage of GDP) gradually declined from 18.38% in 1998 to 3.88% in 2002 – and this is even accounting for the drop in GDP considering it is measured as a share of GDP.

One could consider incorporating a dummy variable for treating the event as an exogenous shock, which could be explored further in the later studies. Another room for improvement may be to consider other factors that may affect the link between population aging and growth.

5.2 *Policy implications*

Recognizing limited external validity of the study, the implications noted here is primarily in the context of Korea. Nevertheless, the analysis done in the context of Korea, could benefit other countries that will experience rapid population aging, from understanding the effect of aging (or the change in old-dependency ratio) on economic growth. Since aging is essentially a shift in the population structure, the process is slow in nature requiring a period of time and lag for the effect to show. Nonetheless, it is a trend that is unlikely to change unless a radical policy intervention takes place; and even so the impact will be visible in a significantly lagged period.

Given the negative relation between economic growth and aging in the short run, policy planning in advance at the national level such as strengthening social support system, and keeping more elderly in the labor market either by incentive package or raising the retirement age could be helpful from a development perspective.

When considering policy intervention, characteristics of the Korean labor market and its institutional arrangement should be taken into account, which include late average effective retirement age, rigid nature of labor market, and yet an existence of contractual mandatory retirement age¹³ in practice leading to an early leave from their main job. The most common mandatory retirement age being practiced in Korean firms is mid-50s (OECD 2004), which is quite early given the average effective retirement age to be late 60s and early 70s. When in doubt as to whether a particular institutional arrangement is still rationale and effective in Korea, policymakers should rethink, and consider carrying out structural reform over time in response to the changing environment.

¹³ Mandatory retirement is an institutional practice with a great level of discretion left to employers which require employees to leave their job regardless of workers' desire or ability to work longer with such conditions stated in employment contracts (Yamada and Higo 2015); although it is often the case where government also has some stake through passing of legislations.

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