**Área 4 - Macroeconomia, Economia Monetária e Finanças**
**JEL: E32; J11; J14**

# THE IMPACT OF POPULATION AGING ON BUSINESS CYCLES VOLATILITY: INTERNATIONAL EVIDENCE

Silvana Dantas Guimarães[1]
Gisele Ferreira Tiryaki[2]

## RESUMO

Os efeitos do envelhecimento da população no desempenho macroeconômico de curto prazo são teoricamente ambíguos. O aumento da longevidade pode comprometer a sustentabilidade dos orçamentos públicos devido aos crescentes gastos com serviços de saúde e previdência social. Também pode afetar a dinâmica do mercado de trabalho e influenciar o comportamento da economia, levando a taxas de juros de equilíbrio mais baixas e espaço de intervenções de política monetária mais restrito. No entanto, consumidores e empreendedores se tornam mais avessos ao risco à medida que a expectativa de vida aumenta, o que pode reduzir a volatilidade do consumo e do investimento. Este artigo tem como objetivo verificar se o envelhecimento populacional promove ou dificulta a estabilidade macroeconômica. Usando dados de 146 economias entre 1996 e 2016, os modelos de dados em painel estático e dinâmico foram estimados controlando outros fatores que afetam o desempenho macroeconômico de curto prazo. Os resultados indicam que os países com uma população em envelhecimento exibem menor volatilidade de consumo e investimento, mas a volatilidade do produto parece aumentar à medida que a população envelhece, provavelmente devido às respostas do mercado de trabalho ao envelhecimento.

Keywords: ciclos de negócios; envelhecimento populacional; demografia.

## ABSTRACT

The effects of population aging on short-run macroeconomic performance are theoretically ambiguous. Increased longevity may compromise public budgets' sustainability due to the growing expenditures with health services and social security. It may also affect labor market dynamics and influence savings' behavior, leading to lower equilibrium interest rates and more restricted monetary policy interventions' space. Yet, consumers and entrepreneurs become more risk-averse as life expectancy grows, which may reduce the volatility of consumption and investment. This paper aims at verifying if population aging promotes or hinders macroeconomic stability. Using data from 146 economies between 1996 and 2016, static and dynamic panel data models were estimated controlling for other factors that affect short-run macroeconomic performance. The results indicate that countries with an aging population exhibit lower consumption and investment volatility, but output volatility seems to increase as the population grows older likely due to the labor market responses to aging.

Keywords: business cycles; population aging; demographics.

[1] PhD student in Applied Economics at the Federal University of Bahia - (UFBA - Bahia - Brazil)
[2] PhD in Economics from George Mason University, GMU, United States. Associate Professor at the Department of Economics, Federal University of Bahia (UFBA) (UFBA - Bahia - Brazil)

## 1. INTRODUCTION

Population aging is no longer a trend restricted to developed countries. Scientific advances and improved access to health care services have contributed to the growth in longevity, while greater participation of women in labor markets have led to lower fertility rates (Yoon, Kim e Lee, 2014; Aiyar, Ebeke e Shao, 2016; Eggertsson, Lancastre e Summers, 2018). The rise in old-age dependency ratios has been blamed for relevant changes in several countries' macroeconomic performance, particularly in more advanced economies[3].

The age distribution profile affects the demand for goods, services, and financial assets, influences the labor-force productivity, overwhelms public finances and alters the credit markets' dynamics. Although a large literature has focused on the impacts of population aging on economic growth, only recently the discussions also started to focus on the link between growth in longevity and business cycles volatility.

The impact of demographic changes on the short-run macroeconomic stability is ambiguous. On one hand, the economic agents' degree of risk aversion tends to increase as life expectancy grows. The prevalence of a more cautious behavior promotes greater consumption smoothing, increases savings, lowers equilibrium interest rates and spurs investments in low-risk endeavors. All these factors contribute to lower consumption and investment short-run volatility.

On the other hand, the fiscal burden caused by the increase in longevity may hinder the use of fiscal policy to promote macroeconomic stability. The impact of population aging is particularly severe in emerging economies, where governments face greater public budget financing restrictions. In addition, as economic agents grow older, their marginal propensity to consume tends to fall, which lowers the fiscal multiplier and further compromises the efficacy of fiscal policy[4].

Population aging may also lead to greater business cycles volatility because of its impact on the effectiveness of monetary policy interventions and on financial markets' stability. As longevity increases and savings grow, the equilibrium interest rates may drop to levels near the zero lower bound, hindering the central bank's ability to stimulate the economic activity at the onset of a financial crisis. Moreover, the growth in savings may be destabilizing if competition for these resources leads to increased risk exposure by financial institutions.

Finally, the increase in longevity may also contribute to greater macroeconomic volatility as aging individuals have lower productivity and face greater barriers to getting rehired after a recession. As a result, business cycles' volatility grows, and economic recoveries tend to be sluggish.

The present article evaluates the impacts of population aging on short-run macroeconomic performance. The paper attempts to verify whether the conservative behavior of older economic agents regarding risk exposure is prevalent, leading to lower cyclical volatility of consumption and investment and neutralizing the possible destabilizing effects of aging on the functioning of the labor market and on fiscal and monetary policy effectiveness.

According to Bean (2004) and Fujita and Fujiwara (2014), demographic changes occur at a slow pace, and their short-run impact on economic activity is deemed negligible. In order to take this restriction into account, the empirical strategy adopted in the paper involved using a panel data set of 146 countries between 1996 and 2016. The time series component was transformed from yearly data into five groups of four-year intervals, which allows that demographic changes are better accounted for. Thus, the transformed dataset has five observations for each of its 146 cross-section units.

The literature which analyzes the impact of aging on business cycles volatility has mostly aimed at developing life-cycle or dynamic stochastic general equilibrium models and at presenting empirical evidence on the link between longevity and short-run macroeconomic performance using microeconomic data (Wong, 2016; Fujita and Fujiwara, 2014; Heer et al, 2017; Sudo and Takizuka, 2018). To the best of our knowledge, no other study has attempted to evaluate the impact of aging on business cycles volatility

[3] The old-age dependency ratio is defined as the number of individuals aged 64 and above, divided by the number of persons aged between 15 and 64, in percentage terms.

[4] As individuals age, their income grow at more modest rates. As a result, they become more patient, and their marginal propensity to consume tend to be lower than when they were young (Carroll et al, 2017).

using such an ample group of countries. Jaimovich and Siu (2009), for instance, used data of only seven countries to verify the impact of aging on macroeconomic performance, and their focus was solely on the labor market dynamics. Aksoy et al (2019) in turn used a vector autoregressive panel dataset of 21 OECD countries to assess the long-run impacts of population aging.

The results presented here reveal that increases in longevity seem to be associated with lower cyclical volatility in consumption and investment, but greater volatility in production. Since the effectiveness of fiscal and monetary policies was measured by separate control variables, the increase in output volatility indicates that the impact of changes in labor market dynamics outweighs the stabilizing impact of changes in economic agents' risk-behavior due to aging.

Besides this introduction, this paper has five more sections. The second section presents the theoretical and empirical literature which explores the link between aging and short-run macroeconomic stability. The third section details the data and the empirical strategy, while the fourth section analyzes the estimations' results. The fifth section presents the concluding remarks.

## 2. POPULATION AGING AND MACROECONOMIC STABILITY: TRANSMISSION CHANNELS

The link between longevity and business cycles' volatility is theoretically ambiguous. The literature has identified channels through which population aging may lead to either greater or reduced macroeconomic stability. Thus, it is a matter of empirically verifying which of these transmission channels are more preeminent. This section initially focuses on the effects of aging on the economic agents' risk behavior and later discusses issues related to the effectiveness of macroeconomic policies, the instability of financial markets and labor market dynamics.

### 2.1. The Growth in Longevity and its Behavioral Consequences

Demographics influence macroeconomic volatility directly because increases in longevity alter the economic agents' risk behavior, financial decisions, and entrepreneurial strategies. Aging not only hinders an individual's cognitive and processing ability but also increases the degree of aversion to risk, alters how expectations are formed, modifies savings decisions and reduces the economic agents' incentives to undertake new ventures.

Agarwal et al (2009) and Gamble et al (2014) state that cognitive ability deteriorates with aging and compromises the efficiency of portfolio allocation decisions. In addition, economic agents tend to become more risk-averse as their expected lifespan increases (Polkovnichenko 2003; Kopecky, 2017). The rise in risk aversion may justify the finding of Gamble et al (2014) that the search for financing counseling increases with aging, even though the economic agents appear to remain confident in the robustness of their financial decisions.

Cognitive restrictions and greater aversion to risk affect saving and consumption decisions. Carpenter and Yoon (2015) point out that older individuals are more conservative in their consumption habits and limit their options to those defined by experience. Younger individuals, on the other hand, are more willing to change their preferences in response to innovations in products and processes, which leads to more volatile consumption patterns. Wong (2016) shows that the response of consumption of younger individuals to changes in interest rates is on average twice greater than that of the elderly, which the author believes is evidence of older consumers' conservative behavior. Therefore, this behavior transmission channel implies that the volatility of consumption tends to decline as population longevity increases.

Several empirical studies show that the degree of risk aversion increases with aging (see, among others, Bakshi and Chen, 1994; Mather et al, 2012; Bonsang and Dohmen, 2015; and Dohmen et al, 2017). Concerns with growing expenditures with health services and declining income after retirement lead economic agents to allocate an increasing share of their income to low-risk assets as they age. Bonsang and Dohmen (2015) and Dohmen et al (2017) also point out that cognitive difficulties may also result in greater risk-aversion. The authors state that limitations in cognitive ability are related not only to the aging process but also to the quality of life during childhood and teenage years.

As older investors become increasingly more representative in capital markets, the prevalence of more cautious behavior tends to promote macroeconomic stability. Yet, some authors argue that financial instability may ensue if assets and credit relocate from financial institutions to pension funds and other institutional investors (D'Arista, 2008; Imam, 2013). The drop in the flow of deposits has shifted the financial institutions' operations away from traditional credit activities. Competitive pressures have led to increases in risk exposure of financial institutions, which have themselves become investment and pension funds' managers with a significant role in capital markets.

Although the greater participation of investment and pension funds allows more liquidity and efficiency in capital markets, their synchronized behavior may lead to sizeable price volatility (Davis, 2002). Thus, capital markets may become more susceptible to systemic risk as changes in risk assessment and in evaluation of economic fundamentals are more quickly incorporated and transmitted through pricing mechanisms.

The relationship between population aging and entrepreneurship may be in turn represented by an inverted U-curve: entrepreneurial activities tend to slow down in economies whose aging distribution reveals the prevalence of either younger or older individuals (Levesque and Minniti, 2006 and 2011; Kopecky, 2017). The incentives to invest in new business ventures tend to decline as individuals grow older because investment projects demand time to pay-off, and time endowment shrinks with age. Some studies have also shown that the decline in creativity, acumen, resilience, and awareness of opportunities that occurs with aging likely hinders investment activities (Florida, 2002; Bohlmann et al, 2017; Liang et al, 2018).

Although the slowdown in entrepreneurial activities inhibits economic growth, the predominance of business ventures led by older individuals promotes greater short-run macroeconomic stability. According to Bluedorn and Martin (2008), experience and income increase as entrepreneurs grow older, which reduces the stress associated with decision making and yields sustained stability to investment activities. Polkovnichenko (2003) and Kopecky (2017) additionally show that since the degree of risk aversion of entrepreneurs increases with age, investment projects led by older individuals are more likely to succeed than ventures managed by younger entrepreneurs. Previous evidence presented by Bates (1990) and Cressy (1996) corroborates the hypothesis that population aging may promote investment stability: these authors show that firms managed by older individuals have higher survival rates than those led by younger managers.

### 2.2. Fiscal and Monetary Policy Effectiveness

Population aging may amplify business cycles' volatility by rendering fiscal and monetary policy initiatives less effective. Regarding fiscal policy, the growth in longevity burdens public finances as expenditures with health and social security grow. When public budgets become increasingly constrained, there is little space for fiscal interventions during economic downturns and the growing public expenditures may be destabilizing. In addition, monetary policy is also less effective in an environment of near-zero interest rates, which is a trend in economies with greater life expectancy.

Leeper and Walker (2011) show that the fiscal stress in most advanced economies is due to spending with social benefits for the elderly, which includes expenditures with health services, retirement pensions, unemployment insurance, and long-term care. If the fiscal burden cannot be financed with greater taxation, variables such as inflation and savings may be greatly affected. For instance, Anderson et al (2014) and Katagiri et al (2019) show that the increase in longevity in Japan has led to deflationary pressures, growth in savings and decreases in real interest rates.

Auerbach (2012) and Kluge (2013) argue that the increase in the old-age dependency ratio leads to (i) a reduction in government tax revenue potential as the labor force shrinks; and (ii) an increase in public expenditures with social security. Thus, population aging likely leads to a rise in public indebtedness, which narrows the fiscal space. Yoshino and Miyamoto (2017) provide empirical evidence that this scenario is already a reality in Japan.

Basso and Rechedi (2018) in turn show that the effectiveness of fiscal policy is also compromised by the impact of the increase in longevity on the fiscal multiplier. In the presence of imperfections in financial markets, credit rationing interferes with intertemporal consumption smoothing. This restriction is particularly severe for young individuals, whose shorter credit history hinders their ability to obtain external financing. As a result, young individuals' marginal propensity to consume tends to be greater than that of older individuals. Thus, increases in longevity likely reduce the fiscal multiplier and, consequently, diminishes the fiscal policy impact on economic activity.

Population aging affects the stance of monetary policy through three channels. Fujiwara and Teranishi (2008) and Wong (2016) show that consumption responses to monetary policy interventions reduce as longevity grows. According to Wong (2016), for instance, an increase in the old-age dependency ratio by 50% leads to a 30% decrease in the consumption response to an increase in interest rate. Since older individuals have access to credit markets on more favorable terms, the financial accelerator mechanism becomes less preeminent.

Aging may also affect the effectiveness of monetary policy through its impact on the equilibrium interest rate (Imam, 2015; Carvalho et al, 2016; Sudo and Takizuka, 2018). As longevity grows, savings tend to increase as economic agents' expected retirement duration rise. The growth in savings leads to lower interest rates, which restricts the monetary policy space, particularly because of the zero lower bound on nominal interest rates.

Finally, population aging may contribute to greater financial instability. The quest for more sustainable public finances has spurred social security reforms in many countries. The consequent proliferation of pension funds and greater availability of resources to financial markets may likely fuel instability as financial institutions aggressively compete for these resources (Iman, 2013). In addition, some studies have shown that an increasing role of pension funds may be destabilizing if competition among these funds leads to risk-prone investment strategies, particularly when fund managers are concerned about reputation and public scrutiny (Hong et al, 2008; Alda, 2017).

Lack of monetary and fiscal policy space amplifies the impact of financial crises, slowing down economic recoveries. Romer and Romer (2017) show that if fiscal space is not restricted, the drop in gross domestic product (GDP) following a financial crisis is only 1.4%, but the contraction in economic activity may reach 8.1% if a country is unable to effectively use fiscal and monetary interventions.

### 2.3. Aging and Labor Market Dynamics

The relationship between business cycles volatility and the population age distribution is non-linear when labor market dynamics are taken into account. The cyclical volatility tends to be significant when very young individuals represent a large share of the population, it declines when most people in the labor force are in the middle ages. Jaimovich and Siu (2009) and Heer et al (2017) use different empirical strategies and diverse cross-country data sets to show that the response of labor market variables' cyclical volatility to changes in age distribution differs in levels and intensities.

Lugauer (2011) argues that the working hours of individuals up to 30 years of age fluctuate significantly across the business cycles because of their reduced experience and the uncertainties related to their career choices. The low productivity of younger individuals leads to more frequent employment separations during recessions. The author also points out that firms tend to avoid creating new labor positions when young individuals make up a large fraction of the population because of the impact of the reduced experience of young individuals on the labor force productivity.

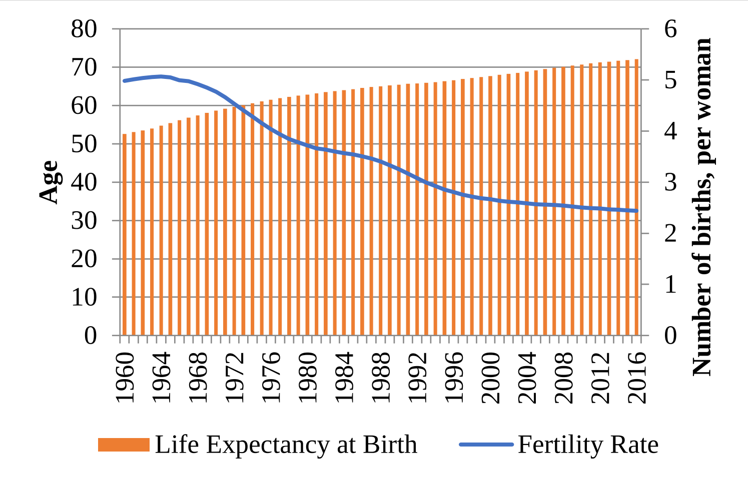
Aged workers also face significant volatility in hours of work. Since cognitive and processual abilities are negatively affected by the aging process, the labor force productivity falls when the population ages, all else constant (Freyer, 2007; Agarwal et al, 2009; Gamble et al, 2014). Additionally, older individuals face greater difficulties in getting their jobs back after recessions, since firms prioritize the hiring of more productive workers (Gomme et al, 2004; Stock e Watson, 2012; Neumark e Button, 2014).

Thus, the influence of population aging on the labor market dynamics contributes to greater short-run macroeconomic volatility. The prevalence of older individuals in the population augments the fluctuations in work hours and increases the length of employment separations. As a result, the slowdown in economic activity is likely more severe and the recovery process becomes more sluggish.

## 3. DATA AND EMPIRICAL STRATEGY

The aging of the population is attributed to two trends that have been observed since the 1970s: the drop in fertility rates and the growing life expectancy (Figure 1). Greater efficiency in information dissemination, easier access to schooling and the growing participation of women in the labor force have all contributed to the drop in fertility rates. Better living conditions and access to health services have in turn led to increases in life expectancy at birth.

**Figure 1 – Fertility Ratio and Life Expectancy at Birth, World Averages**




Source: World Bank (2018)

As a result, the old-age dependency ratio has grown significantly in several countries. Restricted to high-income countries until recently, this trend is now observed in several regions around the world. Except for the Middle East and Africa, all other regions have shown steady growth in old-age dependency ratios (Figure 2). The highest ratios are observed in Europe and North America, particularly in the Euro-zone countries.

The econometric analysis undertaken in the present paper is based on annual data of 146 countries between 1996 and 2016 (World Bank, 2018; IMF; 2018)[5]. Data availability determined the choice of time span, particularly because of restrictions on consumption and investment expenditures' information. The time series component of each country was arranged into five groups of periods: 1996-99; 2000-03; 2004-07; 2008-11; e 2012-16. This data structuring choice is justified ahead in the section describing the empirical strategy.

Equation (1) represents the benchmark static panel data model estimated in this paper:

$$\sigma_{V_{i,t}} = \beta_1 + \beta_2 OLD_{i,t} + \beta_3 X_{i,t} + \mu_i + u_{i,t} \qquad (1)$$

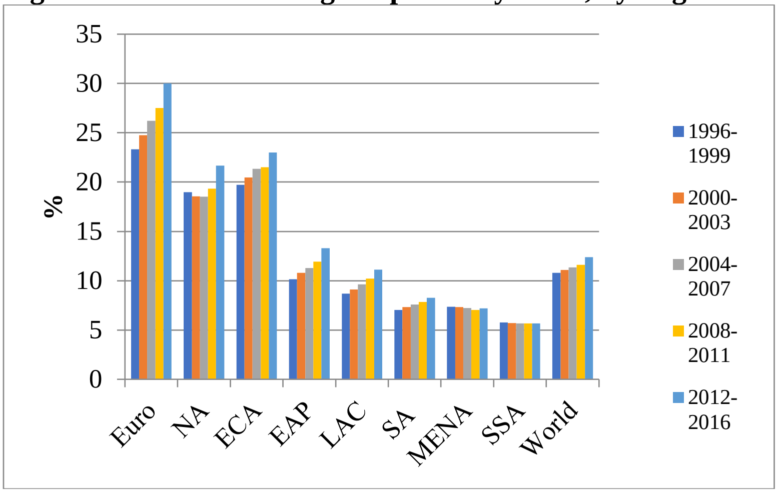
where $\sigma_{V_{i,t}}$ represents the measure of macroeconomic volatility for country i at period t, i = 1, 2, 3..., 146 and t = 1, 2, 3..., 5; V indexes production ($\sigma_{Y_{i,t}}$), consumption ($\sigma_{C_{i,t}}$) or investment ($\sigma_{I_{i,t}}$); $OLD_{i,t}$ represents the main indicator of population aging; $X_{i,t}$ is a matrix of control variables; $\mu_i$ represents the fixed effects; and $u_{i,t}$ is the error term. Several alternative models to this benchmark were estimated to verify the robustness of the results. These alternative models considered different sets of control variables and alternative measures of population aging. In addition, dynamic panel data models were estimated to control for possible endogeneity problems.

This section initially describes the variables used in the empirical analysis: the measures of short-run macroeconomic volatility; the indicator of population aging; and the control variables. Subsequently, the empirical strategy is detailed.

---

[5] Appendix 1 lists the countries included in the data sample.

**Figure 2 – Median Old-Age Dependency Ratio, by Region**




Source: World Bank (2018)
Note: Euro – Euro-zone countries; NA (North America) – United States and Canada; ECA – Europe and Central Asia; LAC – Latin America and Caribe; SA – South Asia; MENA – Middle East and North Africa; SSA – Sub-Saharan Africa.

## 3.1. Variables Used in the Empirical Analysis

The impact of population aging on short-run macroeconomic performance involves several transmission channels. As discussed in the previous section, business cycles volatility may be affected by changes in economic agents' behavior, in the functioning of labor and credit markets and in the stance of fiscal and monetary policies. The volatility of the cyclical components of output, consumption and investment were used as indicators of macroeconomic instability.

The Hodrick-Prescott filter (HP filter) was applied to isolate the low-frequency component of the time series data. After obtaining the cyclical components, the standard deviation of these series in each group of years was calculated and used as measures of the cyclical volatility of production, consumption and investment ($\boldsymbol{\sigma_{Y_{i,t}}}$, $\boldsymbol{\sigma_{C_{i,t}}}$ e $\boldsymbol{\sigma_{I_{i,t}}}$, respectively).

The HP filter has the advantage of preserving the total number of observations in the sample, even though it often produces spurious relations and presents end-of-sample bias (Hamilton, 2017; Schuler, 2018). There are alternative filters with greater precision, such as the band-pass filters (Baxter and King, 1995; Christiano and Fitzgerald, 2003) and the recent methodology proposed by Hamilton (2017), but they all lead to losses in observations. The decision to use the HP filter despite its shortcomings was motivated by the need to avoid restrictions in degrees of freedom and to estimate dynamic panel data models.

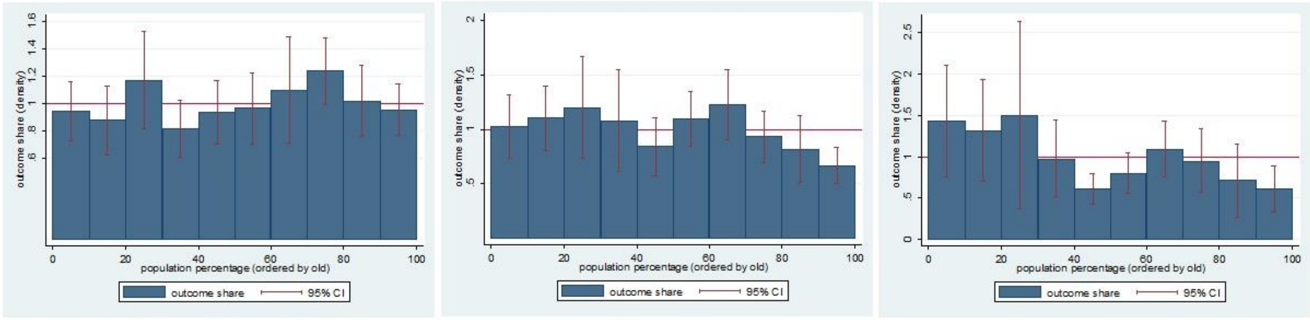
### 3.1.1. Indicator of Population Aging

The main indicator used as a proxy for population aging was the fraction of the population aged 50 years and above (***OLD***). Using the data between 1996 and 2016, the median value of the variable for each of the five groups of periods was calculated. Although the old-age dependency ratio considers those individuals aged 65 years and above as elderly, this study adopted 50 years of age as the lower limit. While this age limit may be low for those countries that have already gone through the demographic transition, it appears suitable for the vast majority of the countries in the sample that are still at the early stages of this process. Moreover, the median life expectancy for some countries in the sample is even below this value.

Theoretical considerations justify the choice of this variable as ideal to represent population aging. Testing the importance of most channels that link population aging with business cycles volatility requires accounting for the prevalence of older individuals in the population, particularly if one desires to test the channels focusing on the changes in economic agents' behavior due to aging. These transmission channels operate regardless of the older individuals' choice to participate in the labor force. To assure the robustness of the results, alternative indicators of population aging were used, as discussed in section 3.2 below.

Figure 3 present preliminary evidence of the relationship between business cycles' volatility and increases in longevity, when the quantile distribution of OLD is taken into account (using the data structured as a cross-section database). The data seems to indicate that the prevalence of older individuals in the population is associated with lower cyclical volatility in consumption and investment, but with greater output volatility. While this latter outcome may be reflecting the impact of changes in labor market dynamics due to aging, the former result indicates the possibility that the behavioral channel off-sets the labor market channel when one considers the volatility of consumption or investment in isolation.

**Figure 3 – Macroeconomic Volatility by Quantile of OLD: Cross-Sectional Data**




(a) Output Volatility (b) Investment Volatility (c) Consumption Volatility

Source: World Bank (2018).

### 3.1.2. Control Variables

Using the business cycles' literature as a reference, control variables were included to account for the impact of credit markets' development, the stance of the fiscal and monetary policy, exchange rate volatility, openness to trade and productivity shocks on macroeconomic volatility.

Several studies have shown that resources tend to flow more efficiently from savers to borrowers as the financial system matures, fostering investment financing and promoting economic growth. Moreover, as the financial system becomes better capable of dealing with information asymmetries, the effects of the financial accelerator on business cycles volatility subsides (Denizer et al, 2002; Ferreira da Silva, 2002). Two of the variables suggested by King and Levine (1993) were used as proxies for financial development[6]:

- The ratio of liquid liabilities to GDP (***LLY***): as the financial system evolves and expands, more resources are channeled to financial institutions, which increases the value of LLY. The referred authors argue that the size of the financial system is an indication of its efficiency;
- The ratio of credit granted to the private sector to GDP (***PRIVY***): financial systems that channel a greater volume of credit to the private sector are likely more efficient in selecting and monitoring borrowers than those that channel most of its resources to public enterprises.

The median values of LLY and PRIVY of each country were calculated for each of the five groups of periods. Because these variables are highly correlated, they were included in the econometric tests one at a time to avoid multicollinearity problems.

Fiscal and monetary policies are often used to promote macroeconomic stability. For instance, balanced public finances enable governments to use expansionary fiscal policy to prevent severe contractions in economic activity. The literature shows that countries with reduced levels of public expenditures relative to GDP are better capable of using fiscal policy to promote stability (see, among

---

[6] Although there are better indicators of financial system efficiency suggested by the literature, such as the Z-score, long time-series data for these variables is often available to very few countries (Cihak et al, 2013). The choice of indicators used here was motivated by the goal of maximizing data sample size.

others, Karras and Song, 1996; Fatas and Mihov, 2001). The median value of this ratio for each group of periods was used as a proxy for the stance of fiscal policy (**GOV**).

Most countries use monetary policy interventions as the main mechanism to reduce business cycles' volatility. This study uses the average inflation rate in each group of periods as a measure of monetary policy efficacy (***INF***). Low inflation rates are also less volatile, which leads to fewer distortions in relative prices and a more stable environment for investment (Karras and Song, 1996; Romer, 1999; Ferreira da Silva, 2002).

Two indicators were used to account for the impact of international trade and exchange rate policies on business cycles' volatility. Bejan (2006) and Di Giovanni and Levchenko (2009) argue that trade openness contributes to greater macroeconomic volatility because the economy becomes more susceptible to external shocks. The degree of trade openness was measured by the median value of the ratio of the sum of imports and exports to GDP in each group of periods (***OPENNESS***).

Stable exchange rates, in turn, facilitate planning by companies and consumers and help to stabilize inflation rates, which fosters macroeconomic stability (Duarte et al, 2007; Gumus and Taspinar, 2015). The degree of exchange rate volatility in each group of periods (***EXC***) was represented by the standard deviation of the exchange rate measured in terms of SDR per domestic currency[7].

At last, it is also important to account for the impact of productivity shocks, which is considered by Real Business Cycles' theorists as the driving source of business cycles (Stadler, 1994). The volatility of the Solow residual's cyclical component in each group of periods is used as a proxy for these productivity shocks (**SOLOW**)[8]. The annual value of the residual was calculated according to Backus et al (1992):

$$\text{ResSolow}_{i,a} = \left(\ln Y_{i,a} - \ln Y_{i,a-1}\right) - (1-\alpha)\left(\ln N_{i,a} - \ln N_{i,a-1}\right) \qquad (2)$$

where $Y_{i,a}$ is the value of the real GDP of country $i$ in year $a$; $N_{i,a}$ is the number of employed workers; and α is the capital stock contribution to production (α = 0.36, by definition). The use of the Solow residual is common in the business cycles literature, even though it is widely recognized that this variable captures not only productivity shocks but also all other factors that are important to the productive process (e.g. institutional governance, managerial practices and the availability of other resources besides labor)[9].

### 3.2.Empirical Strategy

Demographic changes evolve slowly over time. For this reason, the ideal empirical strategy required to evaluate the impact of population aging on business cycles volatility involves the use of panel data. By using annual data over a long time span and grouping this data into quadrennials, it is possible to assess both demographic changes and variations in business cycles volatility. Although population aging is not easily noticed in a trimester or annual horizon, its impact is more easily felt over a four or five-year period.

Thus, annual data of each country were grouped into four-year periods, except for the last time segment which was established as a quinquennial. Pursuing this strategy allowed that the demographic transformations were better accounted for. The data clustering assured that a sufficient number of time observations were kept in order to estimate dynamic panel data models.

Initially, equation (1) was estimated using static panel data models controlling for unobserved individual effects. Hausman tests indicated the choice between using fixed-effects or random-effects models. The fixed-effects' estimations were adjusted for the presence of heteroskedasticity, serial autocorrelation, and cross-section dependence whenever the usual tests indicated the existence of such problems (Hoechle, 2007; Tiryaki, 2017)[10]. Because the data for the cyclical volatility of consumption

---

[7] The SDR (special drawing rights) is the reserve asset created by the International Monetary Fund (IMF, 2019).

[8] The cyclical component of the Solow residual was also derived with the use of the HP filter.

[9] Because the estimation of the Solow residual has several drawbacks, careful evaluation of its role is required. For instance, the estimation assumes constant returns to scale Cobb-Douglas production function, which is not necessarily suitable for all countries. It also assumes that the parameter α is equal to all countries, which is unlikely because countries have different production structures. Finally, it assumes that changes in capital stock are negligible in the short-run.

[10] Panel-corrected standard errors were obtained using the PCSE estimator suggested by Beck and Katz (1995).

and investment is unbalanced, the tests which detect cross-section dependency are impossible to run. Thus, time dummies were used to control for the possible existence of contemporaneous correlation whenever these variables were added as dependent variables.

To verify the robustness of the results, estimations were conducted using different proxies for population aging. In addition, alternative variables were also used to account for the impact of increased longevity on the efficiency of fiscal and monetary policies. Finally, dynamic panel data models were used to avoid the bias associated with endogeneity.

Two variables replaced OLD as indicators of population aging. The first variable, ***DIV***, indicates whether a country is no longer benefiting from the demographic dividend, defined as the increase in economic growth that may arise because the working-age population is growing at a faster rate than the non-working age population[11] (Bloom, et al. 2003). During the dividend phase, the ratio of the non-working age population to working-age population shrinks. Once the dividend phase ceases, longevity increases and fertility rates drop, which causes the dependency ratio to start growing again. The variable DIV takes the value of one when the growth rate of the dependency ratio is persistently positive in the last years of the sample, and zero otherwise[12].

The other variable used as an indicator of population longevity was the old-age dependency ratio (***DEP***), which is often used to test for the impact of aging on the labor market dynamics (Jaimovich e Siu, 2009). Using this variable has the caveat that the life expectancy of a few countries falls below the lower limit used in the variable definition, which is 64 years of age and above. Moreover, both DIV and DEP only capture the labor market dynamics channel linking population aging and business cycles volatility. The behavioral and the macroeconomic policies efficacy channels, for instance, may not be accounted for properly because they relate to the prevalence of elderly in the population as a whole, not as a ratio of the working-age population.

To better assess the efficiency of fiscal and monetary policies in promoting stability, the regressions in which DIV was used as a measure of population aging were estimated including interaction variables with GOV and INF. Since DIV is a dichotomous variable, it is possible to infer that the coefficients of DIVGOV and DIVINF represent the size of the impact of macroeconomic policies on business cycles volatility in the post-demographic dividend phase.

### 3.2.1. Dynamic Panel Data Models

Static panel data models are based on the zero conditional mean hypothesis. Yet, the possibility of endogeneity should not be downplayed. For instance, the effectiveness of macroeconomic policies and business cycles' volatility may be simultaneously determined by governance institutions (Tiryaki, 2008). Moreover, population aging and business cycles' volatility may be concurrently influenced by economic growth. The quality of health and education services increases with growth and lead to greater life expectancy and lower fertility rates (Blackburn e Cipriani, 2002). At the same time, some studies have shown that greater growth is associated with lower output volatility (Ramey and Ramey, 1995). Thus, using dynamic panel data models has the advantage of obtaining consistent estimates of the parameters.

These models include the lagged dependent variable as a regressor, which allows the researcher to model persistence and to take into account innovations with long-lasting effects. Moreover, dynamic panel data models estimated with the generalized method of moments (GMM) deal directly with the endogeneity issue by exploiting all the information available on the data sample. The strategy assumes that the necessary instruments are internal, and there is over-identification. Thus, the number of moment restrictions exceeds the parameters to be estimated (Arellano e Bover, 1995; Blundell e Bond, 1998).

---

[11] The non-working age population is defined as individuals younger than 15 or older than 64 years old whereas the working-age population includes individuals aged between 15 and 64 years.

[12] A value of one is assigned to DIV in a given group of periods "t" if the growth rate in the dependency ratio is positive at least in the last two years of "t" and in all subsequent periods. This condition was adopted to guarantee that the end of the dividend phase was properly identified (there were a few cases in which the growth rate turned positive for a period or two and became negative afterwards).

Equation (2) represents the estimated model when a lagged dependent variable is included as a regressor:

$$\sigma_{V_{i,t}} = \beta_1 + \beta_2\sigma_{V_{i,t-1}} + \beta_3 OLD_{i,t} + \beta_4 X_{i,t} + \mu_i + v_{i,t} \qquad (2)$$

Notice that first-differencing removes the individual effect, $\mu_i$, and allows the use of the lags of the endogenous variables as instruments. Additionally, the GMM estimator yields more efficient estimates by finding a vector of parameters which assures that the correlation between the instrument matrix and the error vector is zero (all moment conditions are null). In the present study, the estimations used either the System GMM (GMM-SYS) or the GMM with forward orthogonal deviations (GMM-FOD).

Let $x_i$ and $y_i$ represent, respectively, the matrix of the endogenous regressors, including the lagged dependent variable, and the vector of the dependent variable. Blundell and Bond (1998) state that if the first-differences of $x_i$ and $y_i$ are not correlated to the cross-sectional individual effect, the lagged variables in levels may be used as instruments for the variables in differences, defined as $x_i^*$ e $y_i^*$, and the variables in differences are appropriate instruments for the variables in levels ($x_i$ and $y_i$). The authors suggest the use of the GMM-SYS estimator, which derives a new stacked dataset, $y_i^+$ and $x_i^+$, and a new matrix of instruments, $Z^+$, defined as:

$$y_i^+ = \begin{pmatrix} y_i^* \\ y_i \end{pmatrix} \quad x_i^+ = \begin{pmatrix} x_i^* \\ x_i \end{pmatrix} \quad Z^+ = \begin{pmatrix} W & 0 \\ 0 & W^* \end{pmatrix}$$

where $x_i^*$ and $y_i^*$ are submatrices of the first-differenced values of the regressors and of the dependent variable, respectively; $x_i$ and $y_i$ are the submatrices of the original data in levels; W is the submatrix of the lagged values of $x_i$ and W* is the submatrix of lagged differences of $x_i$.

Let the individual effect and the error term be defined by $\mu_i$ and $v_{i,t}$ , respectively. The GMM-SYS estimator is valid if the following moment conditions hold (Tiryaki, 2017):

(i) $E[y_{it-2}(\Delta v_{it})] = 0, t = 2 \dots, T \text{ and } E[x_{it-1}(\Delta v_{it})] = 0, t = 2 \dots, T;$

(ii) $E[\Delta y_{it-1}(\mu_i + v_{it})] = 0, t = 2 \dots, T \text{ ; and,}$

(iii) $E[\Delta x_{it-1}(\mu_i + v_{it})] = 0, t = 2 \dots, T, \text{ when } x_{it} \text{ is endogenous; or}$

(iv) $E[\Delta x_{it}(\mu_i + v_{it})] = 0, t = 1 \dots, T, \text{ se } x_{it} \text{ strictly exogenous.}$

Condition (i) states that the variables in levels can only be used as instruments for the variables in differences if they are not correlated to the error term. Conditions (ii) and (iii) state that the variables in differences are not correlated to the fixed effect and to the error term, while condition (iv) needs to be valid when the regressors are exogenous. Condition (iv) assures the absence of contemporaneous correlation between the regressors in differences and the error term in the same time period.

Instead of using first-differencing, the alternative GMM-FOD estimator deducts the average of the future observations such that the observation in the last time period is lost (Arellano and Bover, 1995). Differencing forward assures that the individual fixed effect is removed and allows the use of the lagged levels as instruments for the forward differences. According to Roodman (2009), the GMM-FOD estimator has the advantage of avoiding the loss of observations which is common in unbalanced datasets. Since the consumption and investment time series are not balanced, the GMM-FOD was used in the regressions which included these variables. The GMM-SYS was, in turn, used when output volatility indicated business cycles volatility.

The Sargan/Hansen and Arellano-Bond tests were conducted to verify if the moment conditions were satisfied (Roodman, 2009). The Sargan/Hansen test investigates whether the instruments are valid, while the Arellano-Bond test verifies the presence of second-order serial correlation of the residuals in differences. While first-order serial correlation in differences is likely due to the models' structure, the presence of second-order correlation in differences indicates the presence of first-order serial correlation in levels.

Lastly, Roodman (2009) also points to the need to verify the models' dynamic stability. In the absence of bias, the estimated coefficient of the lagged dependent variable in the dynamic models' estimations must be greater than the value obtained when the estimates are obtained using static fixed-effects models (FE) and smaller than the value obtained with ordinary least squares (OLS) estimations.

## 4. ECONOMETRIC ANALYSIS RESULTS

Overall, the results indicate that population aging is associated with greater cyclical volatility in production, but reduced volatility in consumption and investment. This apparently contradicting result stems from the working of the different channels through which longevity affects macroeconomic volatility. Because the inclusion of control variables account for the effectiveness of macroeconomic policies, the indicators of population aging capture mainly two channels: the behavioral and the labor market dynamics channels. According to the behavioral channel, as longevity increases, economic agents grow increasingly averse to risk, which should bring stability to consumption and investment.

The fact that production volatility grows with aging may be resulting from a more dominant effect of the changes in labor markets' dynamics: as individuals age, involuntary job separations are more likely, but reintegration to labor markets takes a longer time. Thus, economic recessions tend to be more severe and long-lasting as population aging increases.

The econometric results are displayed in Tables 2 through 4. The columns (I) through (V) present the static panel data estimation results, nearly all obtained from fixed-effects models following indications obtained from Hausman tests[13]. Only three estimations were conducted using random effects, all involved the use of the cyclical volatility of production as the dependent variable: (i) LLY represented the indicator of financial development; and (ii) DIV indicated population aging.

Columns (I) and (II) display the estimation results using different financial development indicators, while columns (III) and (IV) show the results obtained for alternative longevity indicators. Column (V) presents the results using control variables to account for the interaction between population aging and the stance of fiscal and monetary policies. Finally, the last four columns illustrate the results obtained from the dynamic panel data model estimations, which used different indicators of longevity (columns VI through VIII) and interaction between aging and the stance of macroeconomic policies (column IX).

### 4.1. Output Volatility

The results displayed in Table 2 show that increases in population aging are related to greater volatility in the cyclical component of production. This outcome is statistically significant in nearly all static and dynamic panel data regressions, although the results in which longevity is measured by DIV indicate a less robust link between output volatility and longevity. Because the effectiveness of monetary and fiscal policies was accounted for separately by specific control variables, this direct relationship between the short-run volatility in production and aging indicates that the impact of changes in labor market dynamics outweighs any possible drop in output volatility that could be associated with the behavioral channel. Yet, the discussions in the next section show that the role of the behavioral channel becomes more relevant once the analysis focuses more particularly on consumption and investment volatility.

The changes in labor market dynamics arise because productivity reduces as individuals grow old and cognitive abilities decline. Thus, the likelihood of involuntary labor market separations during recessions is greater for older individuals, who also face greater difficulties in finding new jobs as the economy bounces back from the recession. Gomme et al (2004), Stock and Watson (2012), and Neumark and Button (2014) argue that this new labor market trend experienced particularly by developed countries likely contributes to increases in the cyclical volatility of production.

To assess the impact of population aging on output volatility, consider the case of Malaysia, whose value for OLD when t = 3 represents the sample median (t = 3 refers to the 2003-2007 period data). Using the results of the dynamic model estimation when OLD is used as the indicator of longevity (column VI of Table 2), a 10% increase in the fraction of the population aged above 64 years would lead to a 4.3% rise in output volatility. If the same exercise is done using data for Japan, whose value for OLD in the last time period represents the sample maximum value, a 10% increase in OLD would lead to a 25% growth in output volatility.

---

[13] The results presented on Tables 2 through 4 are robust to the presence of heteroscedasticity, first-order autocorrelation and cross-section dependence (see Beck and Katz, 1995).

**Table 2 – Population Aging and Business Cycles: Output Volatility**

| | Static Panel Data Models | | | | | Dynamic Panel Data Models (GMM-SYS) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | (I) | (II) | (III) | (IV) | (V) | (VI) | (VII) | (VIII) | (IX) |
| **OLD** | 0.0002*** (0.00008) | 0.0002*** (0.00008) | | | | 0.0003** (0.0001) | | | |
| **DIV** | | | 0.003* (0.001) | | 0.004 (0.006) | | 0.004 (0.002) | | 0.006 (0.009) |
| **DEP** | | | | 0.0002** (0.0001) | | | | 0.0003* (0.0002) | |
| **L.$\sigma_Y$** | | | | | | 0.133* (0.069) | 0.123* (0.070) | 0.126* (0.069) | 0.128* (0.075) |
| **PRIVY** | -9.7e-07 (0.00002) | | 0.00002 (0.00002) | 6.3e-06 (0.00002) | 0.00003* (0.00002) | 0.00002 (0.00005) | 0.0001* (0.00004) | 0.00002 (0.00004) | 0.0001*** (0.00003) |
| **LLY** | | -6.0e-06 (0.00002) | | | | | | | |
| **GOV** | -7.8e-08* (4.5e-08) | -8.5e-08 (2.4e-07) | -1.1e-07 (2.4e-07) | -9.2e-08* (4.8e-08) | -1.1e-07 (2.4e-07) | -1.5e-07*** (4.4e-08) | -1.9e-07*** (5.3e-08) | -1.8e-07*** (4.3e-08) | -2.0e-07*** (4.2e-08) |
| **DIVGOV** | | | | | -0.0002 (0.0002) | | | | -0.0003 (0.0004) |
| **INF** | -1.3e-07 (1.9e-07) | -1.2e-07 (9.2e-08) | -1.2e-07 (9.2e-08) | -1.3e-07 (1.9e-07) | -1.2e-07 (9.2e-08) | 9.9e-07 (8.0e-07) | 1.1e-06 (7.9e-07) | 1.1e-06 (8.1e-07) | 1.0e-06 (7.7e-07) |
| **DIVINF** | | | | | 0.001* (0.0004) | | | | 0.0005 (0.001) |
| **OPENNESS** | -1.4e-06 (0.00001) | -2.5e-06 (0.00001) | -3.8e-06 (0.00001) | 1.4e-06 (0.00001) | -4.0e-06 (0.00001) | -0.0001* (0.00005) | -0.0001** (0.00005) | -0.0001* (0.00005) | -0.0001 (0.00003) |
| **EXC** | 2.8e-07 (8.7e-07) | 1.8e-07 (7.0e-07) | 3.0e-07 (7.0e-07) | 3.0e-07 (9.0e-07) | 3.8e-07 (7.0e-07) | (0.00004) (0.00004) | 0.0001* (0.00004) | 0.00005 (0.00005) | 0.0001 (0.00005) |
| **SOLOW** | 0.714*** (0.049) | 0.714*** (0.022) | 0.713*** (0.022) | 0.713*** (0.049) | 0.710*** (0.022) | 0.809*** (0.090) | 0.800*** (0.101) | 0.815*** (0.097) | 0.799*** (0.098) |
| **Constante** | 0.002 (0.001) | 0.002 (0.002) | 0.005*** (0.001) | 0.003*** (0.001) | 0.005*** (0.001) | 0.002 (0.004) | 0.006 (0.004) | 0.004 (0.005) | 0.002 (0.003) |
| **No. obs.** | 729 | 729 | 729 | 729 | 729 | 584 | 584 | 584 | 584 |
| **No. C.S.** | 146 | 146 | 146 | 146 | 146 | 146 | 146 | 146 | 146 |

Note: standard errors in parenthesis (*** p < 0.01; ** p < 0.05; * p < 0.1); L.X stands for the first lag of the variable X.

The results in Table 2 also show that population aging appears to compromise the effectiveness of the fiscal policy. The regression results indicate that government spending attenuates output volatility, a result that is statistically significant in all dynamic model estimations. Nonetheless, the ability of government expenditures to smooth output volatility vanishes in the post-demographic dividend period (column IX). As pointed out previously by Auerbach (2012) and Kluge (2013), the effectiveness of fiscal policy weakens as public finances are negatively affected by lower tax revenues and greater social security expenditures, leaving little room for using fiscal policy to promote stability.

Regarding the control variables, only OPENNESS and SOLOW show statistical relevance. International trade openness reduces output volatility, but this result is statistically significant solely in the dynamic models' estimations. The Solow residual, in turn, shows statistical relevance in all estimated models, a result which is also in consonance with previous empirical studies (Backus et al, 1992; Ferreira da Silva, 2002; Tiryaki, 2003).

The specification tests show that the results of the dynamic panel data models in which the output volatility is the dependent variable are robust. The Hansen statistics indicate that the instruments are informative, and the presence of second-order serial correlation is ruled out. In addition, the coefficient of the lagged dependent variable used as a regressor remained inside the interval that indicates dynamic stability in almost all estimations[14].

[14] We performed the stability tests through the lagged dependent variable coefficients as a regressor in the estimates using the OLS, GMM (dynamic) or FE (static) models.

### 4.2. Consumption Volatility

The link between short-run consumption volatility and aging appears less robust (Table 3). Increases in longevity reduce consumption volatility, but this result is statistically relevant only in the estimation of the static models which use OLD or DEP as the indicator of population aging.

The negative association between population aging and consumption volatility was also found by Wong (2016) and Dohmen et al (2017). These authors argue that the growth in risk aversion as individuals grow older would lead to greater consumption smoothing. Using the results in column (I) of Table 3 to illustrate the impact of aging on consumption volatility, consider again the case of Malaysia whose value for OLD in t = 3 represents the sample median. A 10% increase in OLD is associated with a 4.3% decline in consumption volatility.

**Table 3 – Population Aging and Business Cycles: Consumption Volatility**

| | Static Panel Data Models | | | | | Dynamic Panel Data Models (GMM-FOD) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | (I) | (II) | (III) | (IV) | (V) | (VI) | (VII) | (VIII) | (IX) |
| **OLD** | -0.0003***<br>(0.00005) | -0.0003***<br>(0.00005) | | | | -0.0006<br>(0.001) | | | |
| **DIV** | | | -0.001<br>(0.001) | | 0.002<br>(0.004) | | 0.015<br>(0.012) | | 0.007<br>(0.036) |
| **DEP** | | | | -0.0003***<br>(0.00006) | | | | -0.0004<br>(0.001) | |
| **L.$\sigma_Y$** | | | | | | 0.097<br>(0.078) | 0.062<br>(0.076) | 0.092<br>(0.076) | 0.073<br>(0.066) |
| **PRIVY** | -0.0001***<br>(0.00001) | | -0.0001***<br>(0.00001) | -0.0001***<br>(0.00001) | -0.0001***<br>(0.00001) | 0.0003**<br>(0.0001) | 0.0004**<br>(0.0002) | 0.0003**<br>(0.0001) | 0.0003<br>(0.0002) |
| **LLY** | | -0.0001***<br>(0.00001) | | | | | | | |
| **GOV** | 0.0002***<br>(0.00005) | 0.0001***<br>(0.00005) | 0.0001**<br>(0.00005) | 0.0001***<br>(0.00005) | 9.72e-05*<br>(0.00005) | -0.0009<br>(0.001) | -0.001<br>(0.001) | -0.001<br>(0.002) | -0.001<br>(0.002) |
| **AGEGOV** | | | | | -0.0004*<br>(0.0002) | | | | -0.0002<br>(0.002) |
| **INF** | 6.7e-07***<br>(7.42e-08) | 6.9e-07***<br>(6.88e-08) | 6.8e-07***<br>(7.42e-08) | 6.8e-07***<br>(7.37e-08) | 6.9e-07***<br>(7.80e-08) | 8.6e-07<br>(1.47e-06) | 5.3e-07<br>(1.67e-06) | 8.7e-07<br>(1.41e-06) | 1.4e-07<br>(1.81e-06) |
| **AGEINF** | | | | | 0.0009***<br>(0.0001) | | | | 0.001<br>(0.001) |
| **OPENNESS** | 0.00005***<br>(0.00001) | 0.00008***<br>(0.00001) | 0.00004***<br>(0.00001) | 0.00004***<br>(0.00001) | 0.00003***<br>(0.00001) | 0.0005**<br>(0.0002) | 0.0005**<br>(0.0002) | 0.0005**<br>(0.0002) | 0.0005**<br>(0.0002) |
| **EXC** | -6.6e-08<br>(1.1e-07) | -1.5e-07*<br>(8.2e-08) | -2.2e-07<br>(1.4e-07) | -1.0e-07<br>(1.1e-07) | -1.4e-07<br>(1.8e-07) | -0.0001*<br>(0.00005) | -0.0001<br>(0.00005) | -0.0001<br>(0.00005) | -0.00001<br>(0.00005) |
| **SOLOW** | 0.657***<br>(0.021) | 0.646***<br>(0.020) | 0.683***<br>(0.019) | 0.662***<br>(0.020) | 0.660***<br>(0.022) | 0.261**<br>(0.103) | 0.263*<br>(0.146) | 0.350***<br>(0.124) | 0.331**<br>(0.138) |
| **Constant** | 0.018***<br>(0.001) | 0.019***<br>(0.001) | 0.015***<br>(0.0008) | 0.017***<br>(0.001) | 0.016***<br>(0.001) | | | | |
| **#obs.**<br>**#cross-sec.** | 629<br>135 | 629<br>135 | 629<br>135 | 629<br>135 | 629<br>135 | 360<br>128 | 360<br>128 | 360<br>128 | 360<br>128 |

Note: standard errors in parenthesis (*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$); L.X stands for the first lag of the variable X.

Among the control variables, the performance of the Solow residual is noteworthy. Productivity shocks increase consumption volatility, and this outcome is statistically significant in all static and dynamic panel data estimations. Aside from the Solow residual, only international trade openness consistently increases consumption volatility, a result that is also statistically significant in all estimations. This outcome is consistent with the results obtained by Bejan (2006) and Di Giovanni and Levchenko (2009).

Increased government spending and failure to control inflation increase consumption volatility, although this outcome is statistically significant only in the static models' estimations. Once the post-demographic dividend period is taken in isolation, the effect of fiscal policy loses statistical relevance. The impact of inflationary pressures on consumption volatility, on the other hand, increases during the post-demographic dividend period, which is an indication that population aging hinders the effectiveness of monetary policy initiatives. Using the information from column (V), consider the case of Ireland, whose average inflation rate in t = 2 represented the sample median value. A 10% increase in average inflation would raise consumption volatility by 0.003% during the demographic dividend phase and 3.1% after the dividend phase had ceased.

Another control variable that seems important to consumption volatility is financial development[15]. The coefficients of the financial development indicators are always statistically significant, but they differ in sign depending on the type of model that is estimated. In the static models' estimations, financial system development appears to reduce consumption volatility, a result that was also pointed out by Denizer et al (2002) and Ferreira da Silva (2002).

Yet, the coefficients of these indicators turn positive and increase in magnitude once the dynamic models are estimated. This positive association between consumption volatility and financial development may arise if greater financial deepening is accompanied by increases in leverage because of competition among financial agents and by innovations in financial products that trigger risk-taking behavior (Loayza and Ranciere, 2005; DeAngelo and Stulz, 2015).

Since the dynamics models' estimations presented in Table 3 are robust and stable, this latter explanation of the link between consumption volatility and financial development is favored. The specification tests indicate that the instruments are informative and second-order serial correlation is absent. Moreover, the coefficients of the lagged dependent variable remained within the required range that guarantees dynamic stability.

### 4.3. Investment Volatility

The results in Table 4 show that increases in longevity reduce the volatility of investment. This result is statistically significant and economically relevant in all regressions' specifications, except in two of the dynamic model estimations. To assess the importance of greater longevity to investment volatility, consider the dynamic model estimation in which OLD represents aging (column VII). If the case of Malaysia, whose value of OLD at t = 3 is the sample median, is used once again as an example, it is estimated that a 10% increase in OLD leads to a 38.1% drop in the investment volatility.

This significant reduction in investment volatility is likely due to behavioral changes associated with aging. As pointed out previously, the indicators of longevity capture essentially the behavioral changes channel and the labor dynamics channel, and this latter channel would imply a positive association between investment volatility and aging. The greater aversion to risk, income stability, and experience of older entrepreneurs are probably the reasons for the fall in investment volatility arising from population aging. This outcome is in consonance with the evidence provided by Bates (1990), Cressy (1996), Bluedorn and Martin (2008) and Kopecky (2017).

Increases in government spending and in average inflation appear to augment investment volatility, but this outcome is only statistically significant in the static models. In addition, the impact of macroeconomic policies on investment volatility loses importance during the post-demographic dividend phase (column V). Regarding the other control variables, only the volatility of the Solow residual is consistently relevant to investment volatility. The coefficient of SOLOW is positive and statistically significant at the 1% level in all estimated regressions.

The Hansen tests show that the instruments used in the dynamic models with investment volatility as the dependent variable are informative. Yet, the Arellano-Bond test indicates the presence of second-order serial correlation, which cannot be eliminated with longer lags due to the lack of data availability. In addition, the coefficient of the lagged-dependent variable used as a regressor lies outside the range that guarantees stability. Thus, the results from the dynamic panel data models should be considered with caution.

[15] All tables present LLY as the financial development indicator solely when OLD represents population aging. All other estimations use only PRIVY as the measure of financial development, because similar results were obtained when LLY was the proxy for financial development. These additioal results are available upon request.

**Table 4 – Population Aging and Business Cycles: Investment Volatility**

| | Static Panel Data Models | | | | | Dynamic Panel Data Models (GMM-FOD) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **(I)** | **(II)** | **(III)** | **(IV)** | **(V)** | **(VI)** | **(VII)** | **(VIII)** | **(IX)** |
| **OLD** | -0.001***<br>(0.0001) | -0.001***<br>(0.0001) | | | | -0.009***<br>(0.003) | | | |
| **DIV** | | | -0.021***<br>(0.002) | | -0.030**<br>(0.012) | | -0.016<br>(0.017) | | -0.135**<br>(0.067) |
| **DEP** | | | | -0.001***<br>(0.0002) | | | | -0.002<br>(0.003) | |
| **L.$\sigma_Y$** | | | | | | -0.085<br>(0.068) | -0.075<br>(0.075) | -0.067<br>(0.074) | -0.088<br>(0.076) |
| **PRIVY** | -0.00001<br>(0.00003) | | -0.00004<br>(0.00004) | -0.00004<br>(0.00003) | -0.00004<br>(0.00004) | 0.0003<br>(0.0002) | 0.0004*<br>(0.0002) | 0.0002<br>(0.0002) | 0.0005**<br>(0.0002) |
| **LLY** | | -0.0001***<br>(0.00003) | | | | | | | |
| **GOV** | 0.0007***<br>(0.0002) | 0.0008***<br>(0.0002) | 0.0007***<br>(0.0001) | 0.0008***<br>(0.0002) | 0.0008***<br>(0.0001) | -0.003<br>(0.003) | -0.002<br>(0.003) | -0.002<br>(0.003) | -0.003<br>(0.003) |
| **AGEGOV** | | | | | 0.0003<br>(0.0005) | | | | 0.005<br>(0.003) |
| **INF** | 1.5e-06***<br>(5.1e-07) | 1.5e-06***<br>(4.8e-07) | 1.5e-06**<br>(5.9e-07) | 1.6e-06***<br>(5.2e-07) | 1.5e-06**<br>(5.9e-07) | 4.1e-06<br>(3.5e-06) | 3.8e-06<br>(4.3e-06) | 3.6e-06<br>(4.3e-06) | 4.0e-06<br>(4.2e-06) |
| **AGEINF** | | | | | 0.0008<br>(0.0008) | | | | 0.003*<br>(0.002) |
| **OPENNESS** | -0.00004<br>(0.00003) | 0.00001<br>(0.00003) | -0.00005<br>(0.00003) | -0.00005<br>(0.00003) | -0.00004<br>(0.00003) | 0.0004<br>(0.0002) | 0.0002<br>(0.0002) | 0.0002<br>(0.0002) | 0.0003<br>(0.0002) |
| **EXC** | 3.3e-07<br>(7.4e-07) | -2.0e-07<br>(5.1e-07) | -6.6e-07<br>(8.0e-07) | 8.2e-08<br>(6.4e-07) | -8.0e-07<br>(1.2e-06) | -0.0001<br>(0.0001) | -0.00004<br>(0.0001) | -0.00003<br>(0.0001) | -0.0001<br>(0.0001) |
| **SOLOW** | 1.345***<br>(0.064) | 1.326***<br>(0.064) | 1.375***<br>(0.066) | 1.358***<br>(0.065) | 1.385***<br>(0.067) | 1.304***<br>(0.280) | 1.283***<br>(0.303) | 1.423***<br>(0.276) | 1.306***<br>(0.304) |
| **Constant** | 0.070***<br>(0.005) | 0.069***<br>(0.004) | 0.058***<br>(0.004) | 0.064***<br>(0.004) | 0.057***<br>(0.004) | | | | |
| **#obs.**<br>**#cross-sec.** | 615<br>132 | 615<br>132 | 615<br>132 | 615<br>132 | 615<br>132 | 352<br>126 | 352<br>126 | 352<br>126 | 352<br>126 |

Note: standard errors in parenthesis (*** p < 0.01; ** p < 0.05; * p < 0.1); L.X stands for the first lag of the variable X.

## 5. CONCLUSION

The growth in longevity is occurring across several countries, although this demographic trend has been more prevalent in developed countries. Among emerging economies, the aging of the population is expected to intensify during the next decades. The old-age dependency ratio should surpass the young-age dependency ratio, and a growing fraction of aged individuals are expected to participate in the labor market.

The growth in longevity modifies economic agents' behavior because it impairs cognitive ability and makes individuals less prone to undertake risk. These behavioral changes tend to promote the stability of consumption and to reduce the risk of entrepreneurial initiatives. On the other hand, the lack of space for fiscal and monetary policies hinders the use of macroeconomic policies to promote short-run macroeconomic stability. This negative effect of aging on business cycles volatility is amplified by the changes in labor market dynamics due to increases in longevity: as economic agents grow old, the likelihood of job separation increases, as well as the duration of unemployment.

The empirical analysis conducted in the present paper aimed at verifying which of these channels linking population aging to macroeconomic volatility are more relevant. Estimating static and dynamic panel data models with a sample of 146 countries, the results indicate that the volatility of investment and, to a lesser degree, of consumption reduces as longevity rises. This outcome appears to be the result of behavioral changes observed as individuals grow older. Nevertheless, the results also show that the drop in investment and in consumption volatility due to aging is not enough to bring about output stability. Production volatility grows as longevity increases likely due to the changes in labor market dynamics brought about by population aging: recessions tend to be more severe as economic agents grow older and face a greater threat of losing their jobs and longer unemployment spells.

As a growing fraction of the population is represented by the elderly, labor force productivity tends to fall. As a result, the likelihood of employment separation rises, and these individuals face greater challenges to find new job offers. Moreover, public budgets become tighter as the population ages because of the growing expenditures with health and social security and due to the negative impact of the drop in productivity on tax revenue collection. Finally, the monetary policy space reduces as the growth in savings keeps the equilibrium interest rates at very low levels. Thus, the use of macroeconomic policies to promote stability becomes restricted.

It is therefore important to identify strategies that ease the fiscal budget burden of an aging population. For instance, the restructuring of social security systems should consider this new demographic profile. Moreover, the government should pursue better management of its expenditures and tax revenue collection. Regarding monetary policy, non-conventional monetary policy tools may be required in an environment of persistently low interest-rates' levels, such as forward guidance, quantitative easiness, and macroprudential initiatives. Finally, it is also important to recognize that the recessions' severity is likely to worsen as the population ages, and labor market initiatives may be necessary to facilitate job matching during economic recoveries.

## REFERENCES


AGARWAL, S.; DRISCOLL, J. C.; GABAIX, X.; LAIBSON, D. The age of reason: Financial decisions over the life cycle and implications for regulation. **Brookings Papers on Economic Activity**, n. 2, p. 51-117, 2009.

AIYAR, S.; EBEKE, C.; SHAO, X. The Impact of Workforce Aging on European Productivity. **IMF Working Paper**, n. 16/238, 2016.

AKSOY, Y.; BASSO, H.S.; SMITH, R.P.; GRASL, T. Demographic structure and macroeconomic trends. **American Economic Journal: Macroeconomics**, v. 11, n. 1, p. 193-222, 2019.

ALDA, M. The relationship between pension funds and the stock market: Does the aging population of Europe affect it? **International Review of Financial Analysis**, v. 49, p. 83-97, 2017.

ANDERSON, M.D.; BOTMAN, D.P.; HUNT, M.B. Is Japan's Population Aging Deflationary? **IMF Working Paper**, n. 14/139, 2014.

ARELLANO, M.; BOVER, O. Another Look at the Instrumental Variable Estimation of Error-Components Models. **Journal of Econometrics**, v. 68, p. 29-51, 1995.

AUERBACH, A, J. **Societal Aging: Implications for Fiscal Policy**. Bank of Japan: Institute for Monetary and Economic Studies., 2012. (IMES Discussion Paper Series 12-e-12).

BACKUS, D.K.; KEHOE, P.J.; KYDLAND, F.E. International real business cycles**. Journal of Political Economy**, v. 100, p. 745-775, 1992.

BAKSHI, G.; CHEN, Z. Baby Boom, Population Aging, and Capital Markets. **The Journal of Business**, 1994, v. 67 n. 2, p. 165-202. 1994.

WORLD BANK. **World Development Indicators**. Washington, DC: The World Bank, 2018

BASSO, H.S.; RACHEDI, O. The young, the old, and the government: demographics and fiscal multipliers. **Bank of Spain Working Paper**, 2018.

BATES, T. Entrepreneur human capital inputs and small business longevity. **The Review of Economics and Statistics**, v. 72, n. 4, p. 551–559, 1990.

BEAN, C. Global demographic change: some implications for central banks. In: **Federal Reserve Bank of Kansas City Annual Symposium**, Wyoming, 2004.

BECK, N.; KATZ, J.N. What to do (and not to do) with time-series cross-section data. American political science review, v. 89, n. 3, p. 634-647, 1995.

BEJAN, M. **Trade openness and output volatility**. MPRA Paper no. 2759, 2006.

BLOOM, D.; CANNING, D.; SEVILLA, J. **The demographic dividend: A new perspective on the economic consequences of population change**. Rand Corporation, 2003.

BLUEDORN, A.C.; MARTIN, G. The time frame of entrepreneurs. **Journal of Business Venturing**, v. 23, n. 1, p. 1–20, 2008.

BLUNDELL, R.; BOND, S. Initial conditions and moment restrictions in dynamic panel data models. **Journal of Econometrics**, v. 87, n. 1, p. 115-143, 1998.

BOHLMANN, C.; RAUCH, A.; ZACHER, H. A lifespan perspective on entrepreneurship: Perceived opportunities and skills explain the negative association between age and entrepreneurial activity. **Frontiers in Psychology**, v. 8, p. 2015, 2017.

BONSANG, E.; DOHMEN, T. Risk attitude and cognitive aging. **Journal of Economic Behavior & Organization**, v. 112, p. 112-126, 2015.

CARPENTER, S.M.; YOON, C. Aging and consumer decision making. In: **Aging and decision making**. Academic Press, 2015. p. 351-370.

CARROLL, C.; SLACALEK, J.; TOKUOKA, K.; WHITE, M. N. The distribution of wealth and the marginal propensity to consume. **Quantitative Economics**, v. 8, n. 3, p. 977-1020, 2017.

CARVALHO, C.; FERRERO, A.; NECHIO, F. Demographics and real interest rates: Inspecting the mechanism. **European Economic Review**, v. 88, p. 208-226, 2016.

CIHAK, M.; DEMIRGUC-KUNT, A.; FEYEN, E.; LEVINE, R. Financial Development in 205 Economies, 1960 to 2010. **Journal of Financial Perspectives**, v. 1, n. 2, p. 17-36, 2013.

BLACKBURN, K.; CIPRIANI, G.P. A model of longevity, fertility and growth. **Journal of Economic Dynamics and Control**, v. 26, n. 2, p. 187-204, 2002.

CRESSY R. Pre-entrepreneurial income, cash-flow growth and survival of start-up businesses: model and tests on U.K. data. **Small Business Economics Journal**, v. 8, n. 1, p. 49–58, 1996.

D'ARISTA, J. The implications of aging for the structure and stability of financial markets. **PERI Working Papers**, n. 125, 2008.

DABLA-NORRIS, E.; SRIVISAL, N. Revisiting the link between finance and macroeconomic volatility. **IMF Working Paper**, n. 13/29, 2013.

DAVIS, E.P. Ageing and financial stability. In: **Ageing, financial markets and monetary policy**. Springer, Berlin, Heidelberg, p. 191-227, 2002.

DEANGELO, H.; STULZ, R.M. Liquid-claim production, risk management, and bank capital structure: Why high leverage is optimal for banks. **Journal of Financial Economics**, v. 116, n. 2, p. 219-236, 2015.

DENIZER C. A.; IYIGUN M. F.; ANN O. Finance and Macroeconomic Volatility, **The B.E. Journal of Macroeconomics**. v. 2, n. 1, p. 1-32, 2002.

Di GIOVANNI, J.; LEVCHENKO, A. Trade openness and volatility. **Review of Economics and Statistics.** v. 91, p. 558–85, 2009.

DOHMEN, T.; FALK, A.; GOLSTEYN, B. H.; HUFFMAN, D.; SUNDE, U. Risk Attitudes Across The Life Course. **Economic Journal**, v. 127, n. 605, p. 95-116, 2017.

DUARTE, M.; RESTUCCIA, D.; WADDLE, A. Exchange Rates and Business Cycles Across Countries. **FRB Richmond Economic Quarterly**. v. 93, n. 1, p. 57-76, 2007.

EGGERTSSON, G. B.; LANCASTRE M.; SUMMERS L. H. **Aging, Output per capita and Secular Stagnation.** Cambridge: National Bureau of Economic Research, 2018. (NBER Working Paper nº 24902).

FATAS, A.; MIHOV, B. Government size and automatic stabilizers: international and intranational evidence. **Journal of International Economics**. v. 55, n. 1, p. 3-28, 2001.

FERREIRA Da SILVA, G. The impact of financial system development on business cycles volatility: cross-country evidence. **Journal of Macroeconomics**, v. 24, p. 233-253, 2002.

FLORIDA, R. The rise of the creative class. New York: Basic Books, 2002.

FEYRER, James. Demographics and productivity. **The Review of Economics and Statistics**, v. 89, n. 1, p. 100-109, 2007.

FUJITA, S.; FUJIWARA, I. **Declining Trends in the Real Interest Rate and Inflation: Role of Aging**. Tokyo: Research Institute of Economy, 2015. (Discussion papers nº 15140).

FUJIWARA, I.; TERANISHI, Y. A dynamic new Keynesian life-cycle model: Societal aging, demographics, and monetary policy. **Journal of Economic Dynamics and Control**, v. 32, n. 8, p. 2398-2427, 2008.

GAMBLE, K.; BOYLE, P.; YU, L.; BENNETT, D. Aging and Financial Decision Management. **Management Science**, v. 61, n. 11, p. 2603-2610, 2014.

GOMME, P.; ROGERSON, R.; RUPERT, P.; WRIGHT, R. The Business Cycle and the Life Cycle. **NBER Macroeconomics Annual.** v. 19, p. 415-61, 2004.

GUMUS, I.; TAŞPINAR, Z.T. Real exchange rate volatility and business cycles in emerging market economies, **Economics Letters**, v. 134(C), p. 127-129, 2015.

HEER, B.; ROHRBACHER, S.; SCHARRER, C. Aging, the great moderation, and business-cycle volatility in a life-cycle model. **Macroeconomic Dynamics**, v. 21, n. 2, p. 362-383, 2017.

HOECHLE, D. Robust standard errors for panel regressions with cross-sectional dependence. **The Stata Journal**, v. 7, n. 3, p. 281-312, 2007.

HONG, H.; SCHEINKMAN, J.; XIONG, W. Advisors and asset prices: A model of the origins of bubbles. **Journal of Financial Economics**, v. 89, n. 2, p. 268-287, 2008.

IMAM, P. Demographic Shift and the Financial Sector Stability: The Case of Japan. **Journal of Population Ageing**, v. 6, n. 1, p. 1-35, 2013.

IMAM, P.A. Shock from graying: is the demographic shift weakening monetary policy effectiveness. **International Journal of Finance & Economics**, v. 20, n. 2, p. 138-154, 2015.

INTERNATIONAL MONETARY FUND (IMF). **International financial statistics yearbook**. Washington, DC: International Monetary Fund, 2018.

JAIMOVICH, N.; SIU, H. E. The Young, the Old, and the Restless: Demographics and Business Cycle Volatility. **American Economic Review**, v. 99 n. 3, p. 804-26, 2009.

KARRAS, G.; SONG, F. Sources of business-cycle volatility: An exploratory study on a sample of OECD countries. **Journal of Macroeconomics**. v. 18, p. 621-637, 1996.

KATAGIRI, Mitsuru; KONISHI, Hideki; UEDA, Kozo. Aging and deflation from a fiscal perspective. **Journal of Monetary Economics**, 2019.

KING, R.; LEVINE, R. Finance and growth: Schumpeter might be right. **Quarterly Journal of Economics**, v. 108, p. 717-737, 1993.

KLUGE, F. The Fiscal Impact of Population Aging in Germany. **Public Finance Review.** v. 41, p. 37-63, 2013.

KOPECKY, J.V. An aging dynamo: demographic change and the decline of entrepreneurial activity in the United States.". **University of California at Davis**, Manuscript, 2017.

LEEPER, E. M.; WALKER, T. B. Fiscal Limits in Advanced Economies. Economic Papers: **A journal of applied economics and policy**, v. 30 n. 1, p. 33-47, 2011.

LÉVESQUE, M.; MINNITI, M. Age matters: How demographics influence aggregate entrepreneurship. **Strategic Entrepreneurship Journal**, v. 5, n. 3, p. 269-284, 2011.

LEVESQUE, M.; MINNITI, M. The effect of aging on entrepreneurial behavior. **Journal of business venturing**, v. 21, n. 2, p. 177-194, 2006.

LIANG, J.; WANG, H.; LAZEAR, E.P. Demographics and entrepreneurship. **Journal of Political Economy**, v. 126, n. 1, p. 140-196, 2018.

LOAYZA, N.; RANCIERE, R. Financial development, financial fragility, and growth. **IMF Working Paper**, n. 5-170, 2005.

LUGAUER, S. Demographic Change and the Great Moderation in an Overlapping Generations Model with Matching Frictions. **Macroeconomic Dynamics**, v. 14, p. 1-26, 2011.

MATHER, M.; MAZAR, N.; GORLICK, M. A.; LIGHTHALL, N. R.; BURGENO, J.; SCHOEKE, A.; ARIELY, D. Risk preferences and aging: The "certainty effect" in older adults' decision making. **Psychology and Aging**, v. 27, n. 4, p. 801-816, 2012.

NEUMARK, D.; BUTTON, P. Age discrimination and the great recession. **FRBSF Economic Letter**, v. 10, n. 1-5, 2014.

POLKOVNICHENKO, V. Human capital and the private equity premium. **Review of Economic Dynamics**, v. 6, n. 4, p. 831-845, 2003.

RAMEY, G.; RAMEY, A. Cross-Country Evidence on the Link Between Volatility and Growth. **American Economic Review**, v. 85, n. 5, p. 1138-1151, 1995.

ROMER, C. Changes in Business Cycles: Evidence and Explanations. **The Journal of Economic Perspectives**, v. 13, n. 2, p. 23-44, 1999.

ROMER, C.; ROMER, D. **Why Some Times are Different: Macroeconomic Policy and the Aftermath of Financial Crises.** NBER Working Papers 23931, 2017.

ROODMAN, D. How to do xtabond2: An introduction to difference and system GMM in Stata. **The Stata Journal**, v. 9, n. 1, p. 86-136, 2009.

STADLER, G. Real Business Cycles. **Journal of Economic Literature**, v. 32, p. 1750-1783, 1994.

STOCK, J.; WATSON, M. **Disentangling the Channels of the 2007–2009 Recession**. NBER Working Paper No. 18094, 2012.

SUDO, N.; TAKIZUKA, Y. Population Aging and the Real Interest Rate in the Last and Next 50 Years - A Tale Told by an Overlapping Generations Model. **Bank of Japan Working Paper Series**, n.18-e-1, 2018.

TIRYAKI, G.F. Financial Develpoment and Economic Fluctuations. **METU Studies in Development**, v. 30, n. 1, p. 87-107, 2003.

TIRYAKI, G.F. The informal economy and business cycles. **Journal of Applied Economics**, v. 11, n. 1, p. 91-117, 2008.

TIRYAKI, G.F. Análise de dados em painel. In: MALBOUISSON, C.; TIRYAKI, G.F. (Orgs.). **Econometria na prática**. Salvador: Alta Books, 2017. cap. 7. p. 313-373.

WONG, A. **Population aging and the transmission of monetary policy to consumption**. Society for Economic Dynamics Meeting Papers, n. 716, 2016.

YOON, J.; KIM, E.; LEE, J. **Impact of Demographic Changes on Inflation and the Macroeconomy.** IMF Working Paper, n. 14-210, 2014.

YOSHINO, N.; MIYAMOTO, H. Declined effectiveness of fiscal and monetary policies faced with aging population in Japan. **Japan and the World Economy**, v. 42, p. 32-44, 2017.

## APPENDIX 1 – LIST OF COUNTRIES

| | | | | | | |
|---|---|---|---|---|---|---|
| Albania | Burkina Faso | Eq. Guinea | Israel | Mozambique | Saudi Arabia | Uganda |
| Algeria | Burundi | Fiji | Italy | Myanmar | Senegal | Ukraine |
| Angola | Cabo Verde | Finland | Jamaica | Namibia | Serbia | United Arab Emir. |
| Argentina | Cambodia | France | Japan | Nepal | Sierra Leone | United Kingdom |
| Armenia | Cameroon | Gabon | Jordan | Netherlands | Singapore | United States |
| Australia | Cent.African Rep. | Gambia | Kazakhstan | Nicaragua | Slovenia | Uruguay |
| Austria | Chad | Georgia | Kenya | Niger | Sri Lanka | Vanuatu |
| Azerbaijan | Chile | Germany | Kuwait | Nigeria | St. Vincent/Gren. | Venezuela |
| Bahamas | China | Ghana | Kyrgyz Republic | Norway | Sudan | Vietnam |
| Bahrain | Colombia | Greece | Lebanon | Oman | Suriname | Yemen |
| Bangladesh | Comoros | Guatemala | Lesotho | Pakistan | Swaziland | Mongolia |
| Belarus | Congo | Guinea | Lithuania | Panama | Sweden | Morocco |
| Belgium | Costa Rica | Guinea-Bissau | Macao | Papua N.Guinea | Switzerland | South Africa |
| Belize | Cote d'Ivoire | Guyana | Macedonia | Paraguay | Tajikistan | Spain |
| Benin | Croatia | Honduras | Madagascar | Peru | Tanzania | |
| Bhutan | Cyprus | Hong Kong | Malawi | Philippines | Thailand | |
| Bolivia | Czech Republic | Hungary | Malaysia | Poland | Togo | |
| Bosnia | Denmark | Iceland | Mali | Portugal | Tonga | |
| Botswana | Dominican Rep | India | Malta | Romania | Tonga | |
| Brazil | Ecuador | Indonesia | Mauritius | Russia | Trinidad/Tobago | |
| Brunei | Egypt | Iran. | Mexico | Rwanda | Tunisia | |
| Bulgaria | El Salvador | Ireland | Moldova | Samoa | Turkey | |