An Assessment of the Effect of Ageing Populations on Interest Rates in OECD Countries

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Abstract

Background: Currently, and in coming decades, populations in OECD countries are expected to age as fertility rates fall and life expectancies increase. It is anticipated that by 2050, nearly a quarter of the world's population will be aged 60 or older. As a result of current demographic shifts and low interest rates in countries like Japan and in the Eurozone, orthodox monetary policies have become ineffective in stabilizing economies (culminating in the implementation of policies like quantitative easing). The effects of demographic transitions, such as population ageing, on the economy may therefore be more important than previously thought by economic researchers.
Method: We hypothesize that interest rates are lower in ageing populations, due to changing attitudes towards savings and investments, which hence also generates a larger term spread. Three economic theories: the life-cycle hypothesis, the market segmentation theory, and the preferred habitat theory are used to analyze our empirical findings and interpretations. We explore the relationship between age and interest rates through the use of fixed effects (FE) and random effects (RE) estimation, and conduct several sets of regression analyses to test the robustness of the causal relationship between age and interest rates.
Conclusion: We find that our results are consistent with our hypothesis: older populations generally have lower real short-term interest rates, and that the causal relationship is more statistically significant in relatively "old" countries compared to "young" countries. When economies are in a normal, non-recessionary state, our findings support our hypothesis that term spread is greater in ageing populations. During a recessionary period, our hypothesis that ageing populations have lower interest rates still holds, as we observe a smaller term spread (in the case of a convex yield curve) due to the effect of age.

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I. Introduction

Currently, and in coming decades, populations in OECD countries are expected to age as fertility rates fall and life expectancies increase. As the post-war "baby boom" generation moves through the demographic structure, it is anticipated that by 2050, nearly a quarter of the world's population will be aged 60 or older, causing serious concerns for policy makers around the world (Bloom et al., 2011). The ramifications of demographic shifts on economic growth and stability are often overlooked in favour of more pertinent issues, like external factors related to foreign investments and trade. Due to current demographic shifts and low interest rates in countries like Japan and in the Eurozone, orthodox monetary policies have become ineffective in stabilizing economies (resulting in implementation of policies such as quantitative easing). As a result, the effects of demographic transitions on the economy may be more important than previously thought by economic researchers. Thus, for the purpose of our research paper, we aim to explore the effects of ageing on interest rates, in order to gain a greater perspective of the role of ageing populations on the economy.

Our motivation for this topic stems from the recent implementation of Quantitative Easing (QE) as a monetary policy tool in several countries, including the United States, Japan, and the Eurozone. The main goal of monetary policy is to maintain economic stability with a low, stable inflation rate, and consistent output growth, which is usually achieved through the targeting of overnight interest rates. When interest rates are already very low, as is presently the case in many OECD countries, it is difficult to stimulate spending or achieve desired output levels in order to stabilize the economy, making interest rates as a tool for monetary policy virtually futile (OECD Statistics, 2015). Japan in particular, with the world's oldest population, has long been suffering from what many economists call "a liquidity trap" (a phenomenon that renders monetary policies ineffective in stimulating consumption and investment through the targeting of lower interest rates, as interest rates are already very low or zero-bound). This has resulted in the employment of unconventional economic policies that have had various effects on its economy, such as excess reserves due to increased liquidity.

Through the investigation of historical trends over the past few decades, we hypothesize that countries with older populations have lower interest rates as a consequence of changing savings and investment behaviours. In order to conduct our research, we collected panel data on a number of variables related to interest rates for 34 OECD nations, with the aim of using this data to empirically determine whether or not interest rates are, in fact, lower in older populations. We endeavour to explore the relationship between age and interest rates through the examination of (II) economic literature

pertaining to this topic, (III) our empirical model and econometric issues, (IV) our findings and analyses, and finally through (V) our general conclusions, which will summarize our findings regarding this research topic.

II. Overview of Economic Literature and Background

It is widely acknowledged that many developed countries will experience ageing populations in the near future, posing several challenges for the economy. Much of the economic literature surrounding the topic of ageing populations concentrates on the general macroeconomic implications of demographic shifts, without specifically examining its effect on monetary policy tools, such as interest rates. Economic theories on savings and investment are unable to reach a definite conclusion as to how ageing populations will affect the economy, and in particular, whether this demographic transition will lower interest rates. While the effects of demographic shifts on 'world interest rates' have been explored in economic literature, there is not an abundance of information on the explicit effect of ageing populations on interest rates. Thus, for the purpose of contributing to economic research and thereby providing greater insight for future monetary policy implementation, we are motivated to determine whether or not a causal relationship exists between ageing and interest rates.

(i) *Determinants of Interest Rates*

According to the IS-LM model developed by John Hicks in 1937, movements in investment and savings rates impact interest rates and concurrently, real GDP levels (Maes, 1989). Until the early 1990s, the majority of economic research on interest rates attempted to determine the factors that caused high interest rates around the world. An early paper written by Robert Barro and Xavier Sala-i-Martin (1990) investigates the reasons behind the high real interest rates across major industrialized countries in the 1980s, somewhat similar to our approach. Their paper discusses the importance of investment demand and desired savings in determining interest rates, and uses data from ten OECD nations to establish that high real interest rates yield positive shocks to investment demand and decrease desired savings. The authors identified favourable stock returns (which increased investment) and high oil prices as the "key elements" inducing high real interest rates in the early 1980s.

By the early 2000s, the focus of economic research concerning interest rates shifted to determine why interest rates had declined to their lowest levels in decades. The majority of economic literature now concentrates on savings and investment changes as causes of the recent low real and nominal long-term interest rates. A paper by Ahrend et al. (2006) investigates the determinants of long-term interest rates in conventional economic models through the use of data from the United States. The authors find that three major factors including monetary policy credibility, saving-investment shifts, and portfolio shifts, account for the recent low real and nominal long-term bond yields. They postulate that yields on long-term bonds should show the expected path of future short-term interest rates. In particular, the study places emphasis on risk premia as the basis of the

'expectations hypothesis',[1] and states that the real short-term interest rate (which reflects monetary policy actions) may be affected by changes in savings and investment, as well as portfolio shifts. In their conclusion, Ahrend et al. (2006) find that the main factor behind the changes in equilibrium real interest rates is the *imbalance* between savings and investment. The paper claims that the "underlying determinants" of these equilibrium real short-term interest rates include shocks to the marginal productivity of capital, the time preference (of long-term or short-term investments), expected future income, and demographic shifts.

Furthermore, a paper published in 2005 by the IMF (2005) explores savings and investment from a global perspective. It suggests that a "global savings glut" is responsible for causing an excessive amount of savings and hence the decline of interest rates during that period. Additionally, it blames the 1997 Asian Financial Crisis for lower investment levels in the early 2000s, and indicates that in an increasingly global economy, the significant change in the early 2000s from a deficit to a surplus in savings was the main cause of low long-term real interest rates around the world. The distribution of savings and investment also has considerable effects on a country's current account balance, particularly in the United States where the deficit in 2005 reached record levels (Bernanke, 2005). This shift in the current account balance, however, was not the only driver of low real interest rates in that year. The savings-investment imbalance was further spurred by key factors such as demographic shifts, declines in public savings, and financial sector reforms (IMF, 2005).

All in all, it is clear from economic literature that opinions vary on the determinants of interest rates, which are made even more complicated by the global interactions of open economies. From a changing demographics perspective, we must look at how ageing populations will impact the determinants of interest rates. Therefore, for the purposes of our research paper, we will focus on the impact of ageing on interest rates through savings and investment, as the majority of economic literature agrees that these two factors are influenced heavily by demographic factors such as age.

(ii) *Savings and the Life-Cycle Hypothesis*

The majority of research surrounding ageing and savings is explained by the life-cycle hypothesis, a theory first proposed by Modigliani and Brumberg (1954). The life-cycle hypothesis suggests that households want to smooth consumption over their lifetime given their income, implying that savings rates increase with income during an individual's working life, and then decline (and eventually becomes negative) during retirement (Bosworth et al., 2004).

In accordance with this theory, countries with a longer life expectancy will generally have higher private savings rates, as more people approach the retirement age. This, in

[1]The hypothesis that long-term rate is the sum of expected short-term rates plus a term premium, in both the present and future and that the shape of the yield curve depends on these market expectations (Wheelock et al., 2009).

turn, theoretically prompts central monetary authorities to suppress interest rates in order to stimulate consumption and investment (as the IS-LM model shows that interest rates adjust to equate saving and investment). As the process of ageing continues, private savings rates will start to decline, as households draw into their savings after retirement. Public savings may also shrink as more pressure is put on governments to spend on public pensions and medical care in order to support ageing populations.

(iii) *Investment, the Preferred Habitat Theory, and the Market Segmentation Theory*

According to conventional term structure models, shifts in portfolio preferences can affect bond yields through changes in term premia and risk premia (Ahrend et al. 2006). These changes could be a result of shifting perceptions, attitudes of investors towards risk, or perhaps the redistribution of wealth. Increases in the demand for long-term government bonds relative to supply, or movements towards investors that are less risk averse, will act to decrease premia and compress yields, even when there are no changes in expected inflation or equilibrium real interest rates (Ahrend et al. 2006). As such, it follows that with respect to ageing populations, older investors prefer short-term investments that are less risky, which should act to decrease premia and yields in the short term and increase them in the long term, giving us a larger term spread (steeper yield curve).

This hypothesis is supported by an extension of the expectations theory called the "preferred habitat theory". There are several interpretations of the expectations theory, but all suggest that forward rates are equivalent to expected spot rates (Cox et. al, 2007). In other words, it suggests that long-term interest rates can predict future short-term interest rates, and thus predict the yield curve. The preferred habitat theory extends this hypothesis and explains why bond yields are higher in the long term than in the short term. It suggests that in addition to expectations of return, potential investors also have a preferred maturity length for the bonds they choose to invest in, called their "preferred habitat". Therefore, in order to incentivize people to invest outside of their preferred habitat (maturity length), they must be compensated with higher returns (higher interest rates).

In addition to the preferred habitat theory of term structure, we also look at the market segmentation theory. The market segmentation theory suggests that long-term and short-term interest rates are not related and move independently of each other, and that the yield curve is shaped according to the supply and demand for bonds with different maturity dates. Given that older investors have to be compensated for the higher risks associated with holding assets for a longer period, especially since they prefer more liquid assets, this theoretically lowers bond prices and drives up interest rates in the long term (preferred habitat theory) (Murphy et al., 2000). Thus, in accordance with these two theories, we hypothesize that the term spread will be greater (a steeper yield curve) in an ageing population.

Cooper and Kaplanis (2000), however, find evidence that international capital markets are neither fully integrated nor segmented. This contradicts the market segmentation theory in that the movement of long-term and short-term interest rates are not totally independent of each other in reality. In their paper, the authors identify studies by Errunza and Losq (1985), Jorion and Schwartz (1986), Cooper and Kaplanis (1986, 1994), Hietala (1989), French and Poterba (1991) and Tessar and Werner (1995), which provide empirical evidence that models of fully integrated or segmented international capital markets are unable to explain trends in portfolio shifts or the behaviour of security returns completely, implying that markets are perhaps not as segmented as the theory suggests.

With decreasing fertility rates and higher life expectancies, it seems that traditional economic policies, especially monetary policies, will no longer work effectively. Increased old dependency ratios will negatively impact GDP levels and GDP per capita growth rates, widening the output gap, and lowering productivity levels. A slowdown in population growth and higher life expectancies also imply lower labour force growth rates, as the number of people entering the workforce is not enough to offset the number of people leaving. As a result, less investment is needed to maintain capital stock, subsequently decreasing investment demand and lowering interest rates in the economy (Turner et al. 1998). These mechanisms suggest that under such circumstances, ageing populations will lower interest rates, rendering orthodox monetary policy useless.

III. Our Model

In order to assess the impact of ageing populations on world interest rates, we collected panel data from all 34 OECD member countries, and ran various regressions to evaluate the robustness of the relationship between the age of a population and interest rates. We chose to focus on OECD countries as they account for approximately 51 percent of the total world GDP (PPP measure, OECD Statistics, 2010), and are all classified as developed countries by the United Nations.

Our variables of interest are represented by three different measures of age in our empirical model: median age (medage), the old dependency ratio (dependencyratio) and the percentage of the population above 65 (pcpop65). We chose to use median age as our primary method of age measurement as this is a common practice across economic literature, and continues to be the most widely used measure in population ageing. However, in order to affirm the strength of our hypothesis, we also chose two other common population age indicators. The old dependency ratio is measured by dividing the number of people over 65 by the number of people in the working age population. The higher the ratio, the more people in retirement that are financially “depending” on a worker. Finally, we use the percentage of the population over 65 as a population age indicator, as this allows us to account for the specific segment of the population that is made up of people in their retirement age.

Additionally, two separate measures of interest rates were used for our dependent variable in order to get a more holistic overview of the causal relationship between age and interest rates: real short-term interest rates (rstir) and the term spread (termspread).

Short-term interest rates are the tools used by central banks to implement monetary policies. They represent either the three-month interbank offer rate, or securities of three-month maturities (such as Treasury bills), which are used to affect any economic changes in the immediate run (OECD Statistics, 2015). The term spread, which is calculated by the long-term interest rate (10-year maturity bonds) less the short-term interest rate (3-month maturity bonds), is equivalent to the slope of the yield curve (Aksoy, Basso, 2014). We therefore ran the following regressions on our three measures of age (denoted as 'agemeasure'):

$$\begin{aligned} rstir = {} & a_0 + a_1\left(agemeasure\right)_{it} + a_2\left(grosssave\right)_{it} + a_3\left(exrate\right)_{it} + a_4\left(lforcegrow\right)_{it} \\ & + a_5\left(grosscapform\right)_{it} + a_6\left(govtdebt\right)_{it} + a_7\left(stockspcgdp\right)_{it} + a_8\left(fdi\right)_{it} \\ & + a_9\left(infl\right)_{it} + a_{10}\left(riskpre\right)_{it} + a_{11}\left(curr\_acc\_bal\right)_{it} + e_{it} \end{aligned}$$

$$\begin{aligned} termspread = {} & b_0 + b_1\left(agemeasure\right)_{it} + b_2\left(grosssave\right)_{it} + b_3\left(exrate\right)_{it} \\ & + b_4\left(lforcegrow\right)_{it} + b_5\left(grosscapform\right)_{it} + b_6\left(govtdebt\right)_{it} \\ & + b_7\left(stockspcgdp\right)_{it} + b_8\left(fdi\right)_{it} + b_9\left(infl\right)_{it} + b_{10}\left(riskpre\right)_{it} \\ & + b_{11}\left(curr\_acc\_bal\right)_{it} + u_{it} \end{aligned}$$

Note: *i* denotes country and *t* denotes year.

In our regression analyses, we included inflation rates (infl), exchange rates (exrate), gross savings rates (grosssave), gross capital formation (grosscapform), labour force growth rates (lforcegrow), the risk premium on lending (riskpre), the total value of stocks traded as a share of GDP (stockspcgdp), foreign direct investments (fdi), government debt (govtdebt), and the current account balance (curr_acc_bal) as control variables, since they play a major role in determining interest rates.

Inflation rates were included as they are good indicators of the central banks' monetary policy actions, and because interest rates are adjusted according to inflation rate targets. Gross savings rates and gross capital formation act to reflect domestic consumer and investors' confidence, which in turn affect inflation and interest rates. The value of stocks traded as a percentage of GDP, the risk premium on lending and foreign direct investments are good measures of international investment decisions, while exchange rates, and the current account balance are indicators for foreign trade, international currency positions and subsequently, the balance of payments (BoP) accounts of countries (Hodgson et al., 1998).

Furthermore, labour force growth is an important determinant of interest rates as explained earlier, and can be negatively impacted by an ageing population. An older population implies lower labour force growth rates, which could decrease the capital stock in the economy when the labour market shrinks. According to Ahrend et al. (2006), productivity, output and investment levels are consequently affected, and fluctuations in interest rates follow. Lastly, government debt was included in our empirical model

because studies show that increasing government debt negatively impacts the value of household assets, in turn affecting interest rates through altered consumption and investment levels (Engen, Hubbard, 2004).

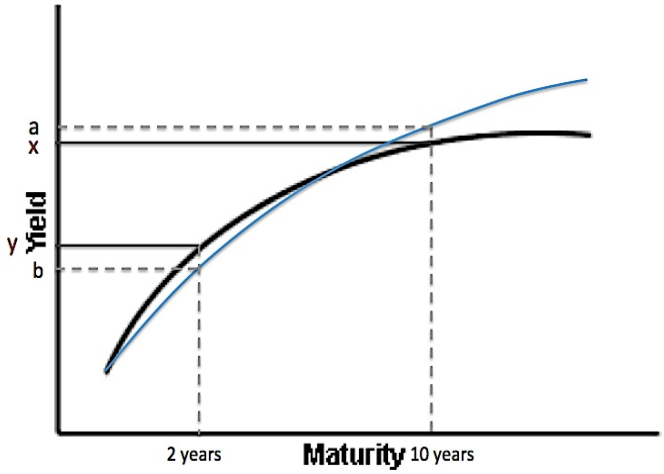

Figure A: An illustration of the effect of ageing on the term spread [*ab* > *xy*], as explained by the Preferred Habitat Theory and the Market Segmentation Theory

As explained by the life-cycle hypothesis, we expect to see a negative correlation between real short-term interest rates and our age measures. Moreover, with support from the preferred habitat theory and the market segmentation theory, we expect to see a larger term spread (steeper yield curve) in ageing populations. This is illustrated in Figure A above, where $ab > xy$ when the elderly demand more short-term bonds, and when the movement of long-term and short-term interest rates are independent of each other (Occhino, 2008).

IV. Econometric Considerations

(i) *Endogeneity*

The control variables added in our regression analyses are the main determinants of interest rates, reflecting mainly domestic consumer and investor confidence, savings and investment behaviour, the central bank's monetary policy actions, as well as external factors such as international trade and investments. However, due to the complexities of world financial and capital markets, the existence of some non-quantifiable factors like market expectations, as well as our inability to collect qualitative data such as the elderly's expectations of changing pension plan schemes in each OECD country, the problem of omitted variable bias is virtually inevitable (Akerlof, 2002).

Moreover, given the macroeconomic nature of our research project, the issue of reverse causation is likely to be present since many macroeconomic indicators are determined simultaneously. For example, it might be the case that higher gross savings (and lower

consumption expenditure) result in lower interest rates in a bid to stimulate the economy. Concurrently, higher interest rates could cause consumption levels to fall due to the higher costs of borrowing, and hence culminate in higher gross savings rates. Thus, our econometric model is likely to be subject to simultaneity bias, and we recognize the need to use alternative methods of estimation other than pooled OLS, as the Gauss-Markov assumption of exogeneity is violated (Nakamura and Nakamura, 1998).

It is also likely that our model suffers from measurement error due to inconsistent data collection methods, and incorrect statistical reporting across 34 OECD countries. This could make our findings on age measures inaccurate measures of the causal effect between age and our two dependent interest rate variables.

Therefore, we acknowledge that our model is not perfect in capturing the true effect between age and interest rates, and our coefficient of determination (R^2) values of 0.3 to 0.5 across our general 1970-2013 regressions may also suggest that there are more factors affecting interest rates that we have not included in our empirical model.

(ii) *Heteroskedasticity*

The problem of heteroskedasticity is prevalent in time-series panel data analysis due to autocorrelation (variation within each country across time), temporal correlation (variation across countries in one period of time) and the inertia of persistent common shocks (Reimers and Harvey, 2011). As a result of different economic policies across OECD member countries, it is not surprising to see cross-country variation among our independent variables. According to Reimers and Harvey (2011), within-country variation is also inevitable, as individuals differ, for example, in income levels and preferences. We therefore use White standard errors to reduce biases in our test statistics and confidence intervals arising from heteroskedasticity.

Given the susceptibility of our model to the various econometric issues mentioned above, OLS estimation is unlikely to give us unbiased or efficient results (Nakamura and Nakamura, 1998). Thus, we estimate our model using both random effects (RE) and fixed effects (FE) estimation; a common method used across economic literature for panel data. The employment of FE estimation allows us to remove any unobserved time-constant variables that may be correlated with our explanatory variables. We assume strict exogeneity, and hence the FE method of estimation proves to be a powerful tool in removing omitted variable bias and abating the problem of endogeneity. However, we cannot ensure that our variables of interest, particularly median age, have enough variability over time for FE to produce the most accurate results.

As such, we compare each set of our FE results with RE estimation. While RE is the less robust measure, it allows us to estimate the effects of time-invariant factors and gives smaller standard errors. However, it is important to note that RE estimated coefficients may be biased, as they do not account for omitted variable bias. Therefore, in order to mitigate these econometric issues and gain a holistic understanding of the relationship between age and interest rates, we estimate our model using both FE and RE strategies.

V. Empirical Evidence and Analysis

In order to reduce biases in our regression coefficients resulting from the large amounts of missing data in the 1970s and 1980s, we ran regressions for two different time subsets: 1970-2013 and 1990-2013. The results from RE and FE estimation differ slightly due to reasons mentioned in section (III), but ultimately support our hypothesis. As the two time subsets produce similar results for both methods of estimation especially for real short-term interest rates, we will continue to test our hypothesis with the full data set ranging from 1970-2013, as it accounts for a wider time frame and contains more data.

In general, we find the FE coefficients of our three measures of age to be significant at a 5 percent level and negatively correlated with real short-term interest rates, supporting our hypothesis (see Table 1). However, we observe a weaker statistical significance, ranging from 10 percent to 20 percent, for the coefficients of our age measures in our term spread regressions, perhaps suggesting that age is less likely to affect the term spread to a large extent, in comparison to real short-term interest rates. We nonetheless find a positive correlation between our age measures and the term spread, which runs in tandem with our hypothesis. Thus, our results are encouraging overall, because the negative (positive) correlation between our age measures and the real short-term interest rate (the term spread) concurs with our hypothesis that ageing populations have lower interest rates. In the following sub-sections, we will use the life-cycle hypothesis, the market segmentation theory, and the preferred habitat theory to analyze our findings, to ultimately determine the robustness of the causal relationship between age and interest rates.

(i) *Comparison of Age Effects in Young and Old Countries*

In order to test the robustness of the relationship between age and interest rates, we ran two separate sets of regressions of our dependent variables (real short-term interest rates and the term spread) on our age measures, for a group of relatively "young" and "old" countries in terms of average median age. Our "young" countries consist of Turkey, Mexico, Israel and Chile, while our "older" countries include Japan, Germany, Canada and Finland.

Through this, we observe that while all three of our age measures are negatively correlated with real short-term interest rates, the relationship is more statistically significant in older countries (at a 1 percent level) compared to younger countries, in which median age is the only statistically significant age measure (at a 5 percent level) (see Table 2). In countries with the lowest average median age, the coefficients for the old dependency ratio and percentage population over 65 are not significant at a plausible level. Alluding to the life-cycle hypothesis, savings rates increase (and consumption expenditure decreases) as a population ages, because individuals near the end of their working lives start saving intensively for their retirement (Ahrend et al. 2006). This subsequently puts a downward pressure on inflation rates, which in turn, prompts central

Table 1: All Countries General Regressions

	1970 - 2013				1990 - 2013			
Median Age								
	(RE)		(FE)		(RE)		(FE)	
Real Interest Rate	**-0.223** *(0.066)*	z: -3.36 P>|z|: 0.001 ***	**-0.638** *(0.272)*	t: -2.34 P>|t|: 0.029 **	**-0.223** *(0.066)*	z: -3.36 P>|z|: 0.001 ***	**-0.638** *(0.272)*	t: -2.34 P>|t|: 0.029 **
Term Spread	**0.097** *(0.001)*	z: 2.10 P>|z|: 0.035 **	**0.160** *(0.093)*	t: 1.73 P>|t|: 0.098 *	**0.090** *(0.049)*	z: 2.10 P>|z|: 0.035 **	**0.099** *(0.071)*	t: 1.39 P>|t|: 0.180
Dependency Ratio								
	(RE)		(FE)		(RE)		(FE)	
Real Interest Rate	**-0.050** *(0.046)*	z: -1.09 P>|z|: 0.278	**-0.558** *(0.234)*	t: -2.38 P>|t|: 0.027 **	**-0.050** *(0.046)*	z: -1.09 P>|z|: 0.278	**-0.558** *(0.234)*	t: -2.38 P>|t|: 0.027 **
Term Spread	**0.023** *(0.044)*	z: 0.51 P>|z|: 0.609	**0.120** *(0.092)*	t: 1.30 P>|t|: 0.206	**0.022** *(0.044)*	z: 0.50 P>|z|: 0.620	**0.069** *(0.107)*	t: 0.64 P>|t|: 0.528
Percentage Population Over 65								
	(RE)		(FE)		(RE)		(FE)	
Real Interest Rate	**-0.151** *(0.061)*	z: -2.45 P>|z|: 0.014 **	**-1.298** *(0.371)*	t: -3.50 P>|t|: 0.002 ***	**-0.151** *(0.061)*	z: -2.45 P>|z|: 0.014 **	**-1.298** *(0.371)*	t: -3.50 P>|t|: 0.002 ***
Term Spread	**0.098** *(0.057)*	z: 1.72 P>|z|: 0.085 *	**0.218** *(0.145)*	t: 1.51 P>|t|: 0.146	**0.097** *(0.057)*	z: 1.72 P>|z|: 0.086 *	**0.206** *(0.161)*	t: 1.28 P>|t|: 0.216

Table 2: Countries with High and Low Average Median Age

	Highest Average Median Age				Lowest Average Median Age			
Median Age								
	(RE)		(FE)		(RE)		(FE)	
Real Interest Rate	**-0.515** *(0.131)*	z: -3.93 P>|z|: 0.000 ***	**-0.524** *(0.024)*	t: -21.51 P>|t|: 0.000 ***	**-1.269** *(0.566)*	z: -2.24 P>|z|: 0.025 **	**-1.168** *(0.236)*	t: -6.90 P>|t|: 0.006 ***
Term Spread	**0.034** *(0.065)*	z: -0.52 P>|z|: 0.602	**-0.048** *(0.041)*	t: -1.16 P>|t|: 0.331	**0.537** *(0.466)*	z: 1.15 P>|z|: 0.249	**-0.390** *(0.484)*	t: 0.81 P>|t|: 0.479
Dependency Ratio								
	(RE)		(FE)		(RE)		(FE)	
Real Interest Rate	**-1.269** *(0.002)*	z: -3.09 P>|z|: 0.002 ***	**-0.404** *(0.216)*	t: -18.78 P>|t|: 0.000 ***	**-0.878** *(0.768)*	z: -1.15 P>|z|: 0.248	**-1.592** *(0.839)*	t: -1.90 P>|t|: 0.154
Term Spread	**-0.040** *(0.028)*	z: -1.44 P>|z|: 0.149	**-0.101** *(0.037)*	t: -2.75 P>|t|: 0.070 *	**-0.375** *(0.527)*	z: 0.71 P>|z|: 0.477	**-0.015** *(0.912)*	t: -0.02 P>|t|: 0.388
Percentage Population Over 65								
	(RE)		(FE)		(RE)		(FE)	
Real Interest Rate	**-0.487** *(0.139)*	z: -3.50 P>|z|: 0.000 ***	**-0.656** *(0.049)*	t: -13.53 P>|t|: 0.001 ***	**-1.462** *(0.831)*	z: -1.76 P>|z|: 0.079 *	**-3.403** *(2.381)*	t: -1.43 P>|t|: 0.248
Term Spread	**-0.060** *(0.055)*	z: -1.10 P>|z|: 0.273	**-0.135** *(0.052)*	t: -2.61 P>|t|: 0.080 *	**-0.321** *(0.279)*	z: -1.15 P>|z|: 0.249	**-2.091** *(1.153)*	t: 1.81 P>|t|: 0.167

banks to lower short-term nominal interest rates[1], in order to stimulate consumption and investment.

We find the coefficients of all three age variables to be more significant in countries with a higher average median age than in those with a lower average median age, indicating that age may play a larger role in affecting interest rates in older populations. The life-cycle hypothesis provides an explanation for this phenomenon, as people tend to save more as they get older and approach their retirement age. With reference to our regressions of the term spread, we generally find statistically insignificant results for all three of our age measures. Moreover, the observation of a negative correlation between the age variable (pcpop65) and the term spread, is not consistent with our hypothesis, or the preferred habitat and market segmentation theories. Therefore, it is likely that in reality, markets are not as segmented as economic theory states, providing explanations for the negative instead of positive correlation that we expected to find, as well as less significant results.

(ii) *Comparison of Age Effects in 'Slowly' and 'Rapidly' Ageing Populations*

In order to further explore the relationship between age and interest rates, we also compare countries that have aged the most rapidly in terms of median age, and those that have aged the most slowly in terms of median age, over the years 1970-2013.

We find highly statistically significant results (at a 1 percent level) for all measures of age with real interest rates in the subset of rapidly ageing countries (see table 3). This implies that in countries with populations that have aged most rapidly in terms of median age, population age has a larger impact on interest rates, than in their slowly ageing counterparts. The coefficients are all negatively correlated with real short-term interest rates, which are once again, consistent with our hypothesis and supported by the life-cycle theory (see table 3).

With regards to the term spread, we see some mixed results in terms of the correlation with our age measures. We observe that in rapidly ageing countries, age is negatively correlated with term spread, whereas in slowly ageing countries, it is positively correlated, though not statistically significant for our FE regressions (see table 3). We expected to see a larger term spread in more rapidly ageing countries, as we observed a statistically significant negative correlation with interest rates and our three age measures. Nevertheless, our hypothesis may still be supported by these findings if the movement of short-term and long-term interest rates is interdependent, as this would generate a yield curve with a smaller slope. In other words, these results may suggest that the market segmentation theory may not hold true, although more research beyond the scope of this paper would be needed in order to determine the term structure.

[1] The Fisher equation: $r = i - \pi$ demonstrates the linear relationship between real and nominal interest rates, where i represents the nominal interest rate, r represents the real interest rate, and π represents inflation.

Table 3: Countries with Rapid and Slow Changing Age Distributions

	Rapid Ageing				Slow Ageing			
Median Age								
	(RE)		(FE)		(RE)		(FE)	
Real Interest Rate	**-0.394** *(0.084)*	z: -4.69 P>|z|: 0.000 ***	**-0.358** *(0.036)*	t: -9.95 P>|t|: 0.002 ***	**-1.457** *(0.271)*	z: -5.37 P>|z|: 0.000 ***	**-1.325** *(0.264)*	t: -5.02 P>|t|: 0.015 **
Term Spread	**-0.114** *(0.049)*	z: -2.36 P>|z|: 0.018 **	**-0.137** *(0.067)*	t: -2.03 P>|t|: 0.135	**-0.433** *(0.074)*	z: 5.90 P>|z|: 0.000 ***	**0.324** *(0.523)*	t: 0.62 P>|t|: 0.580
Dependency Ratio								
	(RE)		(FE)		(RE)		(FE)	
Real Interest Rate	**-0.185** *(0.055)*	z: -3.35 P>|z|: 0.001 ***	**-0.323** *(0.062)*	t: -5.17 P>|t|: 0.014 **	**-0.118** *(0.283)*	z: 0.420 P>|z|: 0.677	**-0.917** *(0.269)*	t: -3.40 P>|t|: 0.043 **
Term Spread	**-0.076** *(0.013)*	z: -5.96 P>|z|: 0.000 ***	**-0.162** *(0.078)*	t: -2.08 P>|t|: 0.130	**-0.043** *(0.058)*	z: 0.76 P>|z|: 0.448	**0.486** *(0.434)*	t: 1012 P>|t|: 0.345
Percentage Population Over 65								
	(RE)		(FE)		(RE)		(FE)	
Real Interest Rate	**-0.351** *(0.106)*	z: -3.32 P>|z|: 0.001 ***	**-0.605** *(0.082)*	t: -7.42 P>|t|: 0.005 ***	**-0.609** *(0.538)*	z: -1.12 P>|z|: 0.261	**-1.482** *(0.186)*	t: -7.95 P>|t|: 0.004 ***
Term Spread	**-0.123** *(0.029)*	z: -4.31 P>|z|: 0.000 ***	**-0.256** *(0.118)*	t: -2.17 P>|t|: 0.119	**-0.344** *(0.116)*	z: 2.96 P>|z|: 0.003 ***	**0.648** *(0.342)*	t: 1.90 P>|t|: 0.154

(iii) *Changing Age Distributions of "Young" Countries*

Given that we have found a causal relationship between age and interest rates in rapid and slow ageing populations, we decided to test this relationship in countries that were relatively the same in terms of median age in 1970 - that is to say, countries with the same approximate starting point. We identify two different subsets of countries that were "young" in 1970, with one group ageing faster than the other. Our "young and rapidly ageing" countries consisted of Canada, Chile, and Ireland, while our "young and slowly ageing" subset included Israel, Portugal, and Slovak Republic.

Overall, we find fairly different results between the two estimation methods in this robustness check, compared to our previous estimations. While this may have some interesting implications for our hypothesis, it is important to note that this may also be a result of a smaller data set, and the fact that it was difficult to ensure countries had approximately the same median age in 1970.

With real short-term interest rates, we find highly statistically significant results at the 1 percent level for all three age measures when using RE estimation within the countries that have had the fastest changing age distributions (see table 4). This is not the case for our RE estimates in slowly ageing countries, as only the variable accounting for the population over 65 is statistically significant. In both subsets, our findings reveal that the

Table 4: "Young" Countries with Rapid and Slow Changing Age Distributions

	Rapid Change				Slow Change			
Median Age								
	(RE)		(FE)		(RE)		(FE)	
Real Interest Rate	**-0.841** *(0.154)*	z: -5.44 P>|z|: 0.000 ***	**-0.662** *(0.304)*	t: -2.18 P>|t|: 0.161	**0.332** *(0.726)*	z: 0.46 P>|z|: 0.647	**-0.614** *(0.462)*	t: -1.33 P>|t|: 0.411
Term Spread	**0.315** *(0.085)*	z: 3.72 P>|z|: 0.000 ***	**0.245** *(0.137)*	t: 1.79 P>|t|: 0.216	**1.175** *(0.126)*	z: 9.32 P>|z|: 0.000 ***	**0.480** *(0.298)*	t: 1.61 P>|t|: 0.354
Dependency Ratio								
	(RE)		(FE)		(RE)		(FE)	
Real Interest Rate	**-1.670** *(0.207)*	z: -8.06 P>|z|: 0.000 ***	**-1.250** *(0.441)*	t: -2.83 P>|t|: 0.105	**0.482** *(0.283)*	z: 0.420 P>|z|: 0.677	**-2.967** *(2.463)*	t: -1.20 P>|t|: 0.441
Term Spread	**0.519** *(0.039)*	z: 14.82 P>|z|: 0.000 ***	**0.409** *(0.078)*	t: 2.19 P>|t|: 0.160	**1.551** *(0.192)*	z: 8.07 P>|z|: 0.000 ***	**-2.07** *(0.160)*	t: -12.98 P>|t|: 0.049 **
Percentage Population Over 65								
	(RE)		(FE)		(RE)		(FE)	
Real Interest Rate	**-2.510** *(0.315)*	z: -7.95 P>|z|: 0.000 ***	**-2.068** *(0.636)*	t: -3.25 P>|t|: 0.083 *	**-5.234** *(1.502)*	z: -3.48 P>|z|: 0.000 ***	**-6.665** *(2.207)*	t: -3.02 P>|t|: 0.204
Term Spread	**0.** 806 *(0.062)*	z: 13.08 P>|z|: 0.000 ***	**0.630** *(0.323)*	t: 1.95 P>|t|: 0.190	**5.332** *(1.117)*	z: 4.77 P>|z|: 0.000 ***	**1.421** *(1.741)*	t: 0.82 P>|t|: 0.564

percentage of the population over 65 variable affects interest rates with the greatest magnitude, with an effect as large as 2 to 5 percentage points for both FE and RE.

We find results consistent with our hypothesis for the term spread regressions in both subsets using RE estimation, with a positive correlation between the term spread and all three age measures (see table 4). Additionally, we observe that they are all significant at the 1 percent level. When FE estimation is used, we observe much less statistically significant coefficients given that it is a more robust method as mentioned in section (III) above, albeit the coefficients are negatively (positively) correlated with real interest rates (term spread) as we predict.

It is interesting to note that in our countries with slowly changing age distributions, both our RE and FE estimates give us statistically insignificant values when regressed on real short-term interest rates, although they are still negatively correlated. As we find significant results in rapidly ageing countries with RE estimation, this provides further proof that age has a larger impact on interest rates in rapidly ageing countries than in their slowly ageing counterparts. Therefore, this is consistent with our previous findings and hypothesis, and is further supported by the life-cycle hypothesis. For our term spread regressions, the coefficients of our age measures remain positively correlated and statistically significant at the 1 percent level with RE estimation, providing more

evidence in support of our hypothesis, the market segmentation theory, and the preferred habitat theory (see table 4).

To reiterate, the results from our analyses above suggest that population age plays a bigger role in determining interest rates in rapidly ageing populations as opposed to slowly ageing populations, regardless of their initial median age in 1970. Policymakers in rapidly ageing countries may thus need to be more cognizant of their ageing populations when making monetary policy decisions, as these results indicate that traditional monetary policy may not work as well.

(iv) *Recessionary Period Analysis*

So far, our analyses of the effect of ageing on interest rates assume that economies operate in a normal state (a non-recessionary period). In order to test our hypothesis as well as the robustness of the effect of ageing on interest rates further, we examine the relationship between these two variables during a recession[1]. In particular, we will focus on the 2008 U.S Financial Crisis due to the rippling economic effects it had on global markets and OECD nations, as well as the 2010 European Union (EU) Debt Crisis, since 21 out of the 34 member countries of the OECD are members of the EU (OECD Statistics, 2015).

With reference to Figure B, which shows a convex yield curve in a recession, we hypothesize that the term spread will be smaller, i.e. $|xy| < |ab|$ (Ang et al, 2006).

In accordance with the preferred habitat theory, older investors must be compensated with higher returns if they hold bonds for a longer term, or a term outside of their "preferred habitat". Subsequently, a greater demand for bonds of a shorter term, by the elderly, will act to lower short-term yields (Cox et. al, 2007). In addition, assuming that the market segmentation theory holds, long-term interest rates do not influence short-term interest rates. Thus, we predict that these combined effects will pull the convex yield curve lower, as can be seen in Figure B, consequently generating a smaller term spread during a recessionary period. The following sub sections: (a) 2008 Financial Crisis, and (b) 2010 EU Debt Crisis summarize our findings in seeking to test the robustness of the causal relationship between age and interest rates.

(a) *2008 Financial Crisis*

With the aim of examining if the term spread is indeed smaller during a recession as a result of age, we interacted all three of our age measures with a 2008 time dummy, representing the initial onset of the financial crisis. We then compared them with our regular estimates from the same regression, representing a stable economic period. Our results were encouraging as they were consistent with our prediction: a recessionary period will yield a smaller term spread (negative correlation between the term spread and age measures).

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[1] A recession is typically defined as two consecutive quarters of negative GDP growth in an economy.

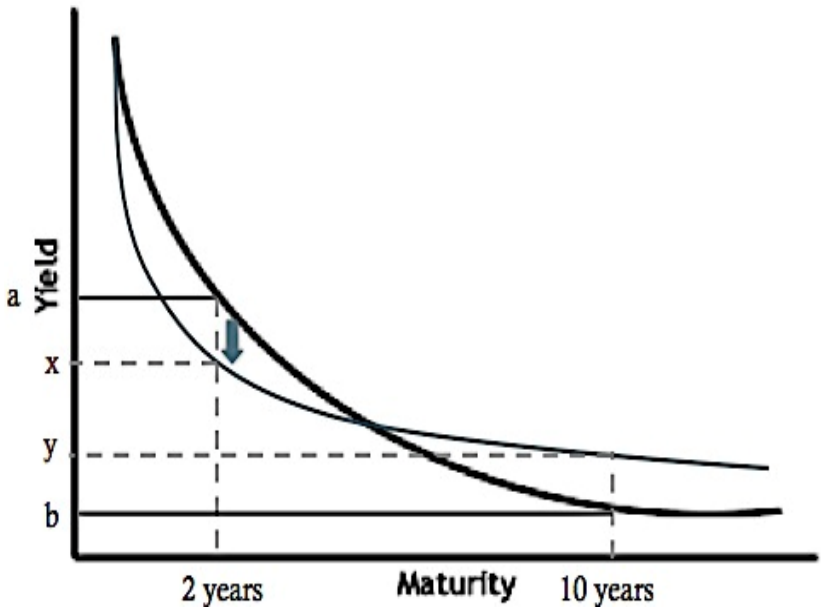

Figure B: An illustration of the effect of ageing on the term spread |*xy*| < |*ab*| during a recession, as explained by the Preferred Habitat Theory and the Market Segmentation Theory

We therefore ran the following regressions:

$$\begin{aligned} rstir = {} & c_0 + c_1\left(agemeasure\right)_{it} + c_2\left(agemeasure * d2008\right)_{it} + c_3\left(grosssave\right)_{it} \\ & + c_4\left(exrate\right)_{it} + c_5\left(lforcegrow\right)_{it} + c_6\left(grosscapform\right)_{it} + c_7\left(govtdebt\right)_{it} \\ & + c_8\left(stockspcgdp\right)_{it} + c_9\left(fdi\right)_{it} + c_{10}\left(infl\right)_{it} + c_{11}\left(riskpre\right)_{it} \\ & + c_{12}\left(curr\_acc\_bal\right)_{it} + e_{it} \end{aligned}$$

$$\begin{aligned} termspread = {} & g_0 + g_1\left(agemeasure\right)_{it} + g_2\left(agemeasure * d2008\right)_{it} + g_3\left(grosssave\right)_{it} \\ & + g_4\left(exrate\right)_{it} + g_5\left(lforcegrow\right)_{it} + g_6\left(grosscapform\right)_{it} \\ & + g_7\left(govtdebt\right)_{it} + g_8\left(stockspcgdp\right)_{it} + g_9\left(fdi\right)_{it} + g_{10}\left(infl\right)_{it} \\ & + g_{11}\left(riskpre\right)_{it} + g_{12}\left(curr\_acc\_bal\right)_{it} + u_{it} \end{aligned}$$

Note: *where i* denotes country and *t* denotes year.

Referring to Table 5, both our FE and RE estimates of the interacted terms (age measures and the 2008 year dummy) with the term spread are negatively correlated, signalling a smaller term spread during a recessionary period. However, none of the estimates of our interacted terms were significant at a 5 percent level, perhaps indicating that age was less likely to affect term spread. Interestingly, we also observe the magnitude of the interacted

terms to be relatively larger than our regular age estimates, demonstrating that the effect of age on interest rates, and term spread specifically, is larger during a recession as opposed to a more stable economic period.

Table 5: 2008 Financial Crisis

Median Age								
	medage* d2008 (RE)		medage* d2008 (FE)		medage (RE)		medage (FE)	
Real Interest Rate	**-1.320** *(0.507)*	z: -2.60 p>|z|: 0.009 ***	**-1.232** *(0.513)*	t: -2.40 p>|t|: 0.026 **	**-0.170** *(0.051)*	z: -3.33 p>|z|: 0.001 ***	**-0.593** *(0.276)*	t: -2.15 p>|t|: 0.043 **
Term Spread	**-0.142** *(0.337)*	z: -0.42 p>|z|: 0.673	**-0.129** *(0.425)*	t: -0.30 p>|t|: 0.765	**0.044** *(0.042)*	z: 1.05 p>|z|: 0.296	**0.073** *(0.063)*	t: 1.15 p>|t|: 0.261
Percentage Population Over 65								
	pcpop65* d2008 (RE)		pcpop65* d2008 (FE)		pcpop65 (RE)		pcpop65 (FE)	
Real Interest Rate	**-1.524** *(0.432)*	z: -3.52 p>|z|: 0.000 ***	**-1.220** *(0.518)*	t: -2.36 p>|t|: 0.028 **	**-0.127** *(0.046)*	z: -2.76 p>|z|: 0.006 ***	**-1.197** *(0.368)*	t: -3.26 p>|t|: 0.004 ***
Term Spread	**-0.133** *(0.315)*	z: -0.42 p>|z|: 0.671	**-0.125** *(0.439)*	t: -0.290 p>|t|: 0.778	**0.093** *(0.371)*	z: 2.50 p>|z|: 0.012 **	**0.148** *(0.165)*	t: 0.900 p>|t|: 0.380
Dependency Ratio								
	dependencyratio* d2008 (RE)		dependencyratio* d2008 (FE)		dependencyratio (RE)		dependencyratio (FE)	
Real Interest Rate	**-1.426** *(0.425)*	z: -3.35 p>|z|: 0.001 ***	**-1.267** *(0.580)*	t: -2.190 p>|t|: 0.040 **	**-0.400** *(0.042)*	z: -0.96 p>|Z|: 0.337	**-0.485** *(0.231)*	t: -2.10 p>|t|: 0.048 **
Term Spread	**-0.121** *(0.344)*	z: -0.35 p>|Z|: 0.725	**-0.126** *(0.451)*	t: -0.280 p>|t|: 0.782	**0.016** *(0.054)*	z: 0.29 p>|Z|: 0.773	**0.040** *(0.200)*	t: 0.360 p>|t|: 0.720

Given that asset liquidity tends to decline during a recession due to tighter market conditions and credit constraints, older investors start buying safer, short-term assets that have greater liquidity (Gibson and Mougeot, 2004). In turn, this requires them to tap into their personal savings, which will ultimately act to affect interest rates, in accordance with the life-cycle hypothesis. Therefore, this mechanism seems to suggest that age should have a larger impact on the term spread during a recession, as savings and investment rates (both of which are highly influenced by an ageing population) move to influence interest rates.

For our regressions of the real short-term interest rate on our age measures, we also find results that support our hypothesis: lower interest rates in older populations. Table 5 shows that both our FE and RE estimates of all interacted terms (age measures and time dummies) are negatively correlated with the real short term interest rate, indicating that interest rates are indeed lower in ageing populations. Overall, our RE and FE estimates have strong statistical significance levels of 1 percent and 5 percent respectively, and we also notice larger coefficients of our interacted age variables with the real short-term interest rate, as compared to the non-interacted terms (see table 5). This could be due to the fact that governments commonly buy more short-term bonds during the initial hit of a financial crisis, in a bid to lower interest rates (Gibson and Mougeot, 2004). Thus, this

effect, compounded with the greater demand of short-term bonds by the elderly, provides an explanation for why we see a larger negative impact of age on interest rates during the 2008 Financial Crisis.

(b) *2010 EU Debt Crisis*

The 2010 EU Debt Crisis had severe economic ramifications on EU member countries, given the high volume of trading and investment activity within the European Economic Union (Brenton and Manchin, 2003). Therefore, in order to test the effect of ageing on interest rates during this period of economic downturn in the region, we tested our regression model on EU member countries within the OECD.

We interacted our age measures with a 2010 time dummy to properly examine the relationship between these two factors during a recession, and subsequently compared it to our regular estimates, as we did above for our analysis on the 2008 Financial Crisis. In general, we find results that are consistent with our prediction using both RE and FE estimation methods: a negative correlation between our interacted age measures, and both the term spread, and the real short-term interest rates. Moreover, our estimates of all three interacted age terms on the term spread are statistically significant at a 5 percent level for both methods of estimation (see table 6).

We ran the following regressions:

$$\begin{aligned} rstir = {} & h_0 + h_1\left(agemeasure\right)_{it} + h_2\left(agemeasure * d2010\right)_{it} + h_3\left(grosssave\right)_{it} \\ & + h_4\left(exrate\right)_{it} + h_5\left(lforcegrow\right)_{it} + h_6\left(grosscapform\right)_{it} \\ & + h_7\left(govtdebt\right)_{it} + h_8\left(stockspcgdp\right)_{it} + h_9\left(fdi\right)_{it} + h_{10}\left(infl\right)_{it} \\ & + h_{11}\left(riskpre\right)_{it} + h_{12}\left(curr\_acc\_bal\right)_{it} + e_{it} \end{aligned}$$

$$\begin{aligned} termspread = {} & j_0 + j_1\left(agemeasure\right)_{it} + j_2\left(agemeasure * d2010\right)_{it} + j_3\left(grosssave\right)_{it} \\ & + j_4\left(exrate\right)_{it} + j_5\left(lforcegrow\right)_{it} + j_6\left(grosscapform\right)_{it} \\ & + j_7\left(stockspcgdp\right)_{it} + j_8\left(fdi\right)_{it} + j_9\left(infl\right)_{it} + j_{10}\left(riskpre\right)_{it} \\ & + j_{11}\left(riskpre\right)_{it} + j_{12}\left(curr\_acc\_bal\right)_{it} + u_{it} \end{aligned}$$

Note: *where i* denotes country and *t* denotes year.

Interestingly, in this set of analysis, we find that our FE coefficients of the interacted age terms, which account for the 2010 EU Debt Crisis, are about six times larger than the regular age measures. This could possibly be due to the implementation of unconventional monetary policy (Quantitative Easing) across the EU right after the debt crisis, which largely affected the expectations of future yields among older investors (Valiante, 2011). Therefore, it follows that the reaction of older investors in these EU nations, in response to changing expectations of future interest rates, provides a fair explanation for the significantly larger impact of age on the term spread in 2010.

Nonetheless, we acknowledge that many other factors could be responsible for this phenomenon as well, due to the complexities of world financial markets, and differing supplementary economic policies that individual countries may have implemented to mitigate the effects of the debt crisis.

Table 6: 2010 EU Debt Crisis

Median Age								
	medage* d2010 (RE)		medage* d2010 (FE)		medage (RE)		medage (FE)	
Real Interest Rate	**-1.392** *(0.599)*	z: -2.33 P>|z|: 0.020 **	**-0.808** (0.693)	t: -1.17 p>|t|: 0.263	**-0.379** *(0.197)*	z: -1.92 P>|z|: 0.055 *	**-0.402** *(0.221)*	t: -1.82 p>|t|: 0.090 *
Term Spread	**-1.023** *(0.297)*	z: 3.45 P>|z|: 0.001 ***	**-0.628** (0.239)	t: 2.63 p>|t|: 0.020 **	**0.079** *(0.075)*	z: 1.05 P>|z|: 0.293	**0.0489** *(0.077)*	t: 0.64 p>|t|: 0.533
Percentage Population Over 65								
	pcpop65* d2010 (RE)		pcpop65* d2010 (FE)		pcpop65 (RE)		pcpop65 (FE)	
Real Interest Rate	**-1.937** *(0.687)*	z: -2.82 P>|z|: 0.005 ***	**-0.758** (0.648)	t: -1.17 p>|t|: 0.261	**-0.317** *(0.186)*	z: -1.70 P>|z|: 0.088 *	**-1.724** *(0.420)*	t: -4.10 p>|t|: 0.001 ***
Term Spread	**-1.068** *(0.302)*	z: 3.53 P>|z|: 0.000 ***	**-0.665** (0.251)	t: 2.65 p>|t|: 0.019 **	**0.099** *(0.062)*	z: 1.61 P>|z|: 0.106	**0.1312** *(0.320)*	t: 0.41 p>|t|: 0.688
Dependency Ratio								
	dependencyratio* d2010 (RE)		dependencyratio* d2010 (FE)		dependencyratio (RE)		dependencyratio (FE)	
Real Interest Rate	**-2.394** *(0.724)*	z: -3.31 P>|z|: 0.001 ***	**-1.202** (0.738)	t: -1.63 p>|t|: 0.126	**-0.075** *(0.192)*	z: -0.39 P>|z|: 0.694	**-0.5529** *(0.216)*	t: -2.56 p>|t|: 0.023 **
Term Spread	**-1.158** *(0.387)*	z: 2.99 P>|z|: 0.003 ***	**-0.666** (0.279)	t: 2.39 p>|t|: 0.031 **	**0.083** *(0.077)*	z: 1.08 P>|z|: 0.280	**0.1041** *(0.178)*	t: 0.59 p>|t|: 0.567

VI. Conclusion and Policy Implications

We conclude that there exists a fairly robust causal relationship between population age and interest rates. Through the use of both FE and RE estimation methods, and with the support of three economic theories (the life-cycle hypothesis, the market segmentation theory and the preferred habitat theory), we find that our model reveals a negative correlation between these two factors overall.

Our regression results show that countries with older populations generally have lower real short-term interest rates, and that the causal relationship is more significant in relatively "older" countries compared to "younger" countries. Moreover, we find that the relationship is most significant in countries that have experienced a rapid increase in the median age of the population, especially in comparison to countries that have had a slow increase in median age over the period 1970-2013. Our analyses also reveal a smaller

term spread during a recession. This turns out to be consistent with our hypothesis, given that age will act to lower real short-term interest rates, and hence generate a smaller term spread, as in the case of a convex yield curve reflecting a recessionary period.

In order to evaluate the policy implications of the effect of ageing on interest rates based on our analyses, it is imperative to examine the economic significance of our empirical results. Given that FE is more robust to various sets of econometric assumptions as compared to RE, we recommend more focus on our FE estimates when interpreting the economic significance of our coefficients. With reference to our 1970-2013 general regression estimates, a one-unit increase in the median age, the percentage of the population above 65, and the old dependency ratio, is associated with a decline in interest rates of 0.64 percent, 0.56 percent and 1.3 percent respectively.

The implications of these estimates on an economy nonetheless differ, depending on the individual country's initial interest rate level. For example, an ageing population could be a detriment to countries with already very low interest rates. As of 2014, Switzerland's real short-term interest rate remained at 0.01 percent, implying that if the median age of the population were to increase by a year, real interest rates would fall to -0.63 percent (OECD Statistics, 2015). Based on economic theory, such a phenomenon could place the Swiss economy at risk of a liquidity trap, as the marginal propensity of the population to consume would be low, and muted interest rates are subsequently unable to stimulate consumption. On the other hand, a country like Iceland, with high current real interest rates of 6.05 percent could benefit from an ageing population, as age will act to suppress interest rates, and in turn increase bond prices (OECD Statistics, 2015). Given the inverse relationship between bond prices and interest rates, investors in the country will therefore benefit when interest rates are suppressed by age, as the value of their bonds rise.

Furthermore, assuming that inflation rates are relatively stable, lower interest could act to stimulate consumption and investment in the country without putting it at risk of falling into a liquidity trap, and subsequently encourage real GDP growth. Nonetheless, we acknowledge that there are limitations to the interpretations of our analyses, as they are based on strong assumptions and theories that may not truly hold. We recognize that our empirical model and data are not perfect in capturing the true effect of demographic shifts on interest rates. We thus accept that there are many more latent and immeasurable variables, such as market expectations, which also act to influence interest rates but are not included in our model.

Overall, however, our findings generally agree with our hypothesis, and we are grateful to be able to contribute to economic research surrounding this topic. Going forward, we hope that our research paper will help to catalyze further exploration of the causal relationship between age and interest rates, in order to aid the implementation of future monetary policy.

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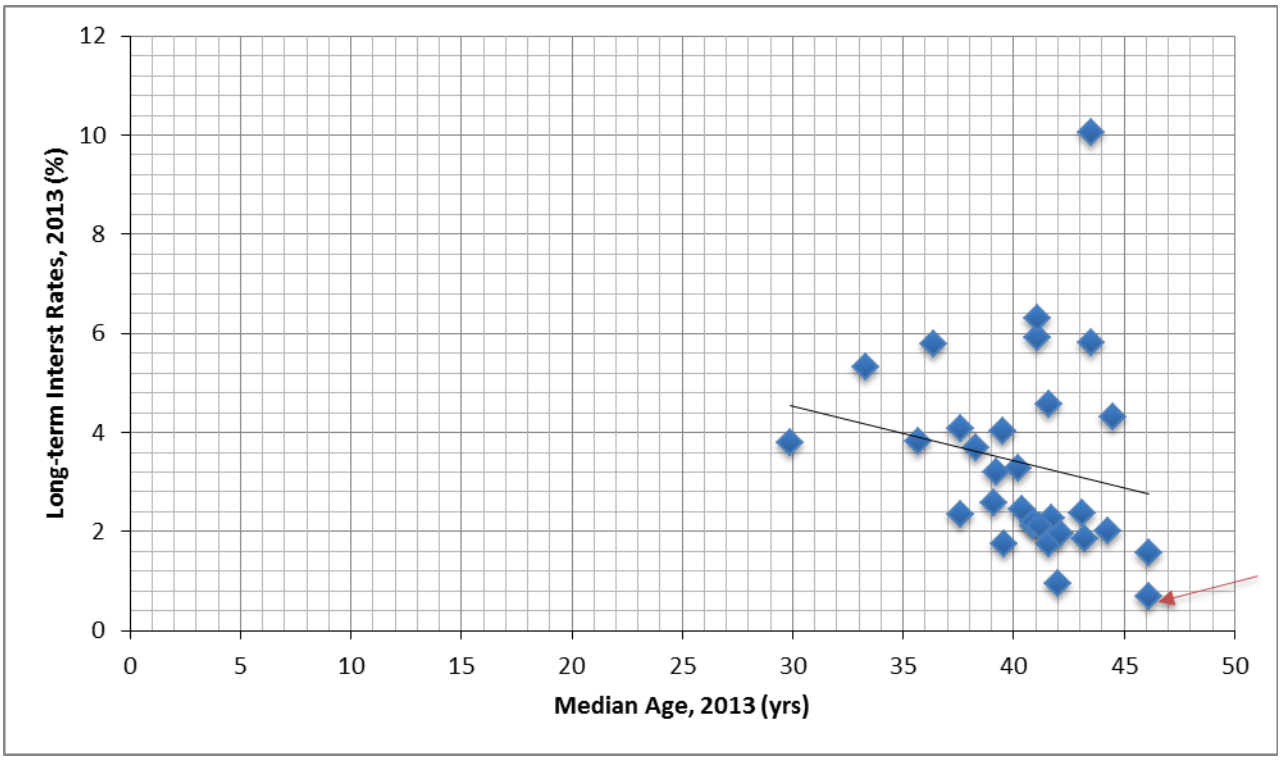
Appendix

Initial Motivation: Scatter plot comparing median age and long-term interest rates in OECD countries (Data extracted from stats.oecd.org). We notice a negative correlation between age and interest rates, across OECD countries in the year 2013.



Dependent Variables	
Stir	Short-term interest rates (3-month interbank offer rate or rate associated with Treasury bills, Certificates of Deposit or comparable instruments).
Termspread	The difference between bond yield rates at different maturities.

Variables of interest: Measures of age	
Medage	Median age of the population in each country.
Pcpop65	Percentage of the population over 65 years old
Dependencyratio	The old dependency ratio.

Control Variables	
Infl	The annual inflation rate in a country
Grosssave	The gross national income less total consumption, plus net transfers (public)
Exrate	The exchange rate for each country expressed in terms of US dollars
Year	1970 - 2015
Countries	Countries label, 1 to 34
Grosscapform	Gross domestic investment as a percentage of GDP
Curr_acc_bal	The sum of net exports of goods and services, net primary income and net secondary income as a percentage of GDP
Lforcegr	The rate of growth of the working age population
Govtdebt	Domestic and foreign liabilities such as currency and money deposits, securities other than shares, and loans
Riskpre	The interest rate charged by banks on loans to private sector customers minus the "risk free" treasury bill interest rate
Stockspcgdp	The total value of shares traded during the period, as a percentage of GDP
Fdi	The sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments

Table (a): Number of observations, the range, mean and standard deviation for each variable (1970-2013)

Variable	Obs	Mean	Std. Dev.	Min	Max
countries	0				
year	1496	1991.5	12.70267	1970	2013
pcpop65	1496	12.52928	3.723874	3.2	25.1
medage	1496	33.46227	5.309255	16.595	44.862
dependency~o	1485	19.02329	5.368115	5.615754	40.3721
rstir	970	.3838557	11.25953	-105.2	11.31
termspread	864	.6818287	2.184138	-13.87	21.93
grosssave	1125	22.84705	5.382264	1.48	40.5
exrate	1406	50.13801	172.8064	.000014	1695
grosscapform	1310	23.97238	4.555345	9.85	49.1
lforcegrow	984	6.853593	32.66794	-.987	224.094
curr_acc_bal	797	-.3531995	5.069344	-23.6	16.2
govtdebt	524	69.80138	37.14443	8.402263	239.2875
stockspcgdp	800	44.74171	57.62829	.0225106	434.9207
fdi	1268	1.27e+10	3.48e+10	-3.08e+10	3.40e+11
infl	1368	12.69342	49.70913	-4.5	1281.4
riskpre	678	4.244204	25.87939	-4.799167	605.7333
c	1496	17.5	9.813989	1	34

Table (b): Number of missing observations, the number of total observations, and the proportion of missing observations (1970-2013)

Variable	Missing	Total	Percent Missing
countries	17	1,513	1.12
year	17	1,513	1.12
pcpop65	17	1,513	1.12
medage	17	1,513	1.12
dependency~o	28	1,513	1.85
rstir	543	1,513	35.89
termspread	649	1,513	42.89
grosssave	388	1,513	25.64
exrate	107	1,513	7.07
grosscapform	203	1,513	13.42
lforcegrow	529	1,513	34.96
curr_acc_bal	716	1,513	47.32
govtdebt	989	1,513	65.37
stockspcgdp	713	1,513	47.12
fdi	245	1,513	16.19
infl	145	1,513	9.58
riskpre	835	1,513	55.19
c	17	1,513	1.12

Table (c): Number of observations, the range, mean and standard deviation for each variable (1990-2013)

Variable	Obs	Mean	Std. Dev.	Min	Max
countries	0				
year	816	2001.5	6.926432	1990	2013
pcpop65	816	13.76507	3.67264	4.3	25.1
medage	816	35.65045	4.70701	19.787	44.862
dependency~o	806	20.57733	5.481005	7.250892	40.3721
rstir	722	.6194044	10.48327	-105.2	11.31
termspread	647	.8874034	2.280662	-13.87	21.93
grosssave	711	22.48205	5.344285	3.1	40.5
exrate	806	59.72305	200.692	.00293	1695
grosscapform	781	23.02762	3.853159	11.77	39.36
lforcegrow	816	7.956434	35.75458	-.987	224.094
curr_acc_bal	670	-.3649254	5.414599	-23.6	16.2
govtdebt	524	69.80138	37.14443	8.402263	239.2875
stockspcgdp	751	46.66617	58.73069	.0225106	434.9207
fdi	780	1.95e+10	4.27e+10	-3.08e+10	3.40e+11
infl	804	7.090547	30.65311	-4.5	567.9
riskpre	417	3.067269	2.237672	-1.35	13.44069
c	816	17.5	9.816725	1	34

Table (d): Number of missing observations, the number of total observations, and the proportion of missing observations (1990-2013)

Variable	Missing	Total	Percent Missing
countries	17	833	2.04
year	17	833	2.04
nstir	133	833	15.97
pcpop65	17	833	2.04
medage	17	833	2.04
dependency~o	27	833	3.24
rstir	111	833	13.33
termspread	186	833	22.33
grosssave	122	833	14.65
exrate	27	833	3.24
grosscapform	52	833	6.24
lforcegrow	17	833	2.04
curr_acc_bal	163	833	19.57
govtdebt	309	833	37.09
stockspcgdp	82	833	9.84
fdi	53	833	6.36
infl	29	833	3.48
riskpre	416	833	49.94
c	17	833	2.04