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The relationship between financial asset returns and demographic variables: evidence from international data

A relação entre retornos de ativos financeiros e variáveis demográficas: evidências de dados internacionais

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The Relationship Between Financial Asset Returns and Demographic Variables: Evidence from International Data

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Resumo

Neste trabalho, nosso objetivo é explorar empiricamente a relação entre variáveis demográficas e os retornos de letras do tesouro de curto prazo, de títulos de renda fixa governamentais de longo prazo e de ações. Dispomos de um painel de dados abrangendo 21 economias desenvolvidas, compreendendo, para a maior parte dos países, o período de 1900 a 2018. Utilizando os dados originais e também o filtro de baixa frequência desenvolvido por Muller e Watson (*Econometrica*, 2018), estimamos a relação supracitada através de correlações de longo prazo e de regressões de efeitos fixos. Tanto as correlações quanto as regressões sugerem que há uma relação negativa entre retornos de letras do tesouro de curto prazo e a proporção da população entre 40 e 64 anos de idade, entre 1950 e 2018. A relação entre a população de meia-idade e os títulos de renda fixa governamentais possui resultados inconclusivos. A população de meia idade também parece não se correlacionar com os retornos de ações. Não há resultados significativos para a população idosa. Por fim, para a amostra longa (1900 - 2018), não há resultados conjuntamente significativos para correlações e regressões.

Palavras-chave: Derretimento de ativos. Hipótese do Ciclo de Vida. Correlações de Longo Prazo. Demografia.

JEL: C23, G12, J11

Abstract

In this study, our objective is to empirically explore the relationship between demographic variables and the returns of short-term treasury bills, long-term government bonds, and equity. We have access to a panel dataset covering 21 developed economies, spanning, for most countries, from 1900 to 2018. Utilizing both the original data and the low-frequency filter developed by Muller and Watson (Econometrica, 2018), we estimate the above-mentioned relationship through long-term correlations and fixed-effects regressions. Both the correlations and regressions suggest a negative relationship between short-term treasury bill returns and the proportion of the population aged 40 to 64 years old, between 1950 and 2018. The relationship between the middle-aged population and government bonds exhibits inconclusive results. The middle-aged population also does not seem to be correlated with equity returns. There are no significant results for the elderly population. Finally, for the long sample period (1900 - 2018), there are no jointly significant results for correlations and regressions.

Keywords: Asset Meltdown. Life cycle Hypothesis. Long-run Correlations. Demographics.

JEL: C23, G12, J11

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Summary

1 Introduction

The debate over the impact of demographics on financial markets gained significant attention in the 1990s due to rising stock prices and returns in the United States, at the same time that the baby boomer generation was entering middle-age, the period of life when people are most likely to save.

The baby boomer generation consists on individuals born immediately after World War II, between 1946 and 1964, and is known for being the largest birth generation in U.S. history. Although it could be a mere coincidence, the hypothesis that the baby boomers were responsible for the boom in the financial market could not be ruled out, and there were concerns about the future of asset prices and returns as this generation began to retire.

Theoretical models, such as those by Yoo (1994) and Abel (2001), predicted that when the baby boomer generation retired, there would be an "asset meltdown". The reason for this is that the middle-aged baby boomers were the biggest savers in the economy, and according to the Life Cycle Hypothesis (LCH) of consumption and saving, developed and discussed by Modigliani and Brumberg (1954) and Ando and Modigliani (1963), retirees tend to dissave to fund their consumption expenses for the rest of their lives. The LCH asserts that individuals accumulate savings until retirement, at which point they start spending their savings to support their consumption.

Therefore, the retirement of this generation would lead to a gradual decline in savings and, consequently, in investments in financial assets. With all retiring baby boomers trying to sell their stocks to the younger and smaller cohorts, the prices and returns of these assets would be expected to fall. This scenario was predicted by the Asset Meltdown Hypothesis (AMH)[1], and was well raised by Siegel (1998) with the question: "Sell? Sell to whom?".

As the aging baby boomer generation could potentially lead to an asset meltdown, it became necessary to empirically test whether demographic variables actually had

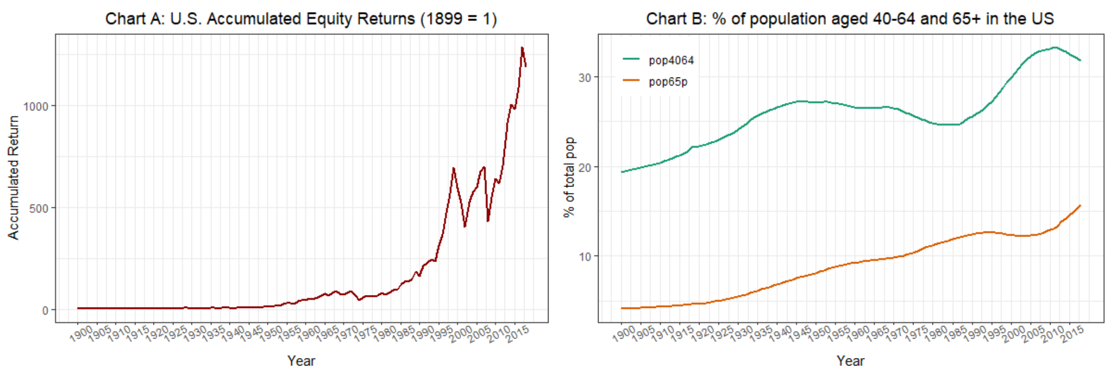
[1]The Asset Meltdown Hypothesis (AMH) predicts that the baby boomers would lead to an oversupply of assets in the financial market when they retired, resulting in an abrupt fall in their prices.

anything to do with asset markets, with special attention to stock prices. Several works in the literature have tried to make inferences about the predictive power of demographic variables on asset prices, returns, demand, and investment flows in the financial market, but the findings from these studies have not always been consistent with one another.

As pointed out by Poterba (2001), while demographic variables evolve very smoothly, prices and returns on financial assets are much noisier, which makes it difficult to draw strong conclusions about the relationship between demographic and financial variables.

This problem is shown in Figure 1. Chart A shows the accumulated equity returns in the United States from 1900 to 2018, while Chart B shows the proportions of the populations aged 40 to 64 (*pop4064*) and 65 and over (*pop65p*). As can be seen, the financial variable is much more noisy than the demographic variables.

Figure 1: U.S. Equity Accumulated Returns and Demographic Variables



Sources: DMS Global, Human Mortality Database and the US Census Bureau.

The discussion on this subject has never been exhaustive, and new works continue to be developed as new datasets and methodologies emerge. We have a large dataset with long time series for three financial assets and 21 countries, which can produce a wide range of results. Moreover, we use a methodology for estimating low-frequency time series, created by Muller and Watson (2018), that has gained widespread adoption among researchers in several fields. This methodology can generate a smooth time series from the original data, eliminating noise and facilitating comparisons between noisy and smooth time series.

Utilizing both the original data and the low-frequency filter developed by Muller and Watson, the objective of this research is to estimate the relationship between demographics and asset returns through long-term correlations and, as a robustness exercise, fixed-effects regressions, as we can take advantage of the panel structure to test if the results remain the same, and to make our results comparable with the previous literature.

Our dataset ranges from the early 1900s to 2018 for most of the 21 countries. We have three financial variables: real treasury bill returns, real long-term government bond returns and real equity returns.

There are three primary contributions of this research: i) Our dataset is larger when compared with the previous literature, as we have 21 countries, three financial variables and secular data for most of them; ii) We expand the correlation results of Lunsford and West (2019) for more countries and compare these results for the U.S. and for our full set of countries; iii) Our regressions, which have specifications similar to those in previous literature, can also provide a wider range of results than the existent literature does, as we encompass three financial variables from the same source, with more observations.

In terms of methodology, we follow closely Lunsford and West (2019). As they are interested in the determinants of the U.S. real interest rates, they use only data on treasury bills for that country. We add to them by using data on multiple countries and three classes of assets. Moreover, we take advantage of our panel structure to estimate fixed effects regressions.

Our hypothesis is that there is a positive relationship between the middle-aged population and equity returns, while there should be a negative relationship between the elderly and these returns. For fixed-income assets, however, the expected results are the opposite: negative for the middle-aged and positive for the elderly, since an impact on the prices of these securities should take their yields in the opposite direction. This is what the implications of the LCH suggest, and we discuss more about this topic in Subsection 2.1.

Overall, our results show partial support for the LCH. On one hand, we found robust evidence of a negative correlation and regression estimates between the middle-aged population and yields on short-term treasury bill returns for the post-war period. On the other hand, for the other two assets, this correlation is less robust. We did not find strong evidence that the share of the elderly population correlates with any of the three asset returns. Moreover, results for the low-frequency transformed series tend to be more robust than results for the original data.

This project is structured into several sections and subsections. Section 2 discusses the literature regarding the relationship between asset markets and demographic variables. Within this section, Subsection 2.1 clarifies our hypothesis for fixed-income assets. Section 3 discusses the data sources used in the analysis. Section 4 explores, with visualization, the demographic and financial booms around the world. In Section 5, we outline the proposed methodology. Section 6 shows the results of the paper. Finally, Section 7 presents the conclusions, and Appendix A compares our results with the literature.

2 Demographics and Asset Markets

2.1 The hypothesis for fixed-income assets

Before discussing the previous research in the area, we follow Bodie, Kane and Marcus (2013) to make a brief observation regarding fixed-income securities: their returns, in our work and in several works in the literature, are computed as yields, and it is important to understand the implications of it.

When an investor buys a fixed-income security, he pays a present value (PV), which is determined by the par value (or face value) of the asset and by its interest rate (i). Equation (1) shows how is the present value determined for a given period of time (n), assuming a fixed interest rate.

$$PV = \frac{FaceValue}{(1+i)^n} \tag{1}$$

If an asset pays coupons, its price will be determined similarly, but each coupon, in each period, will be divided by the discount rate, as shown in equation (2).

$$PV = \frac{coupon}{(1+i)} + \frac{coupon}{(1+i)^2} + ... + \frac{coupon}{(1+i)^n} + \frac{FaceValue}{(1+i)^n} \tag{2}$$

The interest rate used in equation (1) has an important meaning: it is the rate of return that the investor will earn if he keeps his security until maturity; hence, it is the yield to maturity (YTM). For equation (2), if we assume that the investor reinvests his coupons at the same interest rate, we will also have the YTM.

In the vast majority of the papers in the literature, bond yields are the fixed-income variables used, and the expected relationship between them and demographic variables is the opposite of the relationship between equity returns and demographics. For equity, we should expect a simultaneous rise in prices and returns, since an investor who holds these securities has higher returns when prices rise. For yields, on the other hand, the relationship is inverse - higher prices come with lower rates.

The explanation for yields is that when the middle-aged population increases, the same happen to the demand for fixed income assets. These assets, then, should have their prices raised (their PVs), and, since the face values cannot change, it should lead to a consequent decline in their pre-determined interest rates (their yields). Therefore, more middle-aged people in the economy should lead to falling yields, and the opposite can be said about the elderly.

For equity returns, however, there is no face value, and returns are measured, in the dataset used by us in this work, by the growth rate of equity price indexes, which consider the reinvestment of previous returns. Hence, if the price of an asset rises, returns are positive. If the demand for assets increases, we should expect, then, rising prices and positive returns. The middle-aged should have a positive impact on equity returns, while the impact from the elderly should be negative. With this in mind, we can discuss the literature.

2.2 Theoretical Literature

The relationship between demographic variables and financial asset prices and returns has been widely discussed in theoretical and empirical papers, specially from the 1990s to the 2000s. An important theoretical article, considered as one of the pioneers, is that of Yoo (1994), who attempted to study the effects of baby boomers' retirement on asset prices with an OLG model. He found that if the fertility rate increases and then suddenly decreases, this pattern should lead to a significant increase in asset prices, followed by a sudden decrease.

This relationship between stocks and demographic variables should hold even if there was a bequest motive that caused the elderly to prefer holding their assets rather than selling them. In this case, the fall in stock prices should not be attenuated, as concluded by Abel (2001).

Other theoretical models also predicted a strong relationship between the age structure of the population and prices and returns on financial assets. Brooks (2000, 2002) developed OLG models in which agents live for four periods, predicting an asset meltdown as a consequence of the retirement of the baby boomers. This would happen because they would have to sell their financial assets to a much smaller generation, causing prices to fall.

Since demographic variables change at a much slower rate than financial variables, would rational agents be able to anticipate the effects of the demographic changes? According to Geanakoplos et al. (2004), the answer is no. Using an OLG exchange economy to study the anticipation of the rise in the middle-aged population, they actually concluded that the scenario with anticipation causes stock prices to rise by more than in the scenario without anticipation.

Even with a generous social security system, the decline in stock prices after baby boomer retirement should hold. That is what Abel (2003) concluded using a two-period OLG model with a social security system. His model was able to predict a rise in stock prices due to a baby boom, and social security did not prove to be responsible for the long-term price of capital.

As can be noted, the use of OLG models is very common in this field, and all theoretical works considered above have concluded that demographic variables have a significant effect on asset prices and returns. Nevertheless, it is important to note that these theoretical works already consider that the LCH is valid, so the retired generation will always dissave to fund consumption, even if there is a bequest motive or a social security system.

While the theoretical literature is predominantly consensual, the same cannot be said for the empirical literature, which will be addressed next.

2.3 Empirical Literature

Two of the pioneers in empirical research in the area are Yoo (1994) and Bakshi and Chen (1994). The former analyzed the U.S. Survey of Consumer Finances and found that the population aged 45 to 54 has a large negative impact on the returns of several types of assets, including stocks, bonds and bills. The latter, on the other hand, analyzed U.S. stock prices and the average age of the population, concluding that, for the post-World War II period, the relationship is positive. It can be noted, then, that the divergences started early in the literature, since Yoo and Bakshi and Chen, for the same country and for similar time periods, reached different results.

The same can be said about the works of Bergantino (1998) and Poterba (2001, 2004). With an analysis of cross-sectional data from the 1989, 1992 and 1995 Survey of Consumer Finances, Bergantino found that the middle-aged population tends to provide credit to financial markets, while people aged 60 or more tend to drain credit from it. On the other hand, Poterba, by analysing the 2001 Survey of Consumer Finances, found that the saving profile of American families do not follow the life cycle hypothesis, given that the retired cohort does not sell their financial assets, but holds then until death.

Bergantino's findings were fully in line with the LCH, but Poterba's findings suggested that an asset meltdown was out of the question. In fact, due to different econometric specifications and different choices of explanatory and dependent variables, empirical works in the area have results that are very different from each other.

These divergences continue to emerge, since empirical literature has not been exhausted yet. There are recent works, which will be addressed further, whose results are also different from each other. With a large dataset, with three financial assets and 21 countries, we believe that we can contribute to this debate.

As discussed by Poterba (2001), demographic data evolves very slowly, while asset market data is much more volatile. Even though demographics may look a little different from year to year, there are a limited number of degrees of freedom due to low data variation. This makes it difficult to draw strong conclusions about the relationship between demographic variables and financial markets.

Another group of articles that differ from each other, but still find supportive evidence of the the LCH in some way, is composed of the works of Jamal and Quayes (2004), Poterba (2004) and Bae (2010). With a study for the US and the UK between 1950 and 2000, Jamal and Quayes (2004) found that the proportion of the population aged 40-64 impacts stock prices positively. Their results were similar to those of Poterba (2004), who found a positive correlation between the share of the middle-aged population and the level of stock prices in the United States. However, Poterba was skeptical about the results, because, among other reasons, they were very sensitive to small changes in the econometric specification.

Later work by Bae (2010) pointed out that since the data used by Jamal and Quayes (2004) were non-stationary, the authors should not have used an OLS approach. Using U.S. data from 1949 to 2005 and employing cointegration methods, Bae found no significant relationship between the 40-64 age group and stock prices, contrary to Jamal and Quayes (2004) and Poterba (2004). The author actually found a negative link between stock prices and the proportion of the population aged 65 and over.

Unlike most of the previous works, which payed special attention to the United States, there are several works that used data from other countries, like Davis and Li (2003), Ang and Maddaloni (2005), Huynh et al. (2006) and Brunetti and Torricelli (2010).

In a study for Japan, with a similar method to Bae (2010), Kawakatsu and Oliver (2018) found a positive impact of the prime savers (ages 45 to 64) on real stock prices from the post-war period onwards, similarly to the conclusions of Bakshi and Chen (1994). They used cointegration and Granger causality tests, and their results were partially consistent with the LCH.

Davis and Li (2003) explored the problem for 7 OECD countries from 1950 to 1999. They found a positive relationship between the population aged 40 to 64 and the first-differences of real stock prices and bond yields, even controlling for other macroeconomic variables. With a study for Australia, Huynh et al. (2006) reached similar conclusions, finding a positive effect of the middle-aged on stock prices.

These results were shared by Brunetti and Torricelli (2010), who found that Italian bond yields were not aligned with the LCH, but bill returns were. They also found that the middle-aged and the elderly population have both a negative impact on stock returns.

For a set of 15 countries, results of Ang and Maddaloni (2005) also did not echo the previous ones. They examined the link between equity risk premiums and demographic changes throughout the 20th century, concluding that the proportion of retirees showed strong predictive power, establishing a negative relationship with the equity premium.

Therefore, while Davis and Li (2003) and Huynh et al. (2006) endorsed the positive role of the middle-aged, Brunetti and Torricelli (2010) defended that they have a negative impact on stocks, and Ang and Maddaloni (2005) did not find any significant predictive power from this cohort.

These differences, according to Park (2010), may be due to three main factors: i) arbitrary choice of demographic variables; ii) different regression specifications; and iii) arbitrary parametric restrictions. Another reason, as observed by Thenuwara et al. (2017), can be the use of non-stationary data to make inference, which results in spurious regressions. According to the authors, this problem accompanies some works in the literature, such as Poterba (2004), Geanakoplos et al. (2004) and Ang and Maddaloni (2005).

A possible solution to the aforementioned issues (i, ii, and iii) was proposed by Park (2010), who estimated the response of stock prices to changes in age distribution for all G5 countries. The paper found a positive relationship between consumers in their prime working-age and stock prices. The innovation of Park's work is that the non-parametric approach allows measuring the demographic impacts on asset prices from the entire age distribution of the population, and not from a single predetermined age group.

Arnott and Chaves (2012) also did not use single predetermined age groups as predictive variables, opting for the use of a smooth polynomial curve that covered all these groups. They used data from 22 developed countries throughout 60 years to study the effect of demographic changes on stock and bond returns. Their results were similar to those of Park (2010), since they concluded that the middle-aged positively impact returns on financial assets.

In addition to the use of age groups and the population age distribution, another approach commonly used in the literature is to consider the middle-aged-to-young (MY) ratio, which is defined as the proportion of the middle-aged population over the proportion of the young population[2]. Favero et al. (2011), Sević and Brawn (2015) and Gozluklu and Morin (2019) used the MY Ratio, but their results also differ from each other.

[2]The specific age ranges included in each group can vary, but the middle-aged is usually considered as the population aged 40-64, while the young population is defined as the group aged 15-39 or 20-39.

Most works mentioned in this section, so far, have identified a significant impact either in the middle-aged population or in the elderly. However, there are also works, few in number, whose results are perfectly in line with the LCH, that is, they studied the middle-aged population and the elderly, and found supportive evidence, for both age groups, of the LCH. These conclusions were found by Goyal (2004), Singh (2018) and, as mentioned before, for bill returns, Brunetti and Torricelli (2010).

There are also studies that did not find any results compatible with the LCH, that is, they did not find strong evidence by any age group. Some of these works sought to correct methodological errors in previous articles or to test whether the conclusions of these works apply to other countries. That is the case of Erb et al. (1997), who tried to test if the conclusions of Bakshi and Chen (1994) were true for an international data set of 45 countries, for equity returns. They could not find any strong relationship, which goes against the conclusions of Bakshi and Chen for the United States.

Kim and Moon (2022) reached similar conclusions for equity premiums. They pointed out that the regressions conducted by Ang and Maddaloni (2005) were not controlled for cross-section dependence, and proposed to correct this problem. They found no significant relationships.

Another work that is not coherent with the LCH is that of Brooks (2006). Like Park (2010) and Arnott and Chaves (2012), Brooks did not use age groups as predictive variables. With data from 16 countries for most of the 20th century up to 2005, Brooks concluded that there is no strong historical link between demographics and financial markets.

With results similar to those of Brooks (2006), Hettihewa et al. (2018) could not find a relationship between demographics and stock prices in New Zealand, even when controlling for macroeconomic variables.

Finally, Kim et al. (2019), with a sample of 21 countries spanning from 2000 to 2013, found a positive relationship between the older population and the demand for equity funds, which is contrary to the LCH.

2.4 Our Contribution

It can be noted from the literature that as new econometric approaches emerged or new datasets were built, new researches were able to provide contributions. But the debate is still open, considering that even recent studies have achieved different results, such as those by Singh (2018), Kim et al. (2019) and Kim and Moon (2022).

An important concern when dealing with financial data, as already pointed out, is the large volatility presented by them. A methodology for estimating long-run correlations, developed by Muller and Watson (2018), has gained widespread adoption among researchers in several fields due to its apparent reliability[3]. This methodology creates low-frequency time series from the data and then performs correlations between them. The advantage is that as demographic variables vary much more slowly than financial variables, transforming the data into low-frequency time series can eliminate the noise.

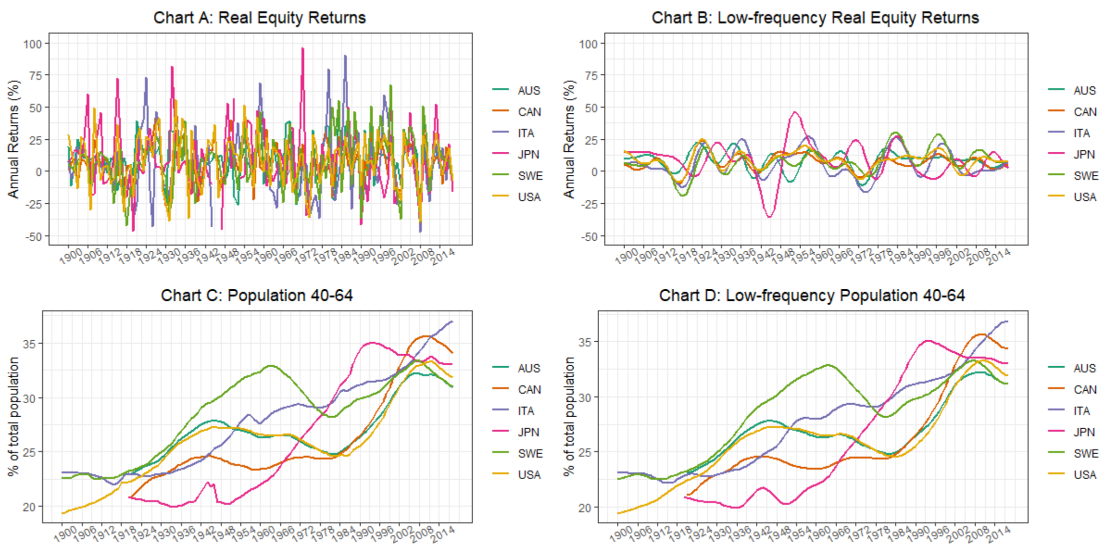
The use of this filter also enables us to compare our results with those of Lunsford and West (2019), whose work inspired this research. They used Muller and Watson's filter to investigate the drivers of the U.S. safe real interest rate. However, in addition to calculating long-run correlations, we also use the low-frequency time series to conduct fixed-effects regressions, for robustness.

Figure 2 shows what the low-frequency transformations do. In Chart A, we have the annual real equity returns for Australia, Canada, Italy, Japan, Sweden and the United States, from 1900 to 2018. In Chart C, we have the proportion of the population aged 40 to 64 for these same countries. In Chart B, the returns are transformed into low-frequency series. In Chart D, the demographic variable also suffers this transformation.

From Chart A to Chart B, the large amount of noise present in Chart A has been removed. Note that Chart D is almost the same as Chart C, because demographic data is smoother. The use of transformed series can provide more reliable results.

[3]See, for example, the sudies on the relationship between natural resources and economic variables from Atil et al. (2020) and Shahbaz et al. (2021), the studies involving the nominal and real exchange rates conducted by Papell and Prodan (2020) and Grisse and Scheidegger (2021), and the study of Moura (2021) on the joint comovements of the Total Factor Productivity (TFP) and the Relative Price of Investment (RPI).

Figure 2: An example of low-frequency transformations



Source: DMS Global, Human Mortality Database, UN World Population Prospects 2022, Statistics Bureau of Japan and the U.S. Census Bureau.

However, our primary contribution extends beyond the application of this helpful transformation. The dataset used in our work has a large amount of observations. While most papers in the literature used data for one or two financial assets, ranging typically from the post-war period onwards, we have data for three financial assets, spanning from 1900 to 2018 for most countries within our sample of 21.

We can produce, with this dataset, results for short-term treasury bills, long-term government bonds and equity returns. This allows for a wider array of results, which can provide more complete evidence on the relationship between demographic variables and financial returns. That said, we can proceed to the discussion of our data.

3 Data

Our dataset comprises financial asset returns for 21 countries, along with some demographic potential correlates spanning mostly from 1900 to 2018.

The financial data utilized in this study were sourced from the Dimson-Marsh-Staunton Global Returns Data (DMS Global). This dataset was compiled by Dimson, Marsh and Staunton (2019) and provides long-term financial data for 21 countries, which are: Austria, Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, United Kingdom and United States.

According to the sources, these 21 countries represented, together, in 1900, around 90% of the global market capitalization, and, in 2018, around 80%. We use all these countries in our research, from 1900 to 2018; however, for some of them, demographic data were not available for the entire time series.

The financial variables included in our dataset are annual, and involve the real treasury bill returns (*tbill*), the real long-term government bond returns (*bond*) and the real equity returns (*equity*). For countries that did not have treasury bills, the authors used similar short-term (3 months, usually) securities with minimal risk. For government bonds, they attempted to consider, when possible, maturities of twenty years. These fixed-income securities (bills and bonds) are represented in terms of yields.

These financial data are discussed, in a summarized version, in the *Summary Edition Credit Suisse Global Investment Returns Yearbook 2019*[4]. However, since it is proprietary data, the document contains only general information and analysis. For more details, see Dimson, Marsh and Staunton (2002).

The demographic data used in our work involve the fraction of the population aged 40 to 64 years old (*pop4064*), the fraction of the population aged 30 to 64 (*pop3064*), the fraction of the population aged 35 to 54 (*pop3554*), the fraction of the population aged 65 and over (*pop65p*) and the dependency ratio (*dependency*), which is defined as the ratio of the population aged less than 20 and more than 64 over the population aged 20 to 64.

The inclusion of *pop3554* and *pop3064* in the analysis is to have other representations of the middle-aged population. With three different age groups, we can have results for a wider "middle-aged" age range (*pop3064*), for a standard measure of this age group (*pop4064*) and for a shorter, younger range (*pop3554*). The majority of the literature used *pop4064*, but some works, like those of Yoo

[4]https://www.credit-suisse.com/media/assets/corporate/docs/about-us/research/publications/csri-summary-edition-credit-suisse-global-investment-returns-yearbook-2019.pdf

(1994), Ang and Maddaloni (2005) and Kim et al. (2019), picked younger or wider age groups.

Despite having financial data from 1900 to 2018 for all countries, we could not find long annual time series of demographic data for some of them. Hence, the range of our dataset is limited by the range of the demographic variables.

The sources of our demographic data are, for the US, the U.S. Census Bureau (1900 - 1949) and the Human Mortality Database (1950 - 2018). For Japan, we use the Statistics Bureau of Japan (1900 - 1949) and the UN World Population Prospects (1950 - 2018). For Germany, Ireland and South Africa, our source is the UN World Population Prospects 2022 (1950 - 2018). Finally, for the other 16 countries of our dataset, the source is the Human Mortality Database, with different start dates for each one of them.

We decided to run our empirical exercises for two different sample ranges: a long sample, from the early 1900s to 2018, and a short sample, from 1950 to 2018. The short sample can be compared with some works in the literature that used data from the second half of the 20th century.

As will be discussed further in Section 5, we conduct a low-frequency transformation to the data, so we have, after all, four different samples, and we gave a name to each one of them, as can be seen in Table 1.

Table 1: All Possible Samples for Correlations and Regressions

	Long sample (1900-2018)	**Short sample (1950-2018)**
Original data	Sample A	Sample B
Low-frequency data	Sample C	Sample D

Note 1: the original data is the data without any low-frequency transformation.

Sample A involves the original data (not transformed) from 1900 to 2018. Sample B has also the original data, but for the 1950 - 2018 period (the "post-war period"). Sample C involves the low-frequency transformed data for the 1900 - 2018 period. Finally, sample D represents the low-frequency transformed data from 1950 to 2018.

For the regressions, all samples have 21 countries, but the difference between the long and the short sample is that, for the long sample, 15 countries (out of 21) have starting dates between 1900 and 1922, while, for the short sample, data for all the 21 countries start in 1950. The number of observations for each sample is shown in Table 2.

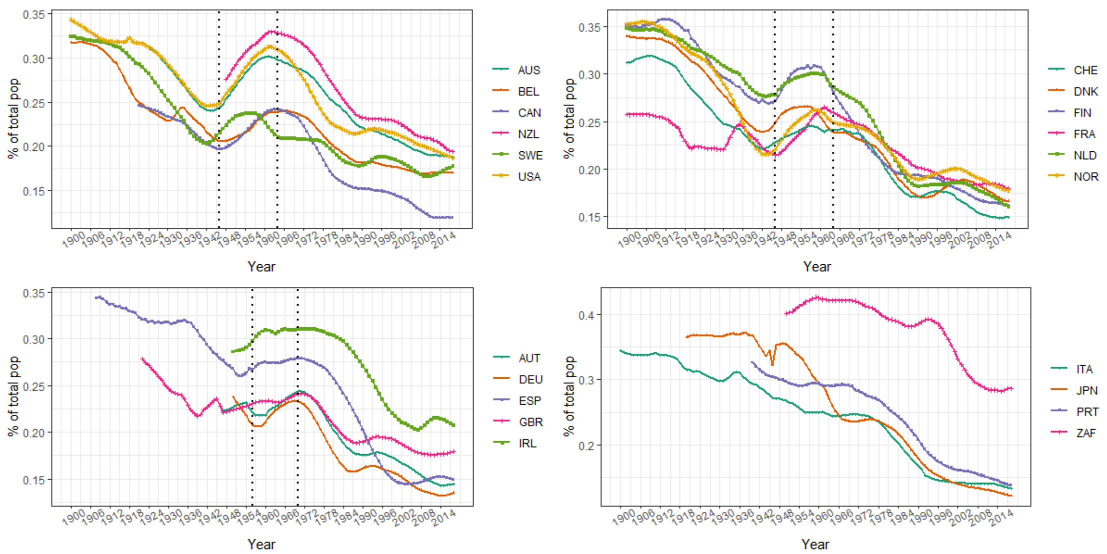
Table 2: Number of observations by country and sample for the regressions

	Samples A and C		**Samples B and D**	
Country	Start date	N	Start date	N
BEL	1900	119	1950	69
CHE	1900	119	1950	69
DNK	1900	119	1950	69
FIN	1900	119	1950	69
FRA	1900	119	1950	69
ITA	1900	119	1950	69
NLD	1900	119	1950	69
NOR	1900	119	1950	69
SWE	1900	119	1950	69
USA	1900	119	1950	69
ESP	1908	111	1950	69
JPN	1920	99	1950	69
AUS	1921	98	1950	69
CAN	1921	98	1950	69
GBR	1922	97	1950	69
PRT	1940	79	1950	69
AUT	1947	72	1950	69
NZL	1948	71	1950	69
DEU	1950	69	1950	69
IRL	1950	69	1950	69
ZAF	1950	69	1950	69
Total	-	**2024**	-	**1449**

Note 1: samples A, B, C and D are showed in Table 1.
Note 2: the end date for all countries is 2018.

In Table 2, "N" is the number of observations. Note that we have 2024 observations for the long samples (A and C) and 1449 observations for the short samples (B and D). For the correlations, and only for them, we excluded five countries (Germany, Ireland, New Zealand, Austria and South Africa) from samples A and C, because their starting dates are already "post-war" dates, so it would make no sense to include them in the long sample results. For the regressions,

Figure 3: The Baby Boom Around the World: % of population 0 - 14



Sources: Human Mortality Database, UN World Population Prospects 2022, Statistics Bureau of Japan and the U.S.Census Bureau.

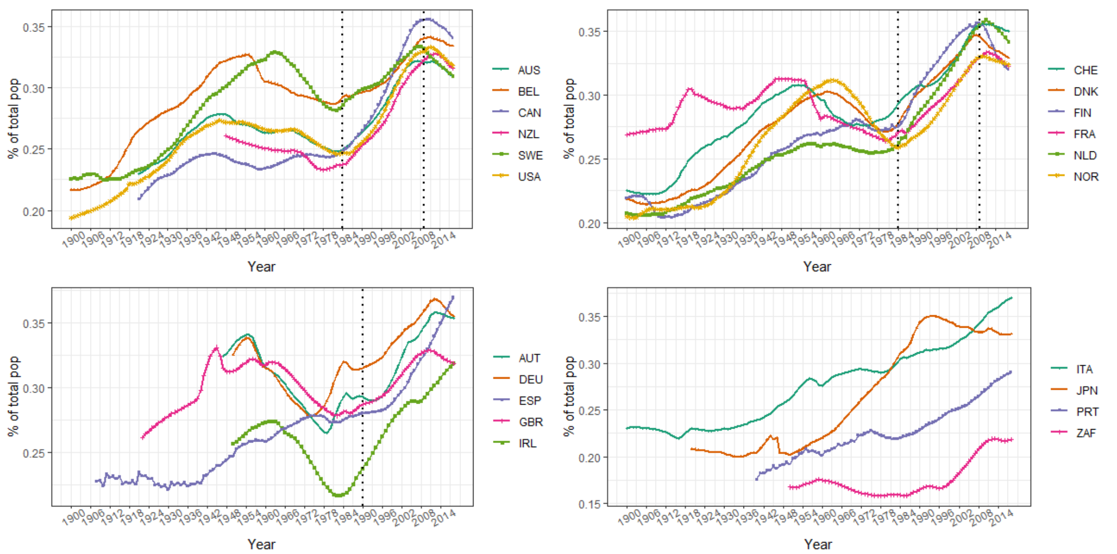
however, they are included in samples A and C, just as shown by Table 2, since we can take advantage of the panel data structure.

4 Observational Evidence

Was the baby boom a global trend or was it just a U.S. trend? Figure 3 shows the evolution of the population aged 0 to 14 during most of the 20th century for our dataset. The figure is divided into four charts to allow for better visualization of all countries, and each chart shows the proportion of the population aged 0 to 14 for different countries.

The black dotted lines show the baby boom period. It can be noted that, for the countries presented in the first two charts at the top of the figure, the baby boom started during World War II. Countries in the third chart, in the lower left corner, also had a baby boom, but some of them a little later. The fourth chart, in the lower right corner, on the other hand, shows countries that do not appear to have experienced a significant baby boom. Since most countries of our sample faced a baby boom during the post-war period, we can assume that it was a global trend, at least for the developed countries.

Figure 4: Baby Boomers Become Prime Savers: % of population 40 - 64



Sources: Human Mortality Database, UN World Population Prospects 2022, Statistics Bureau of Japan and the U.S.Census Bureau.

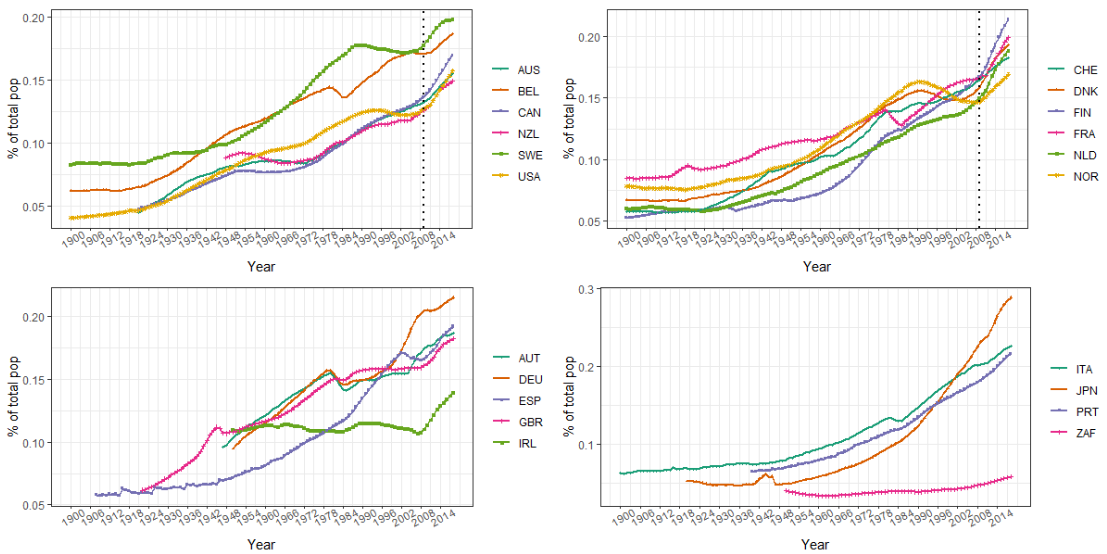
Some decades later, these baby boomers, born in different countries, would join the middle-aged population, which can be defined as the population aged 40 to 64 years old. It is common, in the literature, to consider this age group as the middle-aged population, although the range is very wide. The idea behind this is that people who are nearing retirement are also big savers, just like the younger workers, so both can be put in the same group of "prime savers", which we can also refer to as "middle-aged".

As can be seen in Figure 4, which shows the proportion of the population aged 40 to 64 for each country, these boomers significantly increased the fraction of middle-aged people in the population from 1980 onwards, and this fraction is still very high, suggesting that the possible negative impacts of the elderly are yet to come.

Returning to Figure 3, which shows the baby boom, we can notice that, in the last decade of each time series (2008 - 2018), the proportion of the population aged 0 to 14 reached its historical minimal. On the other hand, Figure 4 shows that the proportion of the population aged 40 to 64 reached its historical peak in the last decade.

The next step is a fast increase in the proportion of the population aged 65 and

Figure 5: Baby Boomers Enter Old Age: % of population 65p



Sources: Human Mortality Database, UN World Population Prospects 2022, Statistics Bureau of Japan and the U.S.Census Bureau.

over, which started to happen in 2009, as can be seen in Figure 5, which shows the proportion of the population within this age bracket.

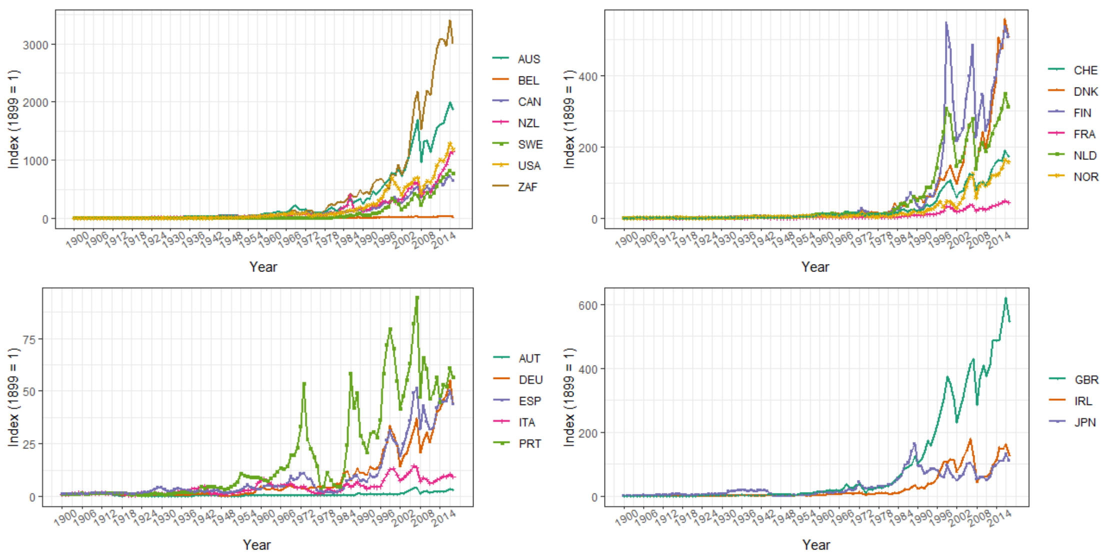
In 2018, the elderly were already responsible for around 20% of the populations of most countries in the figure. Therefore, if an asset meltdown is coming or not, the answer will be known during the third decade of the 21st century.

Together with the entrance of the baby boomers in the middle-aged population came the stock markets boom in the United States. However, was this financial boom also a global trend? Figure 6 shows the accumulated returns on equity for our dataset. Note that we created an index, with *1899 = 1*, for each country, for the variable *equity*, defined in Section 3.

Figure 6 is not divided into the same groups of figures 3, 4 and 5, and each chart has its own scale. It is on purpose, because, as can be noticed, equity returns are very different from country to country, and it would not be possible to visualize all the returns with the previous division or with the same scale for each chart.

Most countries suffered a financial boom from the 1990s onwards, but their magnitudes were not uniform. The largest booms were experienced by South Africa, Australia, the United States and New Zealand (first chart), although not all of these countries have experienced a baby boom.

Figure 6: The Financial Boom Around the World: Accumulated Equity Returns



Source: DMS Global.

Therefore, the figures show that the entrance of the baby boomers in the 40-64 age range occurred at the same time as the financial boom for some countries around the world, and this is what motivated us to investigate this relationship further. Section 5 intends to explain our empirical framework.

5 Empirical Strategy

5.1 Low-frequency series creation

The method developed by Muller and Watson (2018) can create low-frequency averages of the data, which is done by conducting a linear regression of the data on a set of cosine functions.

Following Muller and Watson (2018), consider that x_t, $t = 1, ..., T$ is a time series, and let $\Psi_j(s) = \sqrt{2}\cos(js\pi)$ be the cosine function used in the regressions. The vector $\Psi(s) = [\Psi_1(s), \Psi_2(s), ..., \Psi_q(s)]'$ contains q cosine functions, where the j-th function $\Psi_j(s)$ has period $2/j$. Ψ_T is the $T \times q$ matrix whose tth row is given by $\Psi((t-1/2)/T)'$. The fitted values of the projection of x_t onto $\Psi((t-1/2)/T)$ are:

$$\hat{x_t} = X_T'\Psi((t - 1/2)/T) \tag{3}$$

where $X_T = (\Psi_T'\Psi_T)^{-1}\Psi_T' x_t$ is a vector containing the coefficients of the regressions of x_t on the cosine functions.

The number of cosine functions (q) determines the number of columns of $\Psi(s)$ and depends on the size of the sample and on the selected periodicities of the data. The value of q is always the integer immediately smaller than or equal to the result of $\hat{q} = 2T/periodicity$. For example, in our data set, we have, for some countries, *T=119*, and if we want to capture periodicities longer than, say, 10 years, q will have to be equal to 23, since the decimal value of q is $\hat{q} = \frac{2*119}{10} = 23.8$.

To apply the low-frequency series of Muller and Watson, it is necessary to face a trade-off: the desire to capture low-frequency movements and the need to have enough data to estimate the parameters with sufficient precision.

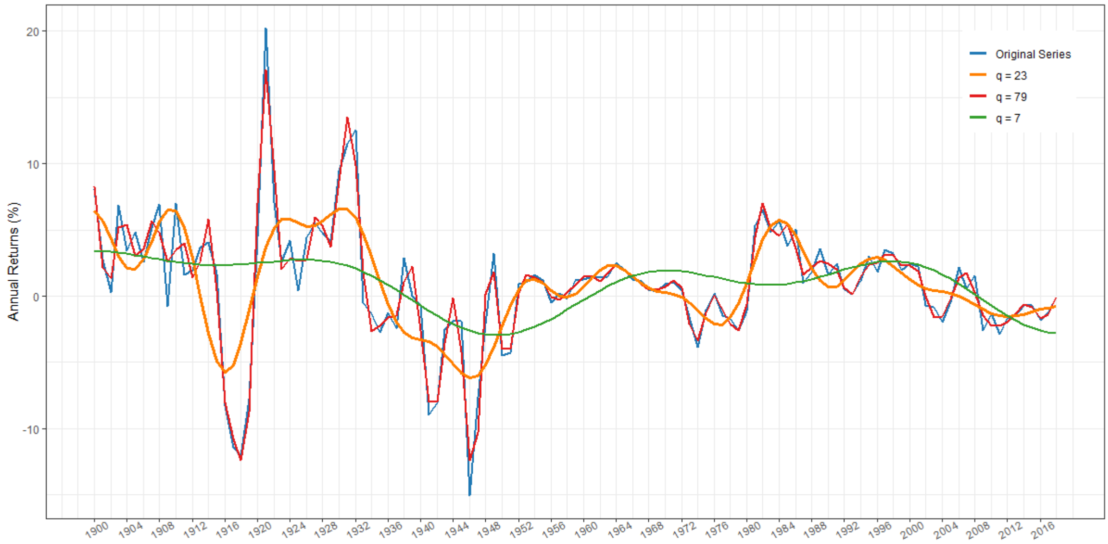
If the researcher picks a large number of cosine waves (a large value of q), the periodicity becomes small, and the regression on the consine functions may suffer from overfitting problems (where the model fits the noise in the data rather than the relationship between the variables). On the other hand, picking a small number of waves may lead to underfitting problems, since with large periodicities, important variations are ignored.

Figure 7 illustrates this trade-off by showing the different low-frequency series generated by different values of q for U.S. real treasury bill returns, from 1900 to 2018. The original data is represented in blue, and the other lines represent different transformed series of U.S. treasury bills.

Note that, from Figure 7, the low-frequency series for q = 7 (high periodicity) does not catch important fluctuations from the data, while the series for q = 79 (low periodicity) is much more volatile and is pretty much the same as the original series (blue line). If a researcher picks the green line (q=7), his results can be very distant from reality. On the other hand, picking the red line (q=79) is useless, since it would be wiser to keep with the original data. The yellow line (q=23) shows a middle ground, with periodicities of 10 years.

Therefore, in our work, we consider periodicities of 10 years, which gives us q = 23 for the long time series (1900 to 2018) and q = 13 for the short time series (1950

Figure 7: The trade-off between data smoothing and precision in low-frequency series



Source: the authors with data from DMS Global.

- 2018). The reason for this choice is that it would not be wise to pick a longer periodicity and ignore important fluctuations of the data. Moreover, Lunsford and West (2019) also considered periodicities of 10 years to conduct low-frequency transformations of U.S. data, since, as mentioned by them, it is close to the U.S. business cycle.

After the creation of the low-frequency series, we follow Lunsford and West (2019) and calculate the Pearson correlations between the variables. We also use a fixed-effects regression model, as we intend to take advantage of the panel structure to have a more concise measure of the studied relationship.

5.2 Fixed-effects model

Our model, for each financial variable, is given by equation (4), where c_i is the unobserved (fixed) effect for country i, $D1901_t$, $D1902_t$, ..., $D2018_t$ are year dummies, and $return_{it}$ is the financial return for country i and period t, and can be one of our three financial returns (*tbill*, *bond* or *equity*, as defined in Section 3).

$$return_{it} = \delta_0 + \delta_1 D1901_t + \delta_2 D1902_t + ... + \delta_{118} D2018_t + \beta_1 pop4064_{it} + \beta_2 pop65p_{it} + c_i + u_{it} \tag{4}$$

Year dummies are included because when the number of time periods (T) is small relative to the number of observations, which is our case, these dummies can account for secular changes that are not included in the model (Wooldridge, 2016, p. 420).

Following Wooldridge (2016, p. 420), we can apply first differences to the variables to eliminate the fixed-effects and to deal with possible unit root issues, which leads us to an estimating equation.

$$\Delta return_{it} = \delta_1 \Delta D1901_t + \delta_2 \Delta D1902_t + ... + \delta_{118} \Delta D2018_t + \beta_1 \Delta pop4064_{it} + \beta_2 \Delta pop65p_{it} + \Delta u_{it} \tag{5}$$

We estimate equation (5) by Pooled OLS. As explained in Section 3, we have an unbalanced panel for samples A and C and a balanced panel for samples B and D.

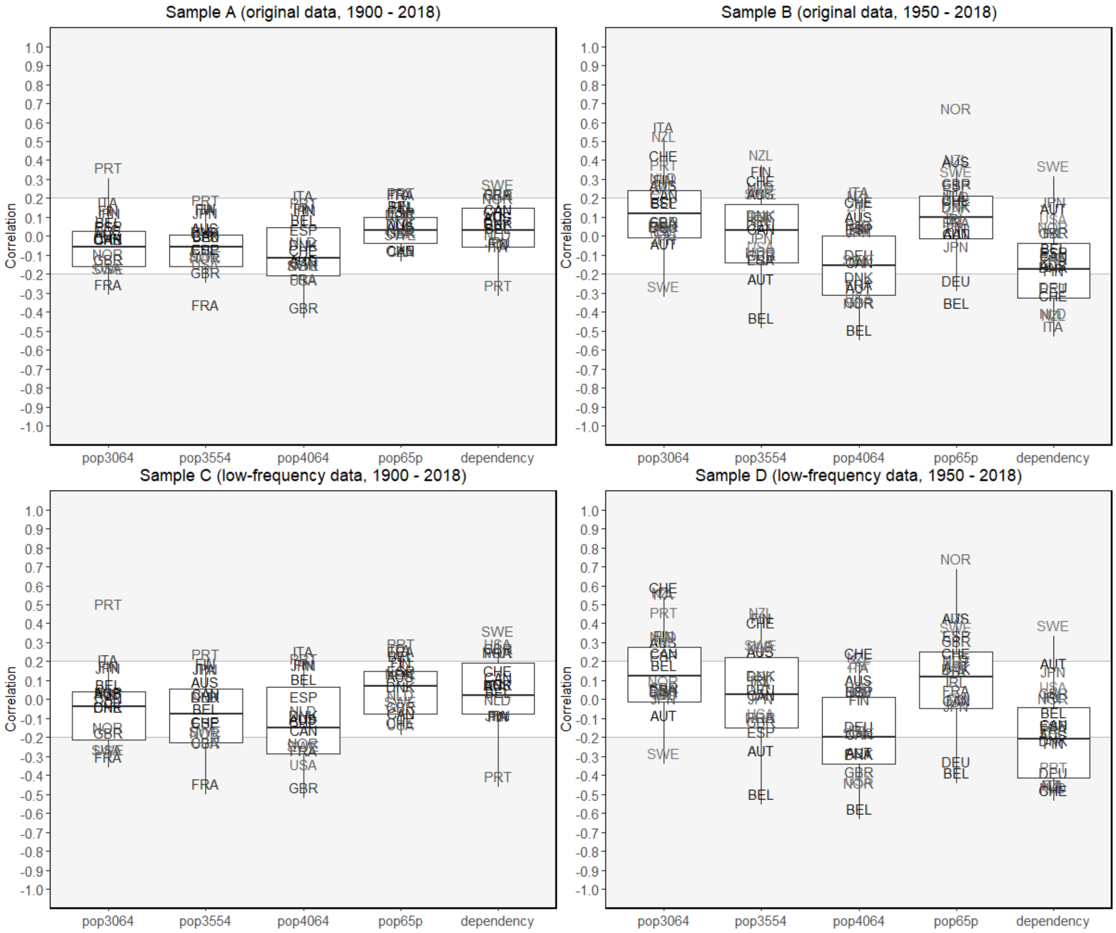
6 Results

6.1 Long-run Correlation Results

As showed in Table 1, in Section 3, we have four samples, and we excluded five countries from our correlation results for samples A and C (Germany, Ireland, New Zealand, Austria and South Africa). As discussed in Subsection 2.1, we expect, based on the LCH implications, a negative relationship between the middle-aged population and the yields on bond and treasury bills, and a positive relationship between the elderly and these variables. For equity, we expect the opposite: positive results for the middle-aged and negative results for the elderly.

Results for the long-run correlations can be visualized, for treasury bill returns, in Figure 8. The boxplots represent the correlations between *bill* and the demographic variable.

Figure 8: Long-run Correlations for Treasury Bill Returns



Source: the authors.

Following Lunsford and West (2019), we consider significant all correlations whose absolute value is equal to or greater than 0.20. Significant correlations are those in the gray area of the figure.

Correlations, in Figure 8, are stronger for the low-frequency transformed data, which shows the importance of capturing the low-frequency component of the time series when dealing with volatile data. Correlation signals remain the same, but they are stronger in the transformed data.

For sample A, in Figure 8, we can note that the correlations are not particularly significant for any variable. For sample C, on the other hand, results are stronger. The middle-aged population, as expected, seem to be negatively correlated with

Treasury Bill returns (when we consider sample C), especially the fraction of the population aged between 40 and 64 years old (*pop4064*). For the elderly and the dependency ratio, the results from 1900 to 2018 are not strong and do not show signs of a significant relationship with bills.

For sample B, which considers the 1950-2018 period, results are quite diverse. Although the fraction of the population aged 30 to 64 suggests a positive relationship between the middle-aged population and bill returns, the negative correlations for *pop4064* suggest that, as observed in samples A and C, the relationship goes in the opposite (and expected) path. The elderly seem to be positively correlated, which was also expected.

The dependency ratio, on the other hand, has a negative median, which contradicts the previous results. This result was not expected, but it seem to have an explanation. If the dependent population increases, the dependency ratio, naturally, also increases, and since the elderly are positively correlated with bills, the dependency ratio should also be. However, note that *pop3064* is a positive correlate for many countries, and the non-dependent population from the dependency ratio is the age range of 20 to 64. We should, then, expect that the fraction of the population aged 20 to 64 would also be a positive correlate of bill returns, which would explain the negative correlations for the dependency ratio[5].

Finally, for sample D, results are very similar to those from sample B, but they are stronger. Overall, we can say that, for the original data, results are weaker, but still show the expected relationships for the population aged 40 to 64 and for the elderly in the post-Second World War period. For the low-frequency samples, which should receive more attention due to their potential benefits, results are stronger and point to the same direction: negative correlations for the middle-aged and positive correlations for the elderly, for both the long period and the post-war period.

For the United States, our results are in line with those of Yoo (1994), who considered U.S. treasury bill returns from 1926 to 1990. His findings also point to a negative relationship with the middle-aged population, which, in his work, is

[5]An increase in the non-dependent population reduces the dependency ratio. If the non-dependent population is a positive correlate of bill returns, the dependency ratio should, then, be a negative correlate, just as observed in the results.

defined as the fraction of the population aged 45 to 54. His regressions show that the relationship is negative for the entire sample and for the post-war period. Our results for the US point to negative and significant correlations for the middle-aged population (*pop4064*, *pop3064* and *pop3554*) for samples A and C, and to negative correlations for *pop4064* also for samples B and D.

Our findings, for the US, are also aligned with those of Lunsford and West (2019), who used the same low-frequency filter used by us. More details can be seen in Appendix A, in which we compare our results with the literature.

Figure 9 shows the results for long-term government bond returns. Again, we have samples A, B, C and D, as discussed in Table 1, from Section 5. At a first look, we can already affirm that the results for the low-frequency transformed series are more significant than those for the original data.

For sample A, we do not have clear significant results, just as we observed for bill returns. For sample C, on the other hand, results are strong. All age groups related to the middle-aged population are positive correlates, with special attention to the fraction of the population aged 30 to 64 (*pop3064*). These results, and also the negative values for the dependency ratio, are not aligned with the LCH. However, for the elderly, the correlations are positive, which may indicate that the behaviour of this age group in consistent with the LCH.

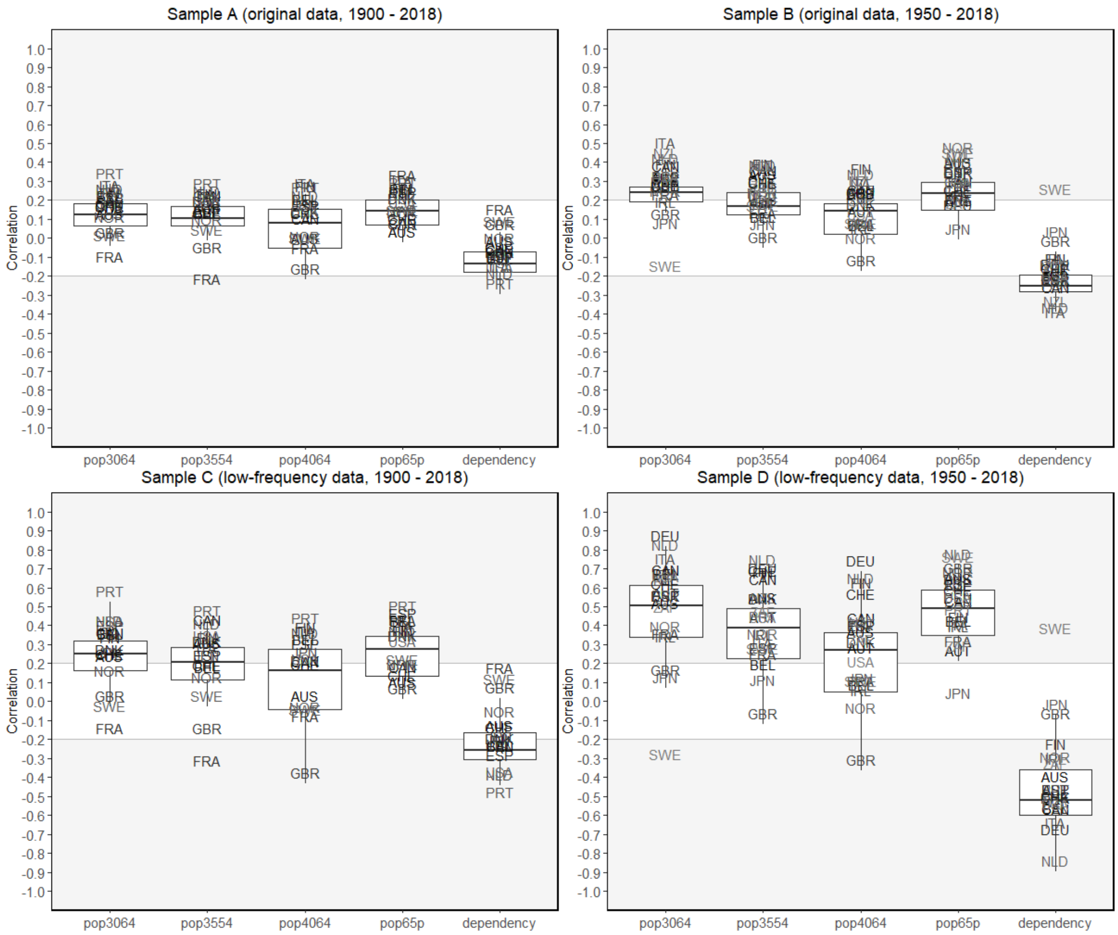
For sample B, *pop4064* is not as significant as the other "middle-aged" groups, but the results are still positive for all ages. For sample D, results are very strong and point in exactly the same direction as the previous ones for bonds: positive correlations for all age groups and negative correlations for the dependency ratio.

Therefore, our results are not significant only for the long time series with the original data (sample A). For the post-war period, correlations are larger, similarly to what we saw for Treasury Bill returns.

These findings are not aligned with those of Yoo (1994), whose results for bonds were negative for the middle-aged population from the United States, but are aligned with those of Davis and Li (2003), since they found a positive relationship between the population aged 40 to 64 and bond yields. Their work explored the post-war period (1950 - 1999), just as our samples B and D (1950 - 2018).

The results of Sević and Brawn (2015), despite being not directly aligned with ours, indicate that we are pointing in similar directions. They studied the MY

Figure 9: Long-run Correlations for Bond Returns



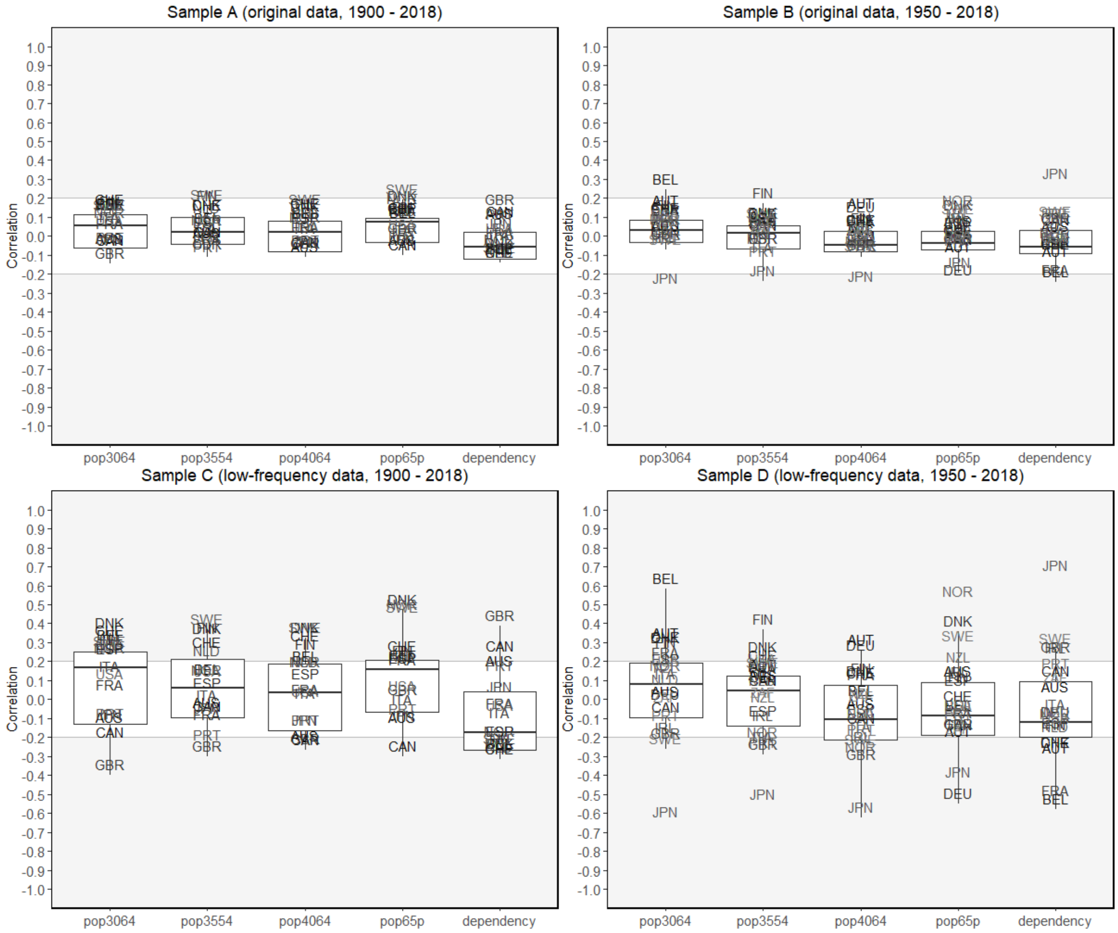
Source: the authors

ratio[6] for seven developed countries and found a positive relationship with bond yields for a post-war sample (1950 to 2012). When the middle-aged population increases, the MY ratio increases, so these variables are positively correlated with each other. Hence, both variables should present the same correlation signals with bond yields, and that is exactly what we can observe when analysing our results and those of Sević and Brawn.

We can affirm that our results for bonds are aligned with the LCH only for the fraction of the population aged 65 and over, considering the long sample (1900 -

[6]Middle-aged to young ratio, defined as the ratio between the population aged 40 to 49 and the population aged 20 to 29.

Figure 10: Long-run Correlations for Equity Returns



Source: the authors

2018) and, specially, the post-war sample (1950 - 2018).

Results for equity returns are presented in Figure 10. We can note that the results for the original sample (samples A and B) are much more concentrated than the results for the low-frequency series. It may happen because the low-frequency transformation helps to eliminate noise, and equity returns are very noisy.

For samples A and B, results are not significant for any variable. For sample C, on the other hand, we have stronger correlations for some countries, although they are not enough to draw a clear trend. It seems that the fraction of the population aged 30 to 64 is a positive correlate of equity returns, which also applies to the elderly. Therefore, our results are not exactly what we expected, since the elderly should be negative correlates.

It is important to remember that, while for bill and bond returns we expected negative correlations for the middle-aged population and positive correlations for the elderly (as discussed in Subsection 2.1), we expect the opposite results for equity returns. More people demanding equity should increase its price and also its return.

The dependency ratio, still in sample C, is negatively correlated with equity returns, which is what we expected. An increase in the dependent population should increase the dependency ratio. Since the dependent population is expected to be negatively correlated with equity returns, the dependency ratio should also be, just as we found.

For sample D, results are weaker than for sample C, which suggests that the results for the post-war period are not so significant when compared to the results for the entire sample (1900 - 2018). Note that the elderly, in sample D, cannot be considered positive correlates anymore, since their median correlations are much lower than 0.20. However, it is not possible to say that the elderly are negative correlates for the post-war period, because there are not so many countries with negative correlations.

Many works in the literature pointed out the positive relationship between the middle-aged population and equity (or stock) returns, such as Kawakatsu and Oliver (2018) (Japan, post-war), Davis and Li (2003) (7 countries, post-war), Huynh et al. (2006) (Australia, post-war) and Arnott and Chaves (2012) (23 countries, post-war). Our results for the post-war period are not aligned with theirs, but the results for the entire sample (1900 - 2018) are.

For the elderly, few papers have found a negative relationship with equity (or stock) returns or with the equity premium, but one can mention Ang and Maddaloni (2005) (15 countries, post-war), Brunetti and Torricelli (2010) (Italy, post-war) and Arnott and Chaves (2012) (23 countries, post-war). Again, our results for the post-war period do not indicate a significant relationship, while, for sample C, correlations tend to be positive.

Table 3 summarizes our long-run correlation results for Treasury Bill returns. "World (median $\hat{\rho}$)" is the median of the correlations for all countries. "% positively/negatively significant" is the percentage of countries with significant positive/negative results. To make interpretation easier, we included significance codes, which represents variables significant for at least 40% of the countries (*), 60% of the countries (**) and 80% of the countries (***).

Table 3: Correlation results for treasury bill returns

Sample	*pop3064*	*pop3554*	*pop4064*	*pop65p*	*dependency*
Sample A (1900-2018, original data)					
World (median $\hat{\rho}$)	-0.06	-0.05	-0.12	0.03	0.03
% positively significant	6.25	0.00	0.00	0.00	6.25
% negatively significant	18.75	18.75	37.50	0.00	6.25
Sample B (1950-2018, original data)					
World (median $\hat{\rho}$)	0.12	0.03	-0.16	0.10	-0.17
% positively significant	33.33	14.29	0.00	28.57	4.76
% negatively significant	4.76	9.52	33.33	9.52	42.86*
Sample C (1900-2018, low-frequency data)					
World (median $\hat{\rho}$)	-0.04	-0.08	-0.15	0.07	0.02
% positively significant	6.25	0.00	0.00	12.5	18.75
% negatively significant	31.25	31.25	37.50	0.00	6.25
Sample D (1950-2018, low-frequency data)					
World (median $\hat{\rho}$)	0.12	0.03	-0.20	0.12	-0.21
% positively significant	38.10	28.57	0.00	28.57	4.76
% negatively significant	4.76	14.29	47.62*	9.52	52.38*

Significant for at least 40% of the countries: [*]. For at least 60% of the countries: [**]. For at least 80% of the countries: [***]
Note 1: Samples A, B, C and D were explained in Table 1, from Section 3.
Note 2: *pop4064* is the fraction of the population aged 40 to 64 years old; *pop3064* is the fraction of the population aged 30 to 64; *pop3554* is the fraction of the population aged 35 to 54; *pop65p* is the fraction of the population aged 65 and over; *dependency* is the dependency ratio, defined in Section 3.
Note 3: "World (median $\hat{\rho}$)" is the median of the correlations for all countries. "% positively/negatively significant" is the % of countries with significant and positive/negative results.

Table 3 shows the same results as Figure 8, but with different measures. We can note that the medians of the correlations are generally not significant, just as we saw in the boxplot. We consider minimally strong correlates, for this table, variables that are significant for at least 40% of the countries.

For all samples, at least 33.3% of the countries are negatively significant for the middle-aged population (*pop4064*), and this number reaches almost 50% of the countries for the post-war period (sample D). The dependency ratio is also a strong correlate, but just for samples B (42.86%) and D (52.38%).

Table 4 summarizes the correlation results for long-term government bond returns. For each sample (A, B, C and D), defined in Section 3, we have the median of the correlations among all countries - "World (median $\hat{\rho}$)" - and the proportions of positively and negatively significant results.

Table 4: Correlation results for bond returns

Sample	*pop3064*	*pop3554*	*pop4064*	*pop65p*	*dependency*
Sample A (1900-2018, original data)					
World (median $\hat{\rho}$)	0.12	0.11	0.08	0.14	-0.14
% positively significant	18.75	6.25	18.75	31.25	0.00
% negatively significant	0.00	6.25	6.25	0.00	25.00
Sample B (1950-2018, original data)					
World (median $\hat{\rho}$)	0.24	0.17	0.14	0.24	-0.25
% positively significant	71.43**	42.86*	19.05	61.90**	4.76
% negatively significant	4.76	0.00	0.00	0.00	71.43**
Sample C (1900-2018, low-frequency data)					
World (median $\hat{\rho}$)	0.25	0.21	0.16	0.28	-0.26
% positively significant	62.5**	50.00*	37.50	56.25*	0.00
% negatively significant	6.25	6.25	6.25	0.00	62.5**
Sample D (1950-2018, low-frequency data)					
World (median $\hat{\rho}$)	0.51	0.39	0.27	0.49	-0.52
% positively significant	85.71***	80.95***	61.90	95.24***	4.76
% negatively significant	4.76	0.00	4.76	0.00	85.71***

Significant for at least 40% of the countries: [*]. For at least 60% of the countries: [**]. For at least 80% of the countries: [***]
Note 1: Samples A, B, C and D were explained in Table 1, from Section 5.
Note 2: *pop4064* is the fraction of the population aged 40 to 64 years old; *pop3064* is the fraction of the population aged 30 to 64; *pop3554* is the fraction of the population aged 35 to 54; *pop65p* is the fraction of the population aged 65 and over; *dependency* is the dependency ratio, defined in Section 3.
Note 3: "World (median $\hat{\rho}$)" is the median of the correlations for all countries. "% positively/negatively significant" is the % of countries with significant and positive/negative results.

Just as shown by the boxplots, the medians are large and, for samples B, C and D, are mostly significant. Results for the elderly range from 31.25% of the countries with positive results to 95.24%, with a maximum median of 0.49 in sample D, which indicates that this variable is highly positively significant. This result is aligned with the LCH.

However, results for the middle-aged population are the opposite of what they were expected to be. Most countries have strong, positive correlations between these age groups and bond returns.

For all variables, results tend to be more significant for the low-frequency data and for the post-war period. The reason is probably that the low-frequency transformation makes the data smoother and that, before 1950, some countries faced higher volatility in their returns due to the Great Depression and to the World Wars.

Figure 5 shows some results for equity returns. For most samples, results suggest that the correlations are not particularly significant for any variable. For sample C, *pop3064* is positively significant for half of the countries (8 of 16), and this is the most significant result we obtained for equity returns, which are very volatile variables.

With the results of the regressions, in Section 6.2, we show what happens when we consider a panel structure with year dummies. These results can be faced as a robustness exercise. After them, we enumerate our overall key findings in Subsection 6.3.

6.2 Regression results

We conduct fixed-effects regressions following equation (5) for all samples (A, B, C and D), which were defined in Table 1, in Section 3. Table 6 shows the regression results for real Treasury Bill returns. Each line represents a different sample, and the columns show the estimated parameters for each independent variable (β_{4064} and β_{65p}), the heteroskedasticity-robust standard errors (RSE_{4064} and RSE_{65p}), calculated following White (1980), and the p-values ($pvalue_{4064}$ and $pvalue_{65p}$). Note that, as showed in Section 3, we applied the first-differences to the variables Therefore, our results are represented in terms of deltas, which changes interpretation when compared to the correlations.

In Table 6, $\Delta pop4064$ is negatively significant for samples B and D, at significance levels of 10 and 1%, respectively. It means that there is a negative relationship between the deltas of the middle-aged and of Treasury Bill returns for the post-war period (1950 - 2018), for both the original data and the low-frequency

Table 5: Correlation results for equity returns

Sample	*pop3064*	*pop3554*	*pop4064*	*pop65p*	*dependency*
Sample A (1900-2018, original data)					
World (median $\hat{\rho}$)	0.06	0.02	0.02	0.08	-0.06
% positively significant	0.00	0.00	0.00	0.00	0.00
% negatively significant	0.00	0.00	0.00	0.00	0.00
Sample B (1950-2018, original data)					
World (median $\hat{\rho}$)	0.03	0.02	-0.05	-0.04	-0.06
% positively significant	4.76	0.00	0.00	0.00	4.76
% negatively significant	4.76	4.76	4.76	4.76	9.52
Sample C (1900-2018, low-frequency data)					
World (median $\hat{\rho}$)	0.17	0.06	0.04	0.16	-0.17
% positively significant	50.00*	25.00	25.00	31.25	12.50
% negatively significant	12.50	12.50	18.75	6.25	50.00
Sample D (1950-2018, low-frequency data)					
World (median $\hat{\rho}$)	0.08	0.05	-0.11	-0.08	-0.12
% positively significant	23.81	9.52	9.52	14.29	19.05
% negatively significant	19.05	23.81	28.57	19.05	23.81

Note 1: Samples A, B, C and D are explained in Table 1, from Section 5.
Note 2: *pop4064* is the fraction of the population aged 40 to 64 years old; *pop3064* is the fraction of the population aged 30 to 64; *pop3554* is the fraction of the population aged 35 to 54; *pop65p* is the fraction of the population aged 65 and over; *dependency* is the dependency ratio, defined in Section 3.
"World (median $\hat{\rho}$)" is the median of the correlations for all countries. "% positively/negatively significant" is the % of countries with significant and positive/negative results.

Table 6: Regression results for treasury bill returns (Δtbill)

	$\Delta pop4064$			$\Delta pop65p$		
Sample	β_{4064}	RSE_{4064}	$pvalue_{4064}$	β_{65p}	RSE_{65p}	$pvalue_{65p}$
A	-0.6605	(0.5469)	0.2273	0.3822	(0.6002)	0.5244
B	-0.3469*	(0.1833)	0.0586	-0.0565	(0.1906)	0.7667
C	-0.1149	(0.3124)	0.7129	0.4381	(0.5886)	0.4568
D	-0.4494***	(0.1724)	0.0092	0.1723	(0.3643)	0.6363

Significance codes: 1% [***], 5% [**], 10% [*].
Model: $\Delta tbill_{it} = \beta_{4064}\Delta pop4064_{it} + \beta_{65p}\Delta pop65p_{it} + \delta_1\Delta D1901_t + \delta_2\Delta D1902_t + ... + \delta_{118}\Delta D2018_t + \Delta u_{it}$
Note 1: samples A, B, C and D were defined in Table 1, from Section 5.
Note 2: β_{4064} is the regression parameter related to $\Delta pop4064$. β_{65p} is the regression parameter related to $\Delta pop65p$. RSE_{4064} and RSE_{65p} are the robust standard errors for each variable, calculated according to White (1980). $pvalue_{4064}$ and $pvalue_{65p}$ are the p-values for each variable.

transformed data, and that the tranformed data shows more significant results. Then, if the fraction of the population aged 40 to 64 increases faster (an increase in the delta), the first-difference of bill returns should decrease (a decrease in the delta). Therefore, this result corroborates, to a certain extent, what we found for the long-run correlations (Section 6.1), although, in the correlations, we did not use deltas.

We can note that, from Table 3, around 47% of the countries had negative and significant correlations with bill returns in sample D, and the world median was -0.20, which shows signal similarities with the regression results presented in Table 6.

However, note that the elderly, in Table 6, are not significant for bill returns, which is not perfectly aligned with our correlation results. For sample D, specially, we should expect positive and significant values.

Overall, we can affirm that the delta of the middle-aged population, represented by the fraction of the population aged 40 to 64 years old, has a negative relationship with the delta of Treasury Bill returns in the post-war period, which is similar to our correlation results and is aligned with two works in the literature[7], as discussed in Section 6.1.

Table 7 shows the regression results for real bond returns (or yields). Similarly to Table 6, each line represents a different sample, and the columns show the estimated parameters, the robust standard errors and the p-values. Contrary to the correlation results, regression results for bonds do not show signs of a positive relationship with the middle-aged population and with the elderly.

The only significant result from Table 7 is for the middle-aged population, whose first-difference has a negative relationship with $\Delta bond$ for sample D, at 5%. It was expected, according to the LCH, but unexpected when we compare with the correlation results. Since we use the same data for correlations and regressions, the differences may be due to the usage of fixed-effects estimators and to the inclusion of year dummies. Therefore, we should give more attention to the regression results, since they are likely to be more robust than the correlation results.

Davis and Li (2003) also found a negative relationship between bond yields and

[7]Yoo(1994) and Lunsford and West (2019).

Table 7: Regression results for bond returns (Δbond)

	$\Delta pop4064$			$\Delta pop65p$		
Sample	β_{4064}	RSE_{4064}	$pvalue_{4064}$	β_{65p}	RSE_{65p}	$pvalue_{65p}$
A	-0.3586	(0.7782)	0.6450	0.8856	(1.0975)	0.4198
B	-0.1533	(0.8272)	0.8529	0.2207	(0.9728)	0.8205
C	-0.2083	(0.5201)	0.6888	0.6160	(0.7198)	0.3922
D	-0.6805**	(0.3117)	0.0292	0.2303	(0.3783)	0.5428

Significance codes: 1% [***], 5% [**], 10% [*].
Model: $\Delta bond_{it} = \beta_{4064}\Delta pop4064_{it} + \beta_{65p}\Delta pop65p_{it} + \delta_1 \Delta D1901_t + \delta_2 \Delta D1902_t + ... + \delta_{118}\Delta D2018_t + \Delta u_{it}$
Note 1: samples A, B, C and D were defined in Table 1, from Section 5.
Note 2: β_{4064} is the regression parameter related to $\Delta pop4064$. β_{65p} is the regression parameter related to $\Delta pop65p$. RSE_{4064} and RSE_{65p} are the robust standard errors for each variable, calculated according to White (1980). $pvalue_{4064}$ and $pvalue_{65p}$ are the p-values for each variable.

the middle-aged population. Brunetti and Torricelli (2010), on the other hand, found no significant link for the middle aged and for the elderly. We compare our results with theirs in Appendix A.

Our results for the elderly, according to Table 7, are not significant, which also is not aligned with the correlations, since they were positive and strong for at least 31.25% of the countries, for all samples, and reached almost 100% of the countries for sample D (post-war with low-frequency transformation).

Table 8 shows the results for real equity returns. Similarly to our correlation results, the relationship is weak. The only significant result is a positive relationship with $\Delta pop4064$ for the post-war period (sample B), at a significance level of 5%.

Combining these results for equity with our correlation results, we can affirm that, for our dataset and with the methods used by us, there is no strong link between equity returns and the elderly population. In Figure 10, we saw that *pop3064* was the age group with the strongest correlations, so what could this variable and *pop3554* show us?

Instead of using *pop4064* as a predictive variable, Table 9 shows the regression results for the three financial variables considering *pop3064* instead of *pop4064*. Panel 1 shows the results for Treasury Bill returns, Panel 2 shows them for bond returns, and Panel 3 contains our findings for equity returns. The rest of the table is similar to the previous ones.

Table 8: Regression results for equity returns (Δequity)

	$\Delta pop4064$			$\Delta pop65p$		
Sample	β_{4064}	RSE_{4064}	$pvalue_{4064}$	β_{65p}	RSE_{65p}	$pvalue_{65p}$
A	1.2091	(1.8268)	0.5081	-1.6013	(2.8783)	0.5780
B	3.2620**	(1.5170)	0.0317	0.7364	(1.6615)	0.6577
C	1.4782	(1.3595)	0.2770	-1.0342	(1.1098)	0.3515
D	1.2977	(1.0801)	0.2298	-0.8700	(0.5904)	0.1408

Significance codes: 1% [***], 5% [**], 10% [*].
Model: $\Delta equity_{it} = \beta_{4064}\Delta pop4064_{it} + \beta_{65p}\Delta pop65p_{it} + \delta_1 \Delta D1901_t + \delta_2 \Delta D1902_t + ... + \delta_{118}\Delta D2018_t + \Delta u_{it}$
Note 1: the samples were defined in Table 1, from Section 5.
Note 2: β_{4064} is the regression parameter related to $\Delta pop4064$. β_{65p} is the regression parameter related to $\Delta pop65p$. RSE_{4064} and RSE_{65p} are the robust standard errors for each variable, calculated according to White (1980). $pvalue_{4064}$ and $pvalue_{65p}$ are the p-values for each variable.

Table 9: Regression results using Δpop3064 instead of Δpop4064

	$\Delta pop3064$			$\Delta pop65p$		
Sample	β_{3064}	RSE_{3064}	$pvalue_{3064}$	β_{65p}	RSE_{65p}	$pvalue_{65p}$
Panel 1: results for Treasury Bill Returns						
A	-0.7909**	(0.3778)	0.0365	0.1626	(0.5971)	0.7853
B	-0.2074**	(0.1054)	0.0493	-0.0456	(0.1890)	0.8093
C	-0.2732	(0.3471)	0.4313	0.3495	(0.5751)	0.5434
D	-0.4769***	(0.1777)	0.0074	0.0943	(0.2977)	0.7514
Panel 2: results for Bond Returns						
A	-1.1407*	(0.6765)	0.0919	0.4953	(0.9598)	0.6059
B	-0.0191	(0.3909)	0.9609	0.2582	(1.0419)	0.8043
C	-0.4682	(0.5309)	0.3780	0.4657	(0.6277)	0.4582
D	-2.0441	(1.4781)	0.1669	0.6585	(0.9934)	0.5075
Panel 3: results for Equity Returns						
A	-1.4069	(1.4310)	0.3256	-2.2873	(2.9554)	0.4390
B	1.8062*	(0.9642)	0.0612	0.5689	(1.8554)	0.7592
C	-0.8402	(0.8295)	0.3112	-1.5403	(1.1022)	0.1624
D	-0.4865	(0.6906)	0.4813	-1.3926***	(0.6825)	0.0415

Significance codes: 1% [***], 5% [**], 10% [*].
Model: $\Delta return_{it} = \beta_{3064}\Delta pop3064_{it} + \beta_{65p}\Delta pop65p_{it} + \delta_1 \Delta D1901_t + \delta_2 \Delta D1902_t + ... + \delta_{118}\Delta D2018_t + \Delta u_{it}$
Note 1: the samples were defined in Table 1, from Section 5.
Note 2: β_{3064} is the regression parameter related to $\Delta pop3064$. β_{65p} is the regression parameter related to $\Delta pop65p$. RSE_{3064} and RSE_{65p} are the robust standard errors for each variable, calculated according to White (1980). $pvalue_{3064}$ and $pvalue_{65p}$ are the p-values for each variable.

When comparing the results from Table 9 with those in Table 6, we can note that the estimations for bill returns are very similar for both tables. The middle-aged population is negatively significant, and the elderly are not significant for any sample. One difference is that while Δ*pop4064* is significant for samples B and D, both for the post-war period, Δ*pop3064* is significant for these samples and also for sample A, which represents the 1900 - 2018 period. Therefore, *pop3064* is a bit stronger than *pop4064* for treasury bill returns.

For bond returns, Panel 2 from Table 9 shows that there is a negative and significant link for sample A, and this is the only relevant result. Just as found for treasury bills, results for Δ*pop3064* are similar to those for Δ*pop4064*. However, for the latter, the significant value is found only for sample A (original data, 1900 - 2018), while for the former, results point at a significant link for sample D (low-frequency data, 1950-2018).

Still in Table 9, Panel 3 shows results for equity returns. The positive relationship between Δ*pop4064* for sample B, in Table 8, is shared by Δ*pop3064* in Table 9. For the elderly, there are changes: while, in Table 8, they were not significant, in Table 9 they have a negative link with equity returns for sample D (post war period), which is aligned with the LCH.

Table 10 shows the regression results when we consider Δ*pop3554* instead of Δ*pop4064*. For Treasury Bills, in Panel 1, as opposed to the results for Δ*pop4064* and Δ*pop3064*, there are not significant links, which was not expected, since we saw, in the correlations, that the three groups of "middle-aged" tend to have similar results.

In fact, based on Table 10, the relationship between Δ*pop3554* and financial variables is not significant in any case. For the elderly, there is a negative link with equity returns in sample D, which was also observed for the regressions with Δ*pop3063*, in Table 9.

6.3 Summary of key findings

For treasury bill returns, we found that the fraction of the population aged 40 to 64 years old is negatively correlated for samples B and D, which means that the relationship is significant for the post-war period (1950 - 2018), and also for sample

Table 10: Regression results using Δpop3554 instead of Δpop4064

	$\Delta pop3554$			$\Delta pop65p$		
Sample	β_{3554}	RSE_{3554}	$pvalue_{3554}$	β_{65p}	RSE_{65p}	$pvalue_{65p}$
Panel 1: results for Treasury Bill Returns						
A	-0.0242	(0.3431)	0.9438	0.4664	(0.5358)	0.3842
B	-0.1946	(0.2026)	0.3370	0.0530	(0.1866)	0.7763
C	-0.1152	(0.3044)	0.7051	0.4623	(0.5559)	0.4057
D	-0.2699	(0.1944)	0.1652	0.2957	(0.3574)	0.4081
Panel 2: results for Bond Returns						
A	0.3735	(0.4681)	0.4250	0.8937	(1.0584)	0.3986
B	0.1339	(0.4241)	0.7522	0.2630	(1.1474)	0.8187
C	0.1694	(0.3080)	0.5823	0.6286	(0.6393)	0.3256
D	0.1282	(0.1902)	0.5004	0.3972	(0.3497)	0.2563
Panel 3: results for Equity Returns						
A	-0.1288	(1.0350)	0.9010	-1.7387	(2.6545)	0.5125
B	-0.1858	(0.9802)	0.8497	-0.2377	(1.6623)	0.8863
C	-0.0920	(0.6401)	0.8857	-1.2153	(1.0136)	0.2307
D	-0.0650	(0.5698)	0.9092	-1.1949**	(0.6547)	0.0682

Significance codes: 1% [***], 5% [**], 10% [*].
Model: $\Delta return_{it} = \beta_{3554}\Delta pop3554_{it} + \beta_{65p}\Delta pop65p_{it} + \delta_1\Delta D1901_t + \delta_2\Delta D1902_t + ... + \delta_{118}\Delta D2018_t + \Delta u_{it}$
Note 1: the samples were defined in Table 1, from Section 5.
Note 2: β_{3554} is the regression parameter related to $\Delta pop3554$. β_{65p} is the regression parameter related to $\Delta pop65p$. RSE_{3554} and RSE_{65p} are the robust standard errors for each variable, calculated according to White (1980). $pvalue_{3554}$ and $pvalue_{65p}$ are the p-values for each variable.

C, which could indicate a relevant relationship for the long period (1900 - 2018). However, for the regression results, the relationship only held for samples B and D, so we should consider that the variable is significant only for the post-Second World War period. Furthermore, our correlations and regressions show that the elderly are very unlike to be significant correlates of bill returns. Hence, our results for treasury bills partially endorse the LCH: the middle-aged have a negative link, but the elderly have none.

For long-term government bond returns, our results for correlations are positive and strong, mainly for samples C and D, for all age groups. For the regressions, there is only a negative link for the fraction of the population aged 40 to 64, in sample D, and a negative link for the fraction aged 30 to 64 in sample A. For the elderly, we did not find significant results, similarly to what we concluded for bills. Since the middle-aged groups did not have consistent results for the regressions, it is not safe to say that they have a link with bond returns. Therefore, our results for bond returns do not endorse the LCH, for both the middle-aged and the elderly.

Finally, for equity returns, correlations and regressions were not strong. In sample C, in the correlations, the fraction of the population aged 30 to 64 was positively significant, but not too much, and this same variable, in the regressions, showed significant parameters in sample B (post-war, original data). However, since these results are for different samples, we cannot affirm that there is a robust link between equity returns and the middle-aged population. For the elderly, results are also not significant.

7 Conclusion

Overall, our results show partial support for the LCH. On one hand, we found robust evidence of negative correlation and regression estimates between the middle-aged population and yields on short-term treasury bill returns for the post-war period. On the other hand, for the other two assets, this correlation is less robust. We did not find strong evidence that the share of the elderly population correlates with any of the three asset returns. Moreover, results for the low-frequency transformed series tend to be more robust than results for the original data.

The possible impact of the middle-aged population on a safe asset (treasury bills) and the apparent nonexistent relationship between this age group and equity returns suggest that there is a preference for risk-free assets, which was, in fact, an expected result only for the elderly. According to Bonem et al. (2015), although it is commonly assumed that risk aversion increases with age, there are divergences in the empirical literature. Therefore, with our findings in mind, the existence of an increasing risk aversion for the countries and assets included in our dataset could be a research avenue.

The relationship between demographic variables and asset markets still holds potential evidence, considering that the world population, especially in developed countries, is aging fast. If an asset meltdown is coming or not, it will be known in a few years, when the last baby boomers retire.

According to our findings, however, the AMH does not hold, and an asset meltdown should not happen, which is in line with the conclusions of Poterba (2001, 2004), who observed that the elderly, in the U.S., hold their assets until death.

Another promising avenue of research is the empirical analysis of different social security systems around the world and their relationship with returns. More benevolent systems should discourage saving, and although Abel (2003) already studied this relationship with a theoretical model, empirical results could provide a large contribution.

Moreover, since the financial markets became more globalized in the last decades, the demographic structure of other countries could affect the domestic market. A highly developed domestic asset market could be more dependent on global variables, which would reduce the impact of the domestic demographic structure on the financial variables.

The social security system and the interdependence between countries were not caught by our work or by any previous empirical work in the literature, and could be the next steps for research in the area.

References

Abel, A. B. (2001). Will bequests attenuate the predicted meltdown in stock prices when baby boomers retire? Review of Economics and Statistics, 83(4), 589-595.

Abel, A. B. (2003). The effects of a baby boom on stock prices and capital accumulation in the presence of social security. *Econometrica*, 71(2), 551-578.

Ando, A., & Modigliani, F. (1963). The "life cycle" hypothesis of saving: Aggregate implications and tests. *The American Economic Review*, 53(1), 55-84.

Ang, A., & Maddaloni, A. (2005). Do demographic changes affect risk premiums? Evidence from international data. *Journal of Business*, 78(1).

Arnott, R. D., & Chaves, D. B. (2012). Demographic changes, financial markets, and the economy. *Financial Analysts Journal*, 68(1), 23-46.

Atil, A., Nawaz, K., Lahiani, A., & Rouband, D. (2020). Are natural resources a blessing or a curse for financial development in Pakistan? The importance of oil prices, economic growth and economic globalization. *Resources Policy*, 67, 101683.

Bae, Y. (2010). Stock prices and demographic structure: A cointegration approach. *Economics Letters*, 107(3), 341-344.

Bakshi, G. S., & Chen, Z. (1994). Baby boom, population aging, and capital markets. *Journal of Business*, 165-202.

Bergantino, S. M. (1998). Life cycle investment behavior, demographics, and asset prices. Doctoral dissertation. MIT Department of Economics.

Bodie, Z., Kane, A., & Marcus, A. J. (2013). Essentials of investments (9th ed.). ISBN 978-0-07-803469-5 (alk. paper).

Bonem, E. M., Ellsworth, P. C., & Gonzalez, R. (2015). Age differences in risk: Perceptions, intentions and domains. Journal of Behavioral Decision Making, 28(4), 317-330.

Brooks, R. (2000). Life cycle portfolio choice and asset market effects of the baby boom. *International Monetary Fund.*

Brooks, R. (2002). Asset-market effects of the baby boom and social-security reform. *American Economic Review*, 92(2), 402-406.

Brooks, R., et al. (2006). Demographic change and asset prices. In: *G20 Workshop on Demography and Financial Markets*, Sydney, July.

Brunetti, M., & Torricelli, C. (2010). Demographics and asset returns: Does the dynamics of population ageing matter? *Annals of Finance*, 6, 193-219.

Davis, E. P., & Li, C. (2003). Demographics and financial asset prices in the major industrial economies. *Economics and Finance Working Papers, Brunel University.*

Dimson, E., Marsh, P. R., & Staunton, M. (2002). Triumph of the Optimists: 101 Years of Global Investment Returns. Princeton University Press.

Dimson, E., Marsh, P., & Staunton, M. (2019). Dimson-Marsh-Staunton Global Returns Data (DMS Global). Morningstar.

Erb, C. B., Harvey, C. R., & Viskanta, T. E. (1997). Demographics and international investments. *Financial Analysts Journal*, 53(4), 14-28.

Favero, C. A., Gozluklu, A. E., & Tamoni, A. (2011). Demographic trends, the dividend-price ratio, and the predictability of long-run stock market returns. *Journal of Financial and Quantitative Analysis*, 46(5), 1493-1520.

Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The Next Generation of the Penn World Table. *American Economic Review, 105(10)*, 3150-3182. Available for download at www.ggdc.net/pwt.

Geanakoplos, J., Magill, M., & Quinzii, M. (2004). Demography and the long-run predictability of the stock market. *Brookings Papers on Economic Activity*, 2004(1), 241-325.

Goyal, A. (2004). Demographics, stock market flows, and stock returns. *Journal of Financial and Quantitative Analysis*, 39(1), 115-142.

Grisse, C., & Scheidegger, F. (2021). Covariability of real exchange rates and fundamentals. *Economics Letters*, 201, 109782.

Gozluklu, A., & Morin, A. (2019). Stock vs. Bond yields and demographic fluctuations. *Journal of Banking & Finance*, 109, 105683.

Hettihewa, S., Saha, S., & Zhang, H. (2018). Does an aging population influence stock markets? Evidence from New Zealand. *Economic Modelling*, 75, 142-158.

HMD. Human Mortality Database. Max Planck Institute for Demographic Research (Germany), University of California, Berkeley (USA), and French Institute for Demographic Studies (France). Available at www.mortality.org.

Huynh, W., Mallik, G., & Hettihewa, S. (2006). The impact of macroeconomic variables, demographic structure and compulsory superannuation on share prices: The case of Australia. *Journal of International Business Studies*, 37, 687-698.

Jamal, A. M. M., & Quayes, S. (2004). Demographic structure and stock prices. *Economics Letters*, 84(2), 211-215.

Kawakatsu, H., & Oliver, M. (2018). Population composition and financial markets: Evidence from Japan. *Studies in Economics and Finance*, 35(4), 505-524.

Kim, S.-W., Lee, B.-S., & Kim, Y.-M. (2019). Early 60s is not old enough: Evidence from twenty-one countries' equity fund markets. *Journal of International Money and Finance*, 92, 62-74.

Kim, S.-H., & Moon, S. (2022). Can demographic structures help predict equity premiums? Evidence from a panel with cross-section dependence. *Applied Economics Letters*, 29(7), 635-639.

Lunsford, K. G., & West, K. D. (2019). Some evidence on secular drivers of US safe real rates. *American Economic Journal: Macroeconomics*, 11(4), 113-39.

Maddison Project Database, version 2020. Bolt, J., & van Zanden, J. L. (2020), Maddison style estimates of the evolution of the world economy. A new 2020 update.

Ministry of Internal Affairs and Communications. (2008). Population Estimates / Time Series Population Estimates of Japan 1920 - 2000 [Data set]. Statistics of Japan. Retrieved from: `https://www.e-stat.go.jp/en/stat-search/files?page=1&layout=datalist&toukei=00200524&tstat=000000090001`.

Modigliani, F., & Brumberg, R. (1954). Utility analysis and the consumption function: An interpretation of cross-section data. *Franco Modigliani*, 1(1), 388-436.

Moura, A. (2021). Are neutral and investment-specific technology shocks correlated? *European Economic Review*, 139, 103866.

Müller, U. K., & Watson, M. W. (2018). Long-run covariability. *Econometrica*, 86(3), 775-804.

Papell, D. H., & Prodan, R. (2020). Long-run purchasing power parity redux. *Journal of International Money and Finance*, 109, 102260.

Park, C. (2010). How does changing age distribution impact stock prices? A nonparametric approach. *Journal of Applied Econometrics*, 25(7), 1155-1178.

Poterba, J. M. (2001). Demographic structure and asset returns. *Review of Economics and Statistics*, 83(4), 565-584.

Poterba, J. M. (2004). The impact of population aging on financial markets.

Shahbaz, M., Sharif, A., Belaid, F., & Vo, X. V. (2021). Long-run co-variability between oil prices and economic policy uncertainty. International Journal of Finance & Economics.

Šević, A., & Brawn, D. (2015). Do demographic changes matter? A cross-country perspective. Journal of Multinational Financial Management, 30, 36-61.

Siegel, J. (1998). Stocks for the Long Run. New York: McGraw Hill.

Thenuwara, W., Siriwardana, M., & Hoang, N. (2017). Demographics and Asset Markets: A Survey of the Literature. Theoretical Economics Letters, 7(4), 782-794.

United Nations, Department of Economic and Social Affairs, Population Division. (2022). World Population Prospects 2022, Online Edition.

United States Census Bureau. (1993). National Intercensal Tables: 1900-1990. Available at: `https://www.census.gov/data/tables/time-series.html`.

White, H. (1980). A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. Econometrica: journal of the Econometric Society, 48(4), 817-838.

Wooldridge, J. M. (2010). Econometric analysis of cross section and panel data.

MIT press.

Wooldridge, J. M. (2016). Introductory Econometrics: A Modern Approach (6th ed.). Cengage Learning.

Yoo, P. S. (1994). Age distributions and returns of financial assets. *Federal Reserve Bank of St. Louis Working Paper Series*, 1994-002.

Appendix A - Comparisons with the literature

Our correlation results can be compared with those of Lunsford and West (2019), who used the same methodology to make inference on the U.S. safe real rates, which they calculated based on short-term treasury bill returns. The comparison can be seen in Table 11, in which we calculated the medians of our results to represent the world correlations.

Table 11: Correlation comparisons with Lunsford and West (2019) for treasury bills

	Our results ($\hat{\rho}$)		LW results ($\hat{\rho}$)
Correlate	World	U.S.	U.S.
Sample C	**1900 - 2018**		**1890 - 2018**
dependency	0.02	0.24	0.38
pop4064	-0.15	-0.40	-0.43
Sample D	**1950 - 2018**		**1950 - 2018**
dependency	-0.21	0.01	0.10
pop4064	-0.20	-0.48	-0.54

For the US, our results are very close to those of Lunsford and West (2019) for both samples. The dependency ratio, in sample D, is not so close, but both ours and their results are not significant for this variable. Since they did not include the elderly among their correlates, we cannot compare results for this age group. Our results for the world are significant for *pop4064*, similarly to their results and to ours for the US. The other results for the world do not present similarities

For the regressions, not all works in the literature are comparable with ours. Works such as those by Arnott and Chaves (2012), Park (2010) and Brooks (2006), for example, used non-parametric methods, so there are no parameters to compare.

Therefore, we selected papers that are closely comparable to ours, which are those of Davis and Li (2003), Brunetti and Torricelli (2010), Ang and Maddaloni (2005) and Kim and Moon (2022).

Table 12 compares our results for treasury bills with those of Brunetti and Torricelli (2010). We chose sample D because it was the only one with a significant result. In the table, column period indicates the range of the analisys, column y shows what is the dependent variable used in the regression, column x shows what is the demographic variable used, and β shows the estimated parameters. Brunetti and Torricelli (2010), for example, with Italian data from 1981 to 2004, used bill returns, without first-differences, and the fraction of the population aged 40 to 64, also without deltas, in their regressions. They found a positive and significant result for the middle-aged at 1% of significance. Our work, on the other hand, found a negative value at 5%.

Table 12: Comparisons with the literature for treasury bills

Reference	Period	y	x	$\hat{\beta}$
Sample D	1950-2018	$\Delta bill$	$\Delta pop4064$	-0.449**
Sample D	1950-2018	$\Delta bill$	$\Delta pop65p$	0.172
Brunetti and Toricelli (2010) (Italy)	1981-2004	$bill$	$pop4064$	4.89***
Brunetti and Toricelli (2010) (Italy)	1981-2004	$bill$	$pop65p$	-1.351***

Significance codes: 1% ‘***’, 5% ‘**’, 10% ‘*’.
Davis and Li (2003): US, UK, Germany, France, Italy, Spain and Japan (1950-1999).

For the elderly, they found a negative and strong effect, while we did not find significant results. It is important to consider that their time series has a very limited size for treasury bills, which may compromise results. We tested our regression model for sample D filtering for the same period used by then (1981 - 2004), for Italy, but our results were not significant for both the middle-aged and the elderly.

Table 13 compares our results for bonds with those by Davis and Li (2003) and Brunetti and Torricelli (2010). Again, we used sample D. Our results for the middle-aged were negative and significant at 5%, similarly to Davis and Lee (2003).

Table 13: Comparisons with the literature for bonds

Reference	Period	y	x	$\hat{\beta}$
Sample D	1950-2018	$\Delta bond$	$\Delta pop4064$	-0.680**
Sample D	1950-2018	$\Delta bond$	$\Delta pop65p$	0.230
Brunetti and Toricelli (2010) (Italy)	1958-2004	$bond$	$pop4064$	-0.065
Brunetti and Toricelli (2010) (Italy)	1981-2004	$bond$	$pop65p$	0.298
Davis and Li (2003)	1950-1999	$bond$	$pop4064$	-0.239**

Significance codes: 1% '***', 5% '**', 10% '*'.
Davis and Li (2003): US, UK, Germany, France, Italy, Spain and Japan (1950-1999).

For the elderly, Davis and Li (2003) did not produce results, and Brunetti and Torricelli (2010) did not find significant values, just as us. Moreover, our sample D, for Italy, from 1981 to 2004, also did not produce significant results. For the same countries and periods used by Davis and Li, we also did not find significant results for the middle-aged. In fact, we found a negative link for the elderly, which cannot be compared to their work, since they did not consider this age group in their analysis.

When we run our regressions by Pooled OLS, without the dummies and the first differences, we obtain an estimated parameter, for the middle-aged population, of -0.232, which is very similar to what Davis and Li (2003) found (-0.239). Moreover, this result is significant at 1%.

Table 14 compares our results for equity returns with the literature. This table requires special attention to column y. One paper, as us, used equity returns: Brunetti and Torricelli (2010). Two papers used the equity premium: Ang and Maddaloni (2005) and Kim and Moon (2022). One paper used stock prices: Davis and Lee (2003). We selected our sample D, since all these countries analysed the post-war period.

Table 14: Comparisons with the literature for equity

Reference	Period	y	x	$\hat{\beta}$
Sample D	1950-2018	$\Delta bond$	$\Delta pop4064$	1.298
Sample D	1950-2018	$\Delta bond$	$\Delta pop65p$	-0.870
Brunetti and Toricelli (2010) (Italy)	1973-2004	$equity$	$pop4064$	-11.452**
Brunetti and Toricelli (2010) (Italy)	1981-2004	$equity$	$pop65p$	-11.504**
Davis and Li (2003)	1950-1999	$stockprices$	$pop4064$	-0.018
Kim and Moon (2022)	1950–2015	$equityprem$	$\Delta pop4564$	0.404
Kim and Moon (2022)	1950–2015	$equityprem$	$\Delta pop65p$	1.136
Ang and Maddaloni (2005)	1970-2000	$equityprem$	$pop2064$	3.802
Ang and Maddaloni (2005)	1970-2000	$equityprem$	$pop65p$	-4.465***

Significance codes: 1% '***', 5% '**', 10% '*'.

Except for Brunetti and Torricelli (2010), who found negative effects from the middle-aged and from the elderly, and Ang and Maddaloni (2005), whose results for the elderly were also consistent with the LCH, the remaining researches, including ours, did not find statistically significant results for these age groups.

Since Brooks (2006), Park (2010) and Arnott and Chaves (2012) used non-parametric methods, it was not possible to include their results in Table 14. As discussed in Section 2, Brooks did not find significant results, while Park and Arnott and Chaves found positive results for the middle-aged.

Therefore, some of our regression results find support in the literature, like the no significant results for equity returns, the negative link between the middle-aged and bill and bond returns and the no significant results for the elderly on bond returns.