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Threshold effects of population aging on stock prices

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Abstract

The aim of this study is to investigate whether the changes in population age structure affect the stock prices in developed countries. Our main findings are that the proportions of population aged 20-39 and 40-64 years have an upward pressure on the stock prices, while the proportion of over 65 years has a downward pressure. Moreover, we find that if the proportion of the retired population aged over 65 years exceeds the threshold value, higher risk premium is required to compensate for the price fluctuation risks, which has a downward pressure on the stock prices. These results are consistent with both the life-cycle investment hypothesis and life-cycle risk aversion hypothesis, and are supportive for the possibility of asset meltdown hypothesis.

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1. Introduction

The population is aging rapidly in many developed countries. Population aging has significant effects on financial markets through its effects on domestic savings and the demand for investment funds. According to Modigliani's (1986) *life cycle hypothesis*, households save during their working periods through their desire to smooth consumption over the entire lifespan, while dis-saving during their retirement. Therefore, domestic savings should decrease as the population ages. The decrease in domestic savings might weaken the demand for investment funds, which has a negative pressure on asset prices.

Moreover, Bakshi, and Chen (1994) propose two hypotheses: the *life-cycle investment hypothesis* and *life-cycle risk aversion hypothesis*. The former states that the composition of an investors' savings portfolio changes over the life cycle. Investors allocate a larger part of their wealth to housing assets when they are young, while dipping into financial assets when they grow older. The latter states that investors become more risk averse as they age, such that they require a higher risk premium to compensate for price fluctuation risk. These two hypotheses together predict that the increase in the proportion of the middle-aged population (i.e., 40-64 years) has an upward pressure on financial asset prices by increasing demand for them, while an increase in the proportion of the old-age population (i.e., over 65 years) has a downward pressure due to the higher risk premium.[1]

Based on these considerations, the *asset meltdown hypothesis*, which states that when baby boomers retire, they will reduce their asset holdings and thus place downward pressure on asset prices, is a major concern in financial markets.

This study investigates whether the changes in the population age structure affect stock prices in developed countries, where the population has been aging. Our main findings are that the proportion of the population aged 20-39 and 40-64 years has an upward pressure on stock prices, while the proportion of the population older than 65 has a downward pressure. Moreover, if the proportion of the retired population above 65 years old exceeds the threshold value, then a higher risk premium is required to have a downward pressure on stock prices. These results are consistent with both the life cycle investment hypothesis and life cycle risk aversion hypothesis, and imply the possibility of an asset meltdown hypothesis.

The remainder of this paper proceeds as follows. In the next section, we provide an overview of related studies that empirically investigate the relationship between demographic age structure and asset prices and/or returns.[2] The third section presents the estimation methodology and results. The last section concludes the paper.

[1] The effects of the proportion of young people (i.e., 20-39) are not obvious because the aggregate demand for financial assets might increase if this group allocates some fraction of their wealth to financial assets, although they might invest more in housing assets than in financial assets.

[2] See Hassan, Salim, and Bloch (2010) for a comprehensive survey.

2. Related Literature

Bakshi and Chen (1994) use US time-series data from 1900 to 1990 and find that stock prices increase as the average age increases, which supports the life cycle investment hypothesis. As for the life cycle risk aversion hypothesis, they employ generalized methods of moment techniques to find that risk aversion increases with age, and thus investors require a higher risk premium. Erb, Harvey, and Viskanta (1997) extend Bakshi and Chen (1994) to examine whether an increase in the *world* average age increases the real return on a stock in an integrated stock market, but they find no relationship.

Poterba (1998) uses data from the US and Canada from 1950 to 1997 and find no significant links between population age structure and stock returns, but a strong relationship with Treasury bill and long-term government bond yields. Poterba (2001) uses data for the US, Canada, and the UK from 1926 to1999 and fails to find any significant relationship between demographic age structure and asset returns (Treasury bill, long-term government bonds, and stocks). Poterba (2004) reports similar results using data from the US, Canada, Germany, Italy, the UK, and Japan, except for the US, in which the price-earnings ratio (PER) of the S&P500 has a significant relationship.

Davis and Li (2003) use data for 7 OECD countries from 1950 to 1999 and find that an increase in the proportion of the middle-aged (40-64 years) population has significant and positive effects on the real prices of stock and bonds. Brunetti and Torricelli (2010) follow Davis and Li (2003) to investigate the case for Italy.

Geanakoplos, Magil, and Quinzii (2004) present a theoretical model that predicts that the PER is proportional to the middle-aged to young-age adult (M/Y) ratio and that asset returns and the M/Y ratio are positively related. They test these predictions against the data they find a significant relationship between real stock prices and the M/Y ratio in France and Japan, but not in Germany or the UK.

Goyal (2004) studies the link between population age structure and both the net outflows from the stock market and stock returns based on the overlapping generations model using US data from 1926 to 1998. The results indicate a positive correlation between the outflows from stock markets and the change in the proportion of the old-age (65 and over) population and a negative correlation with the proportion of the middle-aged (45-64 years) population. Moreover, they find a positive correlation between stock returns and the change in the average age.

Brooks (2006) uses data for 16 OECD countries from 1900-1925 to 2005 and find that asset prices tend to rise with the increase in the proportion of the old-age population, which contradicts the asset meltdown hypothesis.

3. Empirical Analysis

3.1. Methodology

We will derive the estimated equation based on the discounted dividends model. Denoting the risk-free rates as R_{t+1}^f, the return on stock as R_{t+1}, and the risk premium, which we require to compensate for the price fluctuation risk, as RP_{t+1}, the following equation must be satisfied through the arbitrage condition,

$$1 + R_{t+1}^f + RP_{t+1} = 1 + R_{t+1} . \tag{1}$$

Expressing equation (1) in terms of the log or continuous compounded return gives

$$\begin{aligned} r_{t+1}^f + rp_{t+1} = r_t &= \log(P_{t+1} + D_{t+1}) - \log(P_t) \\ &= p_{t+1} - p_t + \log(1 + \exp(d_{t+1} - p_{t+1})) \\ &= k + \rho p_{t+1} + (1-\rho) d_{t+1} - p_t \end{aligned} \tag{2}$$

$$k \equiv -\log(\rho) - (1-\rho)\log\left(\frac{1}{\rho} - 1\right) \text{ and } \rho \equiv \frac{1}{1 + \exp(\overline{d - p})},$$

where $r_{t+1}^f + rp_{t+1} = \log(1 + R_{t+1}^f + RP_{t+1})$, $r_{t+1} = \log(1 + R_{t+1})$, and p_t and d_t denote the natural logarithm of the stock price P_t and the dividend D_t, respectively. Taking the expectation, solving equation (2) forward, and imposing the transversality condition that

$$\lim_{k \to \infty} E_t[\rho^j p_{t+j}] = 0 , \tag{3}$$

we obtain

$$p_t = \frac{k}{1-\rho} + E_t\left[\sum_{j=0}^{\infty} \rho^j \left\{(1-\rho) d_{t+1+j} - (r_{t+1+j}^f + rp_{t+1+j})\right\}\right]. \tag{4}$$

We can rewrite equation (4) in terms of the log price-dividend ratio:

$$p_t - d_t = \frac{k}{1-\rho} + E_t\left[\sum_{j=0}^{\infty} \rho^j \left\{\Delta d_{t+1+j} - (r_{t+1+j}^f + rp_{t+1+j})\right\}\right]. \tag{5}$$

Equation (5) means that the log price-dividend ratio is high today, and that there must be some combination of high dividends and a low risk-free rate and risk premium in the future. This representation is useful when the log prices and log dividends follow a unit root process. In this case, changes in log dividends are stationary, which means that log price and log dividend are cointegrated with cointegration vector [1 -1].

Based on the life cycle investment hypothesis and the life cycle risk aversion hypothesis, we assume that the risk premium depends not only on the volatility of the stock return vol_t, but also on the demographic age structure variables age_t; thus $rp_t = rp(vol_t, age_t)$.

Therefore, we first estimate the following equation by fixed effects panel methods:

$$pd_{i,t} = \alpha_i + \beta_1 \Delta d_{i,t} + \beta_2 r^f_{i,t} + \beta_3 age_{i,t} + \beta_4 vol_{i,t} + \varepsilon_{i,t}, \quad (6)$$

where i is a country index and α_i represents country-specific fixed effects, which are introduced so as to consider the heterogeneity across countries, such as the degree of risk appetite, degree of capital mobility and the tax system on portfolio investments which may impact or bias the regressors and we need to control for this. pd_t is the log price dividend ratio. As the demographic age structure variables, we employ the proportion of the population aged 20-39, 40-64, and over 65 years relative to the total populations; that is, $ratio_{20-39}$, $ratio_{40-64}$ and $ratio_{65+}$ [3], respectively.

Moreover, we examine whether there exists a threshold at which the effects of the proportion of the old-age population on the log price-dividend ratio through the volatility of the stock return would change. Thus, we estimate

$$\begin{aligned} pd_{i,t} &= \alpha_i + \beta_1 \Delta d_{i,t} + \beta_2 r_{i,t} + \beta_3 age_{i,t} \\ &+ \beta_{4,below} vol_{i,t}(raio_{65+,i,t} < \theta) + \beta_{4,above} vol_{i,t}(ratio_{65+,i,t} \geq \theta) + \varepsilon_{i,t}. \end{aligned} \quad (7)$$

3.2. Data

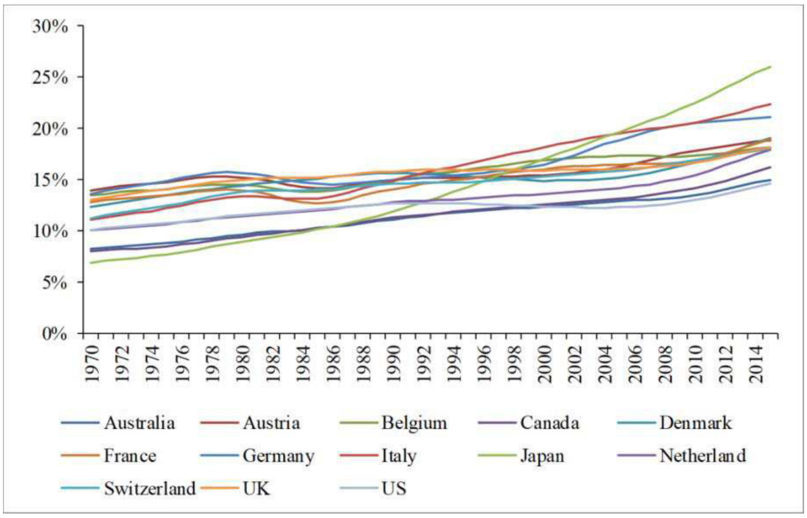
Our sample includes 13 OECD countries (Australia, Austria, Belgium, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, Switzerland, the UK, and the US). Our sample period runs from 1973 to 2015 with annual data due to data availability.

For stock prices, we use data from the *DS-Market Price Index* (PI) from *Datastream* and calculate the data on the corresponding dividends using data on *DS-Market Dividend Yields* (DY). For the volatility of stock returns, we use the annual average of conditional variance of the daily data of the *DS-Market Total Price Index* (RI), which we calculate using a GARCH(1,1) model. The data for short-term interest rates are the interbank 3-month interest rates. We collect these data from *Datastream*. We collect population structure data from *World Population Prospects*: *The* 2017 *Revision.*

Figure 1 illustrates the proportion of the old-age (65 and over) population in the 13 OECD countries, showing that the population is aging rapidly in these developed countries.

[3] We omit the proportion of the population aged 0-19 years to avoid multi-collinearity.

Figure 1. Proportion of the population aged 65 and over



(Source) United Nations: *World Population Prospects*: *The* 2017 *Revision*

3.3. Empirical Results

Table 1 shows the estimation results. From the fixed effects panel estimation of equation (6), we can see that the proportion of the population aged 20-39 and 40-64 years have significant positive effects on the log price-dividend ratio, while the proportion of the population over 65 years has significant negative effects. As for the other control variables, short-term interest rates have significant negative effects. On the other hand, although the signs of coefficients on the changes in log dividends and volatility of stock returns are consistent with theory, they are not significant.

From the threshold effects fixed effects panel estimation of Equation (7), we find threshold effects at below the 5% significance level, and our threshold parameter estimate is 0.1703 within the 95% confidence interval [0.1696 0.1711]. We also find that the volatility of stock returns is not significant when the proportion of the population over 65 years old is below the threshold value, but it is negatively significant when it is above the threshold value. In addition, the proportions of the population aged 20-39 and 40-64 years have significant positive effects on the log price-dividend ratio. As for the other control variables, the results are similar to those from Equation (6).

The results above mean that the proportion of the working population aged 20-39 and 40-64 years have an upward pressure on stock prices, while the proportion of the retired population aged over 65 years have a downward pressure. Moreover, if the proportion of the retired population aged over 65 years exceeds the threshold value, then a higher risk premium is required to compensate for the price fluctuation risks, which yields a downward pressure on stock prices. These results are consistent with both the life cycle investment hypothesis and life cycle risk aversion hypothesis, and imply the possibility of an asset meltdown hypothesis.

Table 1. Estimation Results

	(6)	(7)
Δdividend (β_1)	0.015 (0.094)	0.033 (0.090)
r^f (β_2)	-1.970*** (0.539)	-2.721*** (0.524)
ratio 20-39 (β_3)	6.626*** (0.922)	5.914*** (0.885)
ratio 40-64 (β_3)	10.058*** (0.893)	8.394*** (0.883)
ratio 65 (β_3)	-4.818*** (0.860)	-1.135 (0.964)
vol (β_4)	-7.819 (4.867)	
vol ($\beta_{4,below}$)		2.924 (4.874)
vol ($\beta_{4,above}$)		-29.629*** (5.529)
constant	-0.503 (0.492)	-0.325 (0.470)
adjusted R^2	0.287	0.303
Threshold [95% confidenc interval]		0.1703** [0.1696 0.1711]

Notes: (1) Standard errors are in parentheses. (2) ** and *** denote 5% and 1% significance, respectively.

4. Conclusions

This study investigates whether the changes in the population age structure affects stock prices in 13 OECD countries, where the population is aging. Our main findings are that the proportion of the population aged 20-39 and 40-64 years has an upward pressure on stock prices, while the proportion of the population over 65 years has a downward pressure. Moreover, if the proportion of the retired population aged over 65 years exceeds the threshold value, then a higher risk premium is required to compensate for the price fluctuation risks, which has a downward pressure on stock prices. These results are consistent with the life cycle investment hypothesis and life cycle risk aversion hypothesis, and imply the possibility of an asset meltdown hypothesis.

It is thus necessary to keep the demand for stocks from shrinking. For this purpose, it might be useful to promote lifetime gifts from the old to the young generations and to improve the efficiency and transparency in domestic stock markets to attract foreign investors.

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