The political economy of public investment when population is aging: a panel cointegration analysis

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Abstract

Time preferences vary by age. Notably, according to experimental studies, senior citizens tend to discount future payoffs more heavily than working-age individuals. Based on these findings, we hypothesize that demographic change has contributed to the cut-back in government-financed investment that many advanced economies experienced over the last four decades. We demonstrate for a panel of 19 OECD countries between 1971 and 2007 that the share of elderly people and public investment rates are cointegrated, indicating a long-run relationship between them. Estimating this cointegration relationship via dynamic OLS (D-OLS) we find a negative and significant effect of population aging on public investment. Moreover, the estimation of an error correction model reveals long-run Granger causality running exclusively from aging to investment. Our results are robust to the inclusion of additional control variables typically considered in the literature on the determinants of public investment.

Keywords: Public investment, Population aging, Panel cointegration
JEL Classification: D72, D91, H54, J11, J14

1 Introduction

Public investment as a share of GDP has been constantly declining in most advanced economies for more than four decades. This seems puzzling since the overall empirical evidence indicates that the economic returns to public capital are markedly positive (for an overview see Bom and Ligthart, 2014). Based on these high returns some economists

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(e.g. IMF 2014) have recently advocated additional public investment spending to foster economic growth. However, we argue in this paper that the growing number of elderly voters has contributed to the decline in public investment rates. Thus, raising public investment levels might become increasingly difficult in greying democracies.

The argument that demographic change will shift voting power towards older generations and therefore affects the composition of government spending, dates at least back to Preston (1984). In the last decades, empirical studies have demonstrated that population aging in fact influences government spending components including social welfare, health and education (Harris et al., 2001; Krieger and Ruhose, 2013; Poterba, 1997; Sanz and Velázquez, 2007; Shelton, 2008; Tepe and Vanhuysse, 2009). Furthermore, evidence based on survey data reveals age-specific preferences regarding welfare and educational spending (Boeri et al., 2001; Bonoli and Häusermann, 2009; Cattaneo and Wolter, 2009; Sørensen, 2013). However, existing studies typically focus on different functions of government spending, but do not distinguish between consumption and investment. This paper aims to fill this gap and investigates the effect of aging on public investment as a whole regardless of the specific beneficiary or function of investment.

So far, the most common explanation for the decline in public investment rests on fiscal pressures (Vuchelen and Caekelbergh, 2010). The few existing empirical studies[1] on the determinants of public investment usually find public investment to be negatively correlated with the budget deficit or the debt level "reflecting the political reality that it is easier to cut-back or postpone investment spending than it is to cut current expenditures" (Oxley and Martin, 1991, p. 161)). Based on this line of reasoning, public investment has been declining because it's a flexible budget item and voters seem to be rather insensitive to cuts in times of fiscal pressure, given the limited visibility and more diffuse character of investment spending.

However, public investment did not recover once fiscal stress eased in the 1990s (Vuchelen and Caekelbergh, 2010) rendering the fiscal pressure narrative incomplete. Privatization and the emergence of Public Private Partnerships (PPP) also offer only limited explanatory power for the constant decline in government-financed investment (Heinemann, 2006; Mehrotra and Välilä, 2006). The definition of public investment provides the main reason for the negligible role of privatization. Public investment is commonly measured by gross fixed capital formation of the general government, which does not include investments made by state-owned enterprises that are commercially run (Gonzalez Alegre et al., 2008). Therefore, privatization of these companies does not affect public investment.[2] PPP on the other hand is a rather new phenomenon and still accounts for less than one tenth of public investment spending in developed countries (IMF, 2014). Hence, the factors behind the steady decline in public investment are yet not fully understood.

In this paper, we propose an additional explanation for the declining public investment ratio that is related to ongoing demographic change. The underlying theory rests upon a simple political economy mechanism following the voter

[1] These studies include Bacchiocchi et al. (2011), Haan et al. (1996), Heinemann (2006), Keman (2010), Mehrotra and Välilä (2006), Sturm and Haan (1998), Sturm (2001) as well as Turrini (2004) .

[2] Enterprises are considered commercial, if their sales revenues cover more than 50% of the actual production costs. Some public utilities have been reclassified from the general government to the private sector in the mid '1990s (Balassone and Franco, 2000), however the findings of Heinemann (2006) suggest a minor impact of privatization overall.

group decision model developed by Craig and Inman (1986). We stipulate that the elderly, on average, prefer a smaller investment-to-GDP ratio compared to working-age individuals. This claim is based on experimental studies investigating age-specific time preferences, which find the elderly to discount future payoffs more heavily than working-age people. Since greying societies are characterized by a steadily growing share of elderly people, the voting power of senior citizens rises and thus their preferences should become increasingly influential. Therefore, we hypothesize that population aging reduces the overall support for public investment.

In order to analyze our hypothesis empirically and accounting for non-stationarity in the data, we employ panel cointegration and error correction techniques using data from 19 OECD countries for the period from 1971 to 2007. The cointegration test indicates a long-run relationship between public investment and population aging which we estimate applying dynamic OLS (D-OLS). Consistent with our hypothesis we find a negative relationship between public investment and population aging. The estimated coefficient is statistically as well as economically significant and robust to the inclusion of a range of control variables. Besides variables frequently included in empirical studies on the determinants of public investment (e.g. public debt, GDP per capita, private investment etc.), we also control for the expected population in ten years, constructed using historic UN population forecasts, to account for the nexus between population aging and slower population growth. Estimating the econometric model in first differences, instead of levels, does not alter our conclusion. Moreover, results from an error correction model suggest long-run Granger causality running exclusively from aging to public investment.

Based on our empirical results, we do not expect public investment to provide additional stimuli for economic growth during the demographic transition, at least in the political status quo. Increasing the retirement age, which avoids a crowding-out of public investment by pension expenditures, however, could alleviate the growing opposition to public investment spending.

The outline of the paper is as follows: In the next section we motivate the link between demographic change and public investment using a simple group decision model. In section 3 we introduce the data as well as the empirical approach and present our results in section 4. Section 5 concludes.

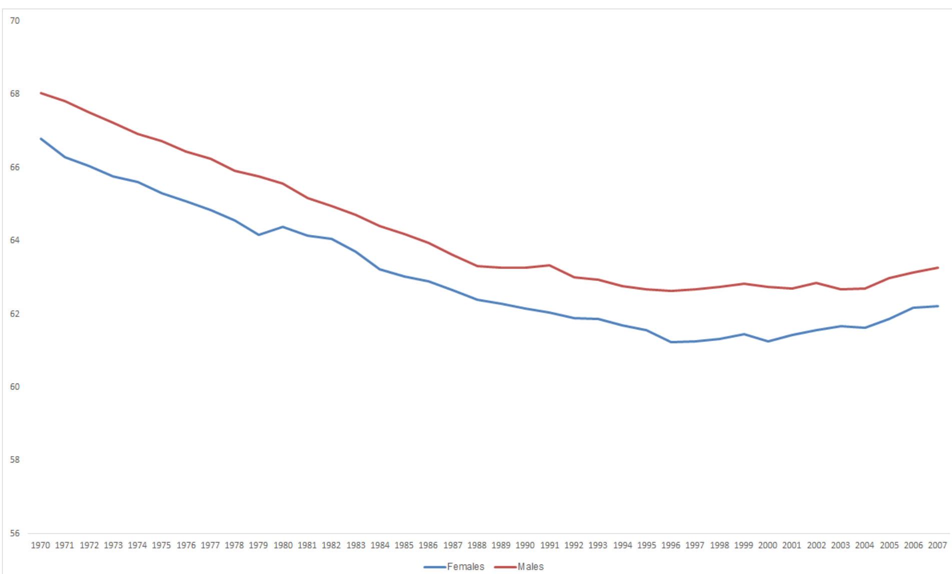
2 Background and Hypothesis

Long-lasting (intergenerational) public goods, such as a clean environment or a sufficient stock of public infrastructure, are potentially undersupplied if generations are selfish (e.g. Kotlikoff and Rosenthal, 1993). This is based on the nature of these goods. While the present generations pay, the future generations reap (most of) the benefits. Population aging could aggravate this problem, since a greater proportion of the population might expect a low individual return from investments in durable public goods.

However, Gonzalez-Eiras and Niepelt (2012) argue based on a two-period OLG-model that the ongoing demographic change has ambiguous effects on the public investment-to-GDP ratio[3]. On the one hand, a larger proportion of elderly people should depress public investment rates. On the other hand, rising longevity heightens the demand for long-lasting public goods since more working-age people live long enough to take advantage of the investments made. In simulations representing a calibrated version of a wealthy OECD economy, Gonzalez-Eiras and Niepelt (2012) show that the net effect depends on the evolution of the retirement age. While population aging tends to elevate public investment as long as the retirement age is postponed, the opposite is true if the retirement age remains constant or even decreases, since such a policy increases social security transfers which crowd out public investment. Based on the prediction of this model, we expect that the age-structure effect dominates the life expectancy effect, since the effective retirement age in our sample has decreased since the 1970s, even though this trend seems to have slightly reversed in the recent past (Figure 1). In this vein, an increase in the effective retirement age, e.g. to levels observed at the beginning of the 1970s, could foster public investment spending in our sample economies.

The Gonzalez-Eiras and Niepelt model assumes that elderly people die before they can benefit from newly started public investment projects. However, this may not be a realistic assumption in all cases. In the following, we argue, based on the concept of time preferences, that elderly people, in general, are more likely to prefer a smaller public investment ratio than working-age people.

Figure 1: **Average effective retirement age (Cross-sectional average), 1970-2007**



Sample except for Iceland and Germany, Source: OECD

[3]Gonzalez-Eiras and Niepelt (2012) base their model on a broader concept of public investment that also includes education expenditures. However, the underlying mechanism should be similar.

The construction of public infrastructure, such as roads and buildings, is time-consuming, but the economic lifetime of these assets is rather long. Hence, those people who discount the future more heavily will be less prone to appreciate additional public investment spending, holding everything else constant. Empirical evidence derived from experimental studies shows that time preferences vary with age. Harrison et al. (2002) find that retired individuals discount future payoffs more than non-retired people. Similarly, the study conducted by Read and Read (2004) suggests higher annual discount rates of elderly individuals. Interestingly, Read and Read (2004) find the differences in annual discount rates between senior citizens and working-age people especially pronounced if one payoff option lies in the distant future (e.g. 10 years after the experiment), a time horizon especially relevant for large public infrastructure projects. A possible explanation for these results is the decline in survival probability associated with rising age (Sozou and Seymour, 2003). A related argument states that the expected utility of future consumption decreases with age since people anticipate a deterioration of their mental and physical capacity (Trostel and Taylor, 2001).

In well-functioning democracies, voter preferences determine the level and composition of public spending. To strengthen intuition and motivate our empirical analysis, we thus model the level of public investment as a weighted average of the level of public investment favored by each voter group. Voter groups can be defined along different dimensions. Craig and Inman (1986), who introduced this type of models, split voters based on their income. Following our hypothesis we assume age to be the crucial socio-economic cleavage and distinguish two groups: elderly people and working-age individuals. In our case the voter group decision model looks like the following:

$$I^* = \pi^{work} * I^{work} + \pi^{old} * I^{old} \tag{1}$$

where I^* is the observed level of public investment determined in the political process. I^{work} and I^{old} indicate the demand for public investment for working-age and elderly individuals respectively. π^{work} and π^{old} specify the political strength of each group, whereas $\pi^{work} + \pi^{old} = 1$. Similar to Sanz and Velázquez (2007) we assume that the political weight of a demographic group is based on their relative size compared to the total voting population.[4] As argued above, we hypothesize that elderly people demand less public investment than working-age individuals ($I^{old} < I^{work}$) based on different time preferences. Thus, holding everything else constant, an increase in π^{old} results in a decline of I^*in our model. The cut-off age which separates working-age from elderly people is necessarily an approximation. Individuals slightly below or above the cut-off age may be very similar. Nonetheless, we believe that the retirement age is a suitable proxy for the cut-off age, given that Harrison et al. (2002) find retirement to be positively related to the discount rate.

Two limitations apply within this theoretical framework. First, as argued above, population aging partially follows from a continuous rise in life expectancy. Therefore, today's citizens are likely to have different time preferences compared to their same-age counterparts four decades ago. Thus, demographic change can also lead to an increase of I^{work} and I^{old}. However, in line with Gonzales-Eiras and Niepelt (2012) we suspect the age composition effect to be

[4] The elderly shares in Sanz and Velázquez (2007) are calculated using total population, instead of total voting-age population, as denominator.

more important[5]. Second, elderly's preferences might not be entirely driven by self-interest, but by altruistic sentiments towards their offspring or the society as a whole. Hence, the question whether a growing share of elderly people has contributed to the decline in public investment has to be solved empirically.

3 Empirical strategy and data

3.1 Econometric model

In order to analyze the nexus between public investment and population aging we apply the following model:

$$ln(public\, investment\, ratio)_{it} = a_i + b_i trend + \beta\, ln(elderly\, share)_{it} + \mathbf{X}'_{it}\gamma + \varepsilon_{it} \tag{2}$$

where i and t denote the country and time dimension. $\mathbf{X}_{it}$ includes control variables that are discussed in more detail in section 3.2. Following the standard in the literature, the public investment ratio is operationalized by gross fixed capital formation of the general government as a share of GDP. The elderly share is defined as proportion of the population aged 65 and older to total voting-age population (population older than 19) and is intended to capture political strength of the elderly (π^{old} from equation (1)). We choose 65 as threshold age because it has been the most frequent legal pension age for males in our sample. A similar variable, using 70 instead of 65 as threshold age, has recently been employed by Krieger and Ruhose (2013) to study the impact of population aging on family benefits and educational expenditures. Related empirical studies have operationalized population aging using old-age dependency ratios (Shelton, 2008; Tepe and Vanhuysse, 2009) or the share of elderly to total population (Harris et al., 2001; Poterba, 1997; Sanz and Velázquez, 2007). However, we think that these indicators are less appropriate for our purposes, because they capture relative voting power of elderly citizens even more indirectly.

Note that the elderly share is only a proxy for π^{old} for at least two reasons. First of all, voter turnout differs between working-age and senior citizens, whereas the latter tend to vote more frequently. Even though, this age-specific participation gap seems to have increased slightly over time, the average difference in voter turnout at the end of our sample was still limited (e.g. on average around 8 percentage points for 12 of our European sample countries)[6]. Secondly, not

[5] In general, I^{old} might be less affected by demographic change given that life expectancy at age 65 increased on average by approximately 5 years within our sample period in the OECD, in contrast to an increase of around 10 years for life expectancy at age 1. Moreover, even though people are expected to live longer this does not imply that the extra years are lived in good health. According to OECD (2013) the average healthy life expectancy, for 24 European OECD countries in 2011, at age 65 was still below 10 years. Hence, the risk of a significant deterioration of their mental and physical capacity in the close future is still a very relevant concern for people at the age of 65.

[6] We calculated age-specific voter turnout rates in national election for all European countries in our sample except for Iceland and Italy based on the four rounds of the European Social Survey between 2002 and 2008 (ESS, 2002). On average, elderly voter turnout rates of national citizens exceed working-age turnout rates by approximately 7 percentage points. This gap increased slightly over time (from 6 to 8 Percentage points), which is in line with the findings by Smets (2010). Similar results have been reported for the US (File, 2014), Canada (Barnes and Virgint, 2010), Japan (Takao, 2009) and New Zealand (Electoral Commission, 2015). Voter turnout is high across age groups in Australia, where voting is compulsory.

all residents are citizens of their host country. In most countries, the voting right is tied to citizenship. Thus, foreign nationals are often not eligible to vote, at least in national elections. Due to data limitations, we rely on population shares that are based on residence instead of citizenship. This procedure does not affect our empirical results as long as the age structure of natives and foreign nationals is identical. In practice, however, foreign nationals tend to be younger than the native population. We calculated elderly shares for the native population versus the total resident population based on UN-data for the years 1990, 2000 and 2010. The differences are small on average for our sample countries (less than 1 percentage point)[7]. Moreover, the change of the elderly share (from 1990 to 2010) of the total resident population matches the change in the native population's elderly share quite well (correlation coefficient 0.98). All in all, the elderly share seems to be a reasonable proxy, even though it might slightly underestimates the "true" shift in elderly voter power.

In addition, we include country fixed effects a_i to capture country-specific factors that are rather stable over time, e.g., geography and the political system. As common in the applied cointegration literature (e.g. Herwartz and Theilen, 2014), we also add deterministic country-specific time trends to account for only imperfectly observable factors that change over time, e.g. the degree of privatization and private public partnerships, the price level of public investment as well as public investment returns. Including time trends is also in line with previous work on the determinants of public investment (Bacchiocchi et al., 2011; Mehrotra and Välilä, 2006).

The estimated relationship between population aging and public investment might be spurious if both variables are non-stationary and not cointegrated, because in this case the error term ε_{it} becomes non-stationary potentially resulting in distorted t-statistics that falsely indicate statistical significance (Entorf, 1997; Granger and Newbold, 1974; Phillips, 1986). If the public investment ratio and the elderly share by contrast are cointegrated (which means both variables are non-stationary but a linear combination of them is stationary) some favorable properties apply such as the robustness of panel cointegration estimators against omitted variables and reverse causation (Herzer et al., 2012). In addition, the parameter estimates of cointegration relationships are superconsistent and therefore converge faster to their true values (Stock, 1987).

3.2 Control variables and identification issues

The relationship between population aging and public investment might be driven by omitted variables. Theoretically, panel cointegration relationships can be estimated consistently, even though the explanatory variable is endogenous (Choi, 2006; Kao and Chiang, 2001). Hence, at least asymptotically, cointegration estimates should be more robust to omitted variables bias compared to regressions based on stationary variables. However, given our limited sample size, we augment the bivariate model by the following control variables: total population, the expected population in ten years, the debt-to-GDP ratio, the private investment-to-GDP ratio and real GDP per capita. We take the logarithm

[7] Switzerland stands out as an extreme case with a difference of around 3 percentage points. Excluding Switzerland does not alter our empirical results.

of all controls in order to estimate elasticities. Further information on the construction of the control variables and summary statistics can be found in appendix A. In the following, we rationalize the use of our control variables and discuss additional identification problems.

Population aging might be associated with public investment returns either via population size or the age composition. Unfortunately, returns to public investment are hard to measure and hence not available as a control variable. Nonetheless, we think diminishing returns following from population aging are only a minor problem for our analysis at least once some additional variables are included. In order to account for the nexus between population aging and the absolute population size linked through declining fertility rates, we include the current population as well as the expected population in ten years (constructed using old vintages of the UN population prospects) as control variables. In doing so, we avoid that our elderly share variable captures the declining demand for public investment which follows from population shrinkage (or slower population growth) associated with the demographic transition. Generally, we expect a higher demand for public investment as population grows. Our identification strategy, also hinges on the assumption that there is no strong direct effect of the population structure on public investment returns. In other words, we assume that reducing public investment ratios is not simply an optimal policy response to population aging from an overall welfare point of view. We believe this is a plausible assumption, at least once current and projected population is held constant, since population aging also increases the demand for hospitals, nursing homes or recreational activities.

The decline of public investment could in fact be caused by developments which are causally unrelated but correlated with population aging, e.g. due to a similar evolution over time. The three following alternative hypotheses qualify for a deeper analysis.

So far, fiscal pressure stands out as the most robust hypothesis for the decline of public investment, even though fiscal stress does not fully explain the ongoing decline of public investment from 1990 onwards. To make sure, that our results are not merely capturing the positive correlation between public debt and population aging, we include the public debt ratio as a control variable.

Fernald (1999) among others has argued that returns to public investment have decreased over time because of transportation infrastructure being a network. More intuitively, he claims that "building an interstate network might be very productive; building a second network may not" (p.621). Falling returns to public investment over time could explain the decline of government capital expenditures. However, whether returns have indeed fallen significantly is subject to debate. Not only transportation infrastructure but also transport itself has increased over time. Given that infrastructure is, at least to a certain degree, a rival public good due to congestion effects, increasing the network might still yield sizeable returns. In a recent metastudy, Melo et al. (2013) find returns to transportation infrastructure to be positive on average, whereas the estimates are higher for roads than for other transport modes. Moreover, Bom and Ligthart (2014) report even higher output elasticities for more recent studies, holding other study characteristics constant. Furthermore, the network argument is most relevant for transportation infrastructure which constitutes less than half of total public investment. Returns to public capital spending on education or health might have evolved very differently. Even if the returns are indeed decreasing, this should at least partly be captured by the country-specific time trend in our regression framework.

The decline in private investment-to-GDP ratios is another potential explanations for the decline in public investment rates, at least under the assumption that public and private investments are complementary. Empirically, private and public investment rates tend to move together (e.g. Haan et al., 1996) which supports the hypothesis that private investment (e.g. via privatization) has not substituted public investment. Hence, we also include the private investment ratio as a control. We also control for GDP per capita as a rough measure of average income which might affect the citizen's demand for public investment.

3.3 Data

In this study we use data for a panel of 19 OECD[8] countries for the period of 1971 to 2007 yielding more than 600 observations which is a common sample size for panel cointegration studies (e.g. Herzer et al., 2012; Mark and Sul, 2003; Schmidt and Vosen, 2013). We only consider democracies because political decision making differs from authoritarian societies. We also exclude the period after 2007 to avoid distortions resulting from the deep drop in GDP as well as massive fiscal stimulus packages following the financial crisis. Although the sample mean of public investment has increased substantially in 2009, it returned to pre-crisis levels in 2011. Therefore, we believe the period between 2008 and 2011 is exceptional.

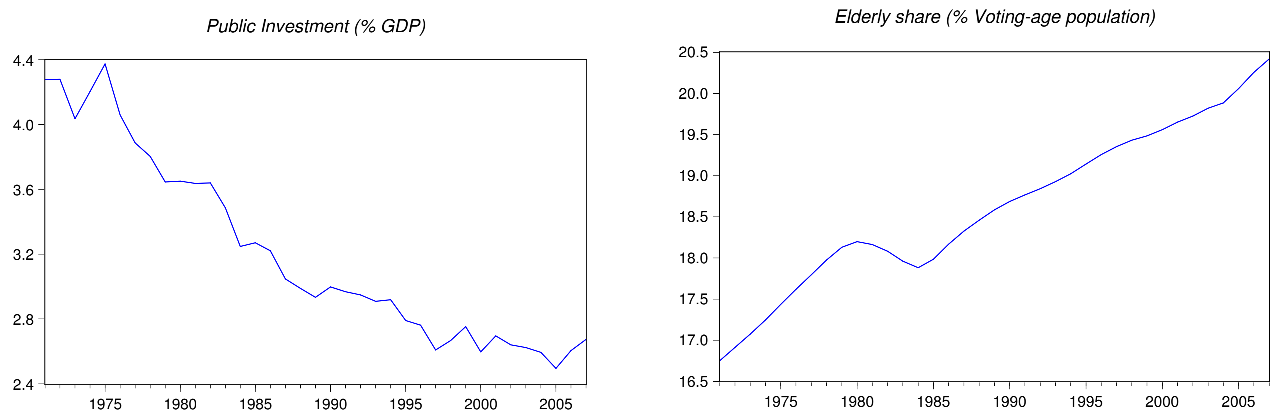
Data on gross fixed capital formation of the general government as well as on GDP stems from the AMECO database of the European Commission. Both variables are measured in nominal terms. According to the 1993 System of National Accounts (SNA 93), which is the relevant version for our sample, capital formation is defined as the net acquisition of assets such as equipment or buildings that are used in production for more than one year. Maintenance is classified as consumption unless it improves the performance, increases the capacity or prolongs the expected working lives of these assets. In contrast to the most recent SNA version from 2008, public investment spending in our study does not include expenditures on research and development as well as on military weapon systems. Public investment data for Australia, Iceland, New Zealand, Norway, Switzerland and the US in the SNA 93 version stems from the OECD. The aging variable has been constructed using OECD data, too.

Based on the intuition of the voter group decision model, we expect the public investment ratio to vary with the share of elderly people to the voting-age population. Figure 2 plots the average public investment-to-GDP ratio and the average elderly share for the 19 OECD countries in our sample. It clearly indicates a negative correlation. The country-specific figures, provided in the appendix (Figure A.1, Figure A.2), demonstrate that the opposing trends in public investment

[8] Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom, United States.

rates and elderly voting shares can be observed in almost every sample country. Summary statistics are presented in Table A.1 in the appendix.

Figure 2: **Cross-sectional average of main variables, 1971-2007**



The existing empirical evidence suggests that population aging and the composition of public spending are related. Specifically, aging has been shown to affect spending on education, health, social security and defense. This is important because public investment also includes spending on those items. Table 1 demonstrates that in the last year of our sample (2007), on average, one third of public capital formation was devoted to economic affairs which mainly includes transportation infrastructure. Theoretically, it is not obvious which age group benefits most from transportation infrastructure. In contrast, the 15.8 percent of public investment spent on education can be assumed to be less beneficial for the elderly (Harris et al., 2001; Inman, 1978; Poterba, 1997), whereas the 14.3 percent attributed to health, defense and social welfare expenditure has been shown to be favored by senior citizens (Sanz and Velázquez, 2007). Hence, the composition of public investment in 2007 does not clearly favor one specific age group. Data on investment for specific functions is not consistently available before 1995 for most sample countries with the exception of the US. However, the composition of public investment has remained more or less stable since then and can therefore be assumed to be rather constant. This argument is supported by the composition of public investment in the US which changed only modestly since 1970.

Table 1: **Public Investment by function, cross-sectional average, 2007**

Function	Investment share
Economic affairs	34.72%
Education	15.83%
General public services	9.94%
Housing and community amenities	8.22%
Recreation, culture and religion	7.49%
Health	7.01%
Environment protection	5.58%
Public order and safety	3.91%
Defense	3.71%
Social protection	3.58%

Sample except Australia, Canada, New Zealand. US data: Investment in "Environment protection" is included in "Housing and community amenities".

4 Empirical results

4.1 Time series properties

The public investment ratio as well as the elderly share tend to be non-stationary (see Appendix B for panel unit root test results). To avoid spurious regression results, we test for cointegration using the residual based test developed by Pedroni (2004, 1999). The idea of the Pedroni test is to estimate equation (2) and check whether the residuals $\widehat{\varepsilon}_{it}$ are stationary. Pedroni (2004, 1999) suggests several test-statistics. We employ Pedroni's panel cointegration test based on the panel ADF statistics, because it outperforms all other panel cointegration tests considered in Wagner and Hlouskova (2010). The Pedroni test indicates a cointegration relationship between the public investment ratio and the elderly share. Furthermore, the residuals also remain stationary if additional control variables are included.

Panel OLS estimates of cointegrated variables might result in distorted t-statistics and suffer from a non-negligible bias in small samples (Kao et al., 1999; Kao and Chiang, 2001). Hence, we estimate (2) using the pooled D-OLS estimator developed by Kao and Chiang (2001) and Mark and Sul (2003), which has been shown to outperform OLS. In order to estimate D-OLS, we augment equation (2) by elderly shares in first differences as well as leads and lags of elderly shares in first differences. We include the same dynamics for our control variables. To keep comparisons valid and preserve degrees of freedom, we use one lead and one lag for all D-OLS specifications. In order to mitigate the problem of cross-sectional dependence, we generally estimate our regressions with cross-sectionally demeaned data.

Moreover, we have estimated the model in first differences, using simple OLS, to account for the possibility of flawed cointegration test results. In this case, our results might be in fact spurious. Given that most of our variables are likely to be integrated of order 1 (see Appendix B), estimating everything in first differences eliminates this spurious regression problem. However, first differencing comes at the cost of ignoring a potential long-run relationship which potentially biases the results if the variables are indeed cointegrated. We include country and year fixed effects to reduce omitted variable bias as well as cross-sectional dependence.

4.2 Regression results

In line with our theoretical argument, we find a negative and significant effect of the elderly share on the public investment ratio in all D-OLS specifications. As demonstrated in Table 2 the estimated coefficients suggest that a 1% increase in the elderly share is associated with an average decrease in the public investment ratio between 0.88% and 1.74%. To illustrate the magnitude of these coefficients, we exploit the evolution of sample means over time. During our period of investigation, the mean of the elderly share rose by 22%. At the same time, the cross-sectional average of the public investment as a ratio to GDP decreased by 37%. Based on a coefficient of -1, population aging would explain more than half of the decline in the sample mean of the public investment ratio. This implies a sizeable effect of aging[9].

The results presented in column 3 of Table 2 illustrate that β is indeed relatively unaffected by the inclusion of additional control variables. The results for the D-OLS estimation are very similar to the bivariate case. β has a similar size and remains significant at the 5% significance level. The coefficients of most control variables have the expected signs (except for the population variable) but are not statistically significant. Only real GDP per capita variable seems to have a statistically significant effect on public investment. In line with Wagener's Law, the demand for public investment tends to increase with income.

The pooled D-OLS estimate of the elderly share coefficient reported in table 2, lies in between the estimates obtained by the mean-group equivalent of the D-OLS estimator introduced by Pedroni (2001a, 2001b) and the pooled fully modified OLS (FMOLS) estimator developed by Phillips and Moon (1999) (results see Appendix C). However, in the specifications with additional variables, the elderly share coefficient, is only significant at the 10% level. We also included the real long-term interest rate on government bonds along with the other control variables as an additional robustness check. Since, in this case, we lose many observation we do consider the results less reliable. Nonetheless, the elderly share coefficient remains significant at the 10% level while the size of the coefficient even increases.

Even if all control variables are included, the time trend remains significant for a range of countries. The public investment ratio is declining over time, relative to the rest of the sample, in 5 countries (Australia, France, Iceland, Norway,

[9]To check whether the "oldest old" are more favorable to investment spending, because they are more altruistic towards future generations (for instance because the female share is higher, see Krieger and Ruhose (2013)), we have split the elderly share into two components (individuals 65-80 and individuals 80+) and included both in the regression. We find a negative coefficient for both age groups. However, the coefficient for the 80+ share is generally smaller. Given that the share of people 80+ to total voting population on average doubled within the sample period, however, even a small coefficient implies an economically significant effect.

UK) as indicated by a negative time trend. In contrast, 6 countries (Canada, Germany, Ireland, Italy, Netherlands, Sweden) exhibit positive time trends and hence have significantly outperformed the remaining sample in terms of public investment ratios over time, at least holding their economic fundamentals constant. Potential explanations are multifold, including different stances toward privatization or varying public investment prices. An in depth analysis of the country-specific trends is beyond the scope of this text.

Column 4 of Table 2, presents the first-difference OLS regression results. The effect of the elderly share on the public investment ratio is smaller than in the previous specifications. However, the coefficient remains negative and is at least significant at the 10% significance level. Since the coefficients in column 4 rather pick up short-run relationships, the magnitude of the elderly share coefficient is still consistent with the estimates in column 1-3, under the assumption that the full effect of growing elderly voter power unfolds slowly over time – a plausible supposition, given the duration of election cycles. Similarly as in column 3, the majority of the control variables are not significant. The coefficient on GDP per capita remains positive and significant but almost halved. In contrast to the D-OLS estimates the population variable exhibits a positive and significant coefficient which is in line with the hypothesis that population growth increases the demand for public investment.

Table 2: **Estimation results**

Explanatory variables	D-OLS (1)	D-OLS (2)	D-OLS (3)	First-differences OLS (4)
Elderly share	-1.51** (-4.02)	-1.74** (-4.42)	-1.33* (-2.58)	-0.88 (-1.67)
Population			-0.36 (-0.27)	5.06** (3.73)
Expected population			0.10 (0.24)	-0.14 (-0.88)
Debt-to-GDP			-0.01 (-0.18)	0.01 (0.12)
Private investment ratio			0.21 (1.06)	-0.16 (-1.95)
Real GDP per capita			1.05** (2.81)	0.55* (2.18)
Country fixed effects	Yes	Yes	Yes	Yes
Country specific time trends	Yes	Yes	Yes	No
Year fixed effects	No	No	No	Yes
Variables cross-sectionally demeanded	No	Yes	Yes	No
Pedroni panel ADF t-statistic	-3.99**	-4.38**	-4.18**	.
N	646	646	597	657

Note: The dependent variable is the public investment ratio. All variables in logs. t-statistics in parentheses. D-OLS Estimation includes one lead and one lag . D-OLS covariance estimated using the sandwich estimator allowing for heterogeneous variances. OLS standard errors estimated using Huber/White sandwich estimator. Lags for the Pedroni tests have been selected using the Schwartz criterion starting from 5 lags. ** (*) Indicates significance at the 1% (5%) level.

4.3 Long-run Granger causality

So far we have assumed that causality runs from population aging to public investment. However, our previous results only indicate a long-run relationship between two variables with no information on the direction of causality. Therefore, we employ an error correction model (ECM) to test the response of each variable to a deviation from the long-run equilibrium. Given that the inclusion of control variables does not alter the estimated relationship between the public investment ratio and the elderly share considerably, we focus again on the bivariate relationship. As standard in the literature we measure the deviation by the residual:

$$\widehat{\varepsilon}_{it} = ln(public\ investment\ ratio)_{it} - \widehat{a}_i - \widehat{b}_i trend - \widehat{\beta}\, ln(elderly\ share)_{it}$$

obtained from the bivariate cointegration regression. In order to test for long-run Granger causality we estimate the following two equations and examine the significance of α_1 and α_2 using a t-test, respectively. The lagged first differences of *public investment* and *elderly voter shares* account for potential short-run effects.

$$\triangle\, ln(public\ investment\ ratio)_{it} = c_{1i} + \alpha_1 \widehat{\varepsilon}_{it-1} + \sum_{j=1}^{5} \delta_{11} \triangle\, ln(public\ investment\ ratio)_{it-j} + \sum_{j=1}^{5} \delta_{21} \triangle\, ln(elderly\ share)_{it-j} + u_{1it} \tag{3}$$

$$\triangle\, ln(elderly\ share)_{it} = c_{2i} + \alpha_2 \widehat{\varepsilon}_{it-1} + \sum_{j=1}^{5} \delta_{12} \triangle\, ln(public\ investment\ ratio)_{it-j} + \sum_{j=1}^{5} \delta_{22} \triangle\, ln(elderly\ share)_{it-j} + u_{2it} \tag{4}$$

A significant α_1 would suggests long-run Granger causality running from the *elderly voter share* to *public investment*, while a significant α_2 signals long-run causality from *public investment* to the *elderly voter share* (e.g. Herzer et al., 2012). Granger causality is not restricted to be unidirectional, in fact, both variables might be actually endogenous. Since all variables in the model are stationary we can estimate (3) and (4) using OLS. Following common practice, we start from a general model with 5-lags and successively eliminate insignificant short-run dynamics (e.g. Herzer et al., 2012), though the main results do not depend on the lag length. Table 3 shows that α_1 but not α_2 is statistically significant from zero suggesting that long-run Granger causality exclusively runs from the elderly share to the public investment ratio, and not vice versa, supporting the argument that population aging has contributed to the decline in public investment. The same is true for short run Granger causality ($\delta_{12}$and δ_{21}). However, the overall short run effect (sum of the short-run coefficients δ_{12}) of the elderly share on the public investment ratio is positive but not statistically significant.

Table 3: **Error correction model**

	Dependent variable: Public Investment	Dependent variable: Elderly Share
	α_1	α_2
Pooled D-OLS residuals	-0.28** (-8.86)	-0.00 (-0.41)
Short-run Granger causality	δ_{12}	δ_{21}
Granger causality	34.71**	2.81
Effect	+	+

Note: Insignificant short-run dynamics have been removed based on their t-value starting from 5 lags until all lagged differences are significant at the 10% level. Pooled D-OLS residuals: t-statistics in parentheses. Short-run Granger causality: chi-square statistic (Wald Test) of all significant lags. Effect: Sign of the sum of all significant coefficients. ** (*) Indicates significance at the 1% (5%) level.

5 Conclusion

The share of public investment declined almost steadily in most advanced economies since the seventies. The prevalent explanation for the cut-back in government financed investment centers on fiscal pressures caused by a rising level of public debt. Due to strong opposition against spending cuts for public consumption, governments consolidate by reducing public investment. In this paper, we suggest an additional explanation for the declining investment share. Based on a voter group decision model developed by Craig and Inman (1986), we argue that the ongoing demographic transition has contributed to the decline in public investment ratios. Experimental research reveals that senior individuals value future payoffs less than working-age people. Therefore, a raising fraction of elderly people is likely to cause a reduction in the overall demand for durable public goods and hence public investment.

We demonstrate for a panel of 19 OECD countries between 1971 and 2007 that the share of elderly people and public investment rates are indeed cointegrated and negatively correlated. This relationship is not driven by confounding variables such as public debt, expectations about future population size or the evolution of private investment. Moreover, long-run Granger causality exclusively runs from aging to investment. Thus, our results suggest that public investment tends to decline in greying societies, even though returns to public capital are considerably positive, simply because the aging electorate does demand less and less investment spending. This finding is in line with previous empirical evidence on the negative impact of population aging on educational expenditures (Harris et al., 2001; Poterba, 1997). Hence, the economic consequences of ongoing demographic change might be even less favorable than previously anticipated.

To alleviate the growing opposition to public investment spending, decision-makers may engage in policies that affect the intergenerational distribution of voting power. Strategies could include the introduction of demeny voting or measures that aim to increase the relatively low voter turnout of working-age people, e.g. through a compulsory voting system. However, these policies will only be effective in the short-run, if at all, given that senior voting power will keep increasing over the long-run based on the underlying demographic trends. Alternatively, public investment projects could be made less "painful" for senior voters, e.g., by financing them via Public Private Partnerships or long-term government bonds, hence, shifting the financial burden into the future, ideally to a time when the benefits occur. From this point of view, a move towards a system relying more heavily on user fees, where feasible, might help to sustain a higher level of public investment. These proposals are no call for an unsustainable accumulation of direct or indirect public debt, though.

Delaying the retirement age might be the most promising strategy to increase public investment ratios because it would also help to stabilize Pay-as-you-go pension systems and boost economic growth by increasing labor supply. Simulations based on an two period OLG-model by Gonzalez-Eiras and Niepelt (2012) show that pension expenditures will increasingly crowd-out public investment as long as the retirement age is not postponed. Moreover, under the assumption that retirement itself affects time preferences, as indicated by the results of Harrison et al. (2002), a higher pension age also enhances the future orientation of the society.

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A Variable information and summary statistics

Population and private investment data stems from the OECD, debt-to-GDP ratios and real long term interest rates on government debt are obtained from Mauro et al. (2013) and information on GDP comes from the AMECO database. We deflate GDP using the GDP deflator provided by the AMECO database. For the debt-to-GDP and real interest ratio some observations are missing. To construct the expected population in ten years, we utilize historic UN-population projections, which are a widely used data source. Specially, we have obtained forecasts from 8 UN-projections (Year of publication: 1973, 1977, 1980, 1985, 1989, 1993, 1999, 2003) so that population expectations are updated every 5 years.

Figure A.1: **Public investment (% GDP), 1971-2007**

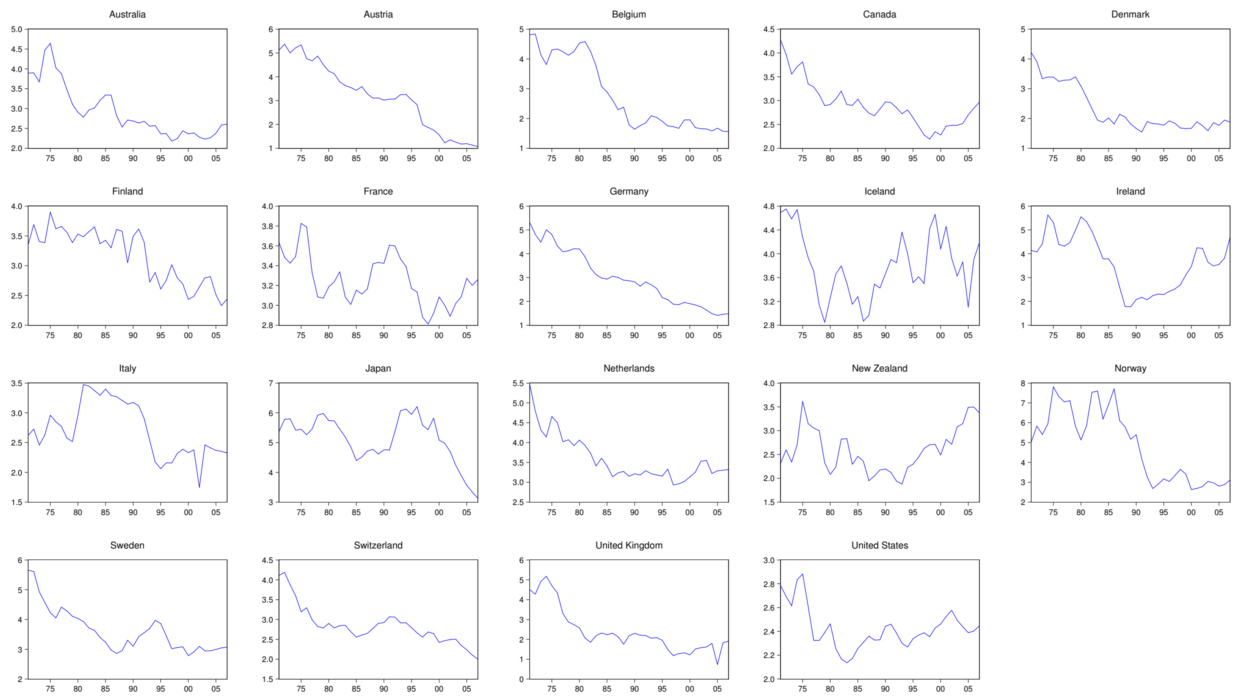
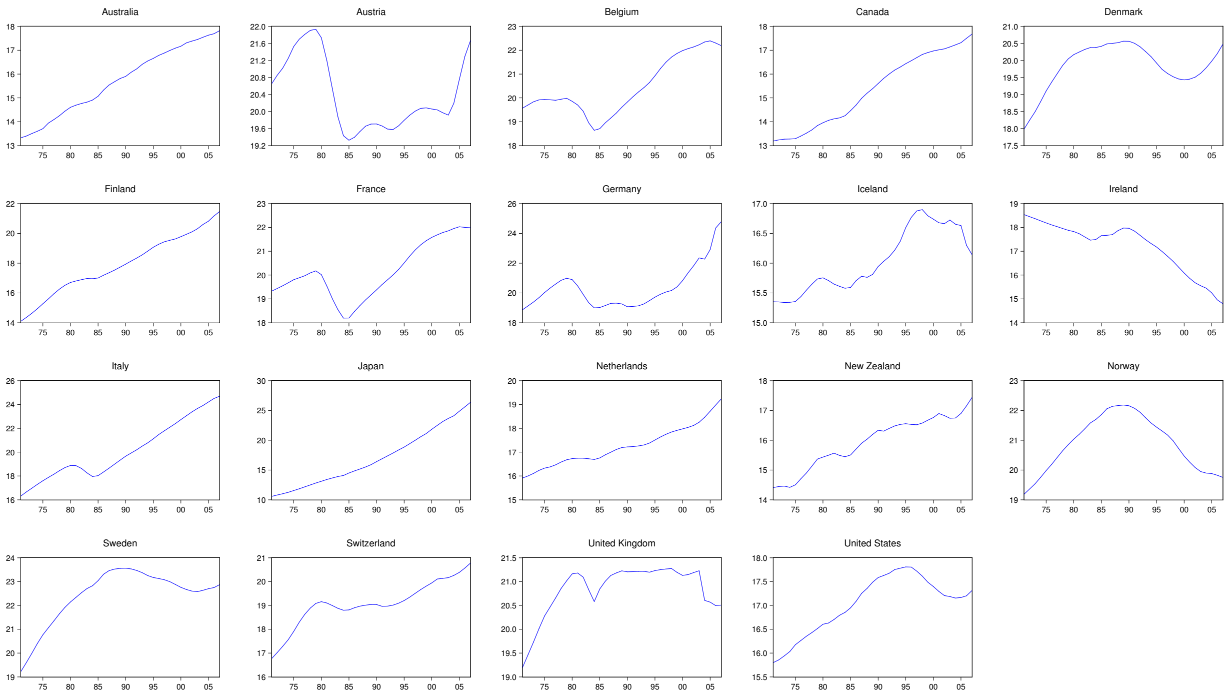


Figure A.2: **Elderly share (% Voting Population), 1971-2007**



B Panel unit root tests

In order to achieve robust results and taking the relatively low power of unit root tests into account, we analyze the time series properties of the public investment ratio and the elderly share as well as of our main control variables by employing the following three slightly different "first generation" panel unit root tests (PURTs): the LLC-PURT proposed by Levin et al. (2002), the IPS-PURT suggested by Im et al. (2003) and the Fisher-augmented Dickey Fuller-PURT (Fisher-ADF) following Maddala and Wu (1999). All employed tests are derived from augmented Dickey Fuller regressions, thus a rejection of the null hypothesis suggests stationarity at least for a fraction of the panel. We choose these type of tests, because they generally outperform panel stationary tests Hlouskova and Wagner (2006).

However, first generation PURTs may be misleading under cross-sectional dependence. We address this issue by subtracting cross-sectional averages for each observation, a procedure suggested by Levin et al. (2002) and often

Table A.1: **Summary Statistics**

Country	Public investment		Elderly share		Population		Expected Population		Public Debt		Private investment		GDP per capita		Real interest rate	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Australia	2.93	0.66	15.70	1.43	16.81	2.36	18.82	2.10	21.81	5.86	22.63	1.87	22.08	4.69	3.09	3.56
Austria	3.18	1.38	20.40	0.84	7.78	0.25	7.84	0.30	48.49	18.72	21.12	1.36	22.14	5.15	3.51	1.54
Belgium	2.78	1.20	20.46	1.19	10.03	0.25	10.22	0.19	95.39	34.26	18.31	1.94	21.96	4.61	3.61	2.64
Canada	2.92	0.48	15.32	1.53	27.33	3.33	29.99	3.04	70.12	18.26	18.13	1.59	21.45	4.05	3.65	2.57
Denmark	2.30	0.76	19.84	0.67	5.19	0.13	5.28	0.12	42.39	22.79	18.12	1.94	29.38	5.97	4.64	2.34
Finland	3.16	0.45	17.88	2.00	4.97	0.20	5.06	0.17	26.78	19.33	20.39	4.06	21.14	5.31	2.72	4.02
France	3.26	0.25	20.44	1.22	57.93	3.14	58.54	2.34	39.87	18.19	16.78	1.91	21.52	3.97	3.05	2.57
Germany*	2.97	1.15	20.17	1.51	79.49	2.27	80.14	2.97	44.38	15.69	18.85	1.63	21.54	4.31	3.82	1.27
Iceland	3.80	0.54	16.03	0.53	0.25	0.03	0.28	0.02	33.90	13.17	20.01	5.18	31.35	7.13	.	.
Ireland	3.62	1.14	17.20	1.06	3.58	0.33	3.82	0.35	58.79	22.66	17.92	3.05	20.69	10.26	2.68	3.44
Italy	2.71	0.46	19.36	3.28	56.29	1.29	57.79	1.44	86.62	25.59	19.51	2.13	19.42	4.09	2.19	4.21
Japan	5.12	0.78	16.96	4.72	121.05	6.54	125.93	3.46	85.77	52.72	23.45	3.38	22.13	5.60	1.86	3.42
Netherlands	3.59	0.58	17.25	0.84	14.90	0.97	15.59	0.81	57.70	14.16	18.13	1.59	23.76	5.02	3.25	2.30
New Zealand	2.60	0.47	15.93	0.87	3.48	0.39	3.82	0.24	47.78	15.17	19.64	2.47	17.26	2.47	1.78	4.60
Norway	4.84	1.80	20.88	0.93	4.26	0.22	4.45	0.19	38.87	10.10	19.74	3.89	37.02	10.45	2.92	3.06
Sweden	3.62	0.74	22.42	1.15	8.56	0.32	8.71	0.36	55.49	18.94	15.83	2.13	24.39	4.82	3.08	2.79
Switzerland	2.84	0.48	19.08	0.93	6.76	0.43	6.90	0.51	47.85	11.64	22.71	3.21	36.15	3.84	1.28	1.68
United Kingdom	2.40	1.13	20.92	0.56	57.56	1.50	58.83	1.94	49.07	5.92	16.06	1.23	21.20	5.65	2.67	3.19
United States	2.42	0.17	17.02	0.61	251.16	28.76	273.17	29.82	53.54	12.88	16.39	1.21	26.06	5.86	3.28	2.71

Public investment, public debt, private investment in % of GDP. GDP per capita in thousand 2005 Euro. Population and expected population in million. Real interest rate in percentage points.*German series have been linked using growth-rates of West Germany.

applied in empirical research (e.g. Canning and Pedroni, 2008; Schmidt and Vosen, 2013)[10]. Furthermore, we make use of the cross-sectionally augmented IPS-PURT (CIPS) developed by Pesaran (2007) which accounts for the potential cross-sectional dependence by adding cross-section averages to the ADF regressions. Since most variables seem to be heavily trending, we include a trend in the level equations.

The PURTs presented in Table B.1 suggest that public investment and the elderly share are both non-stationary in log-levels, but stationary in first differences. Moreover, most controls tend to be integrated of order 1 as well.

Table B.1: **Panel unit root tests**

Variables	Linear trend	Unadjusted data			Cross-sectionally demeaned data			
		LLC	IPS	Fisher ADF	CIPS	LLC	IPS	Fisher ADF
Log-Levels								
Elderly share	yes	-0.90	0.11	46.81	-1.77	-1.68*	1.46	33.55
Public investment ratio	yes	-0.41	-0.15	43.60	-2.67	-0.33	-0.44	47.23
Population	yes	-0.71	-0.18	61.37**	-2.37	0.55	1.73	39.56
Expected population	yes	-0.47	0.74	33.01	-2.28	0.79	-0.05	41.34
Debt-to-GDP	yes	4.06	5.53	18.58	1.14a	-0.14	1.24	40.35
Private investment ratio	yes	-0.77	-2.44**	61.94**	-2.60	-1.38	-2.15*	60.22*
Real GDP per capita	yes	-2.13*	-2.13*	54.88*	-1.73	-2.13*	-1.70*	55.23*
First differences								
Elderly share	no	-3.97**	-5.42**	99.25**	-1.72	-2.73**	-3.27**	68.26**
Public investment ratio	no	-20.33**	-19.16**	361.20**	-4.18**	-20.42**	-19.36**	364.33**
Population	no	-1.10	-4.11**	92.64**	-2.44**	-2.82**	-4.39**	87.02**
Expected population	no	-23.73**	-21.84**	418.40**	-3.72**	-19.75**	-20.04**	380.15**
Debt-to-GDP	no	-6.67**	-8.69**	148.55**	-4.94a**	-11.42**	-11.67**	207.43**
Private investment ratio	no	-13.19**	-13.22**	238.71**	-3.68**	-14.44**	-14.29**	258.61**
Real GDP per capita	no	-15.15**	-14.00**	252.36**	-3.26**	-14.94**	-14.21**	256.22**

Note: All variables in logs. All ADF regressions include a constant. Lags have been selected using the Schwartz criterion starting from 5 lags. 1 Lag used for the CIPS test. ** (*) Indicates significance at the 1% (5%) level. a= standardized Z~t-bar statistic (unbalanced panel).

[10] Other approaches proposed in the literature include the estimation of common factors using principle component analysis (Bai and Ng, 2004). Given that the precision based on few cross-sections (less than 20) is limited (Sul, 2009) we refrain from using PCA.

C Additional robustness checks

Table C.1: **Estimation results: Other estimators and real interest rate**

Explanatory variables	FM-OLS (pooled) (1)	D-OLS (grouped) (2)	OLS (3)	D-OLS (4)	First-differences OLS (5)
Elderly share	-0.52 (-1.72)	-2.64 (-1.89)	-0.54* (-2.21)	-3.29 (-1.77)	-0.96 (-1.67)
Population	2.53** (2.94)	-2.70 (-0.67)	3.47** (5.63)	1.93 (0.69)	5.15** (3.31)
Expected population	0.12 (0.39)	5.52** (4.43)	0.10 (0.43)	-2.77 (-1.44)	-0.25 (-1.70)
Debt-to-GDP	-0.08* (-2.04)	-0.08 (-0.53)	-0.08** (-3.33)	0.04 (0.13)	-0.04 (-0.56)
Private investment ratio	-0.08 (-0.88)	-0.56* (-2.10)	-0.10 (-1.42)	1.15 (1.42)	-0.36** (-3.13)
Real GDP per capita	1.03** (4.67)	0.02 (0.02)	0.96** (4.92)	1.13 (0.86)	0.81* (2.52)
Real interest rate				0.03 (0.31)	-0.01 (-1.38)
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Country specific time trends	Yes	Yes	Yes	Yes	No
Year fixed effects	No	No	No	No	Yes
Cross-sectionally demeanded	Yes	Yes	Yes	Yes	No
N	657	572	687	317	512

Note: The dependent variable is the public investment ratio. All variables in logs. t-statistics in parentheses. D-OLS Estimation includes one lead and one lag. D-OLS covariance estimated using the sandwich estimator allowing for heterogeneous variances. OLS standard errors estimated using Huber/White sandwich estimator. Lags for the Pedroni tests have been selected using the Schwartz criterion starting from 5 lags. ** (*) Indicates significance at the 1% (5%) level.