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MASTER OF SCIENCE IN

MONETARY AND FINANCIAL ECONOMICS

MASTERS FINAL WORK

DISSERTATION

POPULATION AGEING AND MONETARY POLICY

ANDREIA SOFIA BOANOVA VIEIRA PEREIRA

MARCH – 2016

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Master in Monetary and Financial Economics

Abstract

The ongoing demographic changes can affect the dynamic of economics in several ways, with implications for the conduct of monetary policy and price stability. This paper analyses the future prospects on demographic changes and how they are expected to influence the macroeconomic environment where monetary policy is conducted, which can directly or indirectly generate unwanted inflation dynamics. By adopting a polynomial technique, an estimation is carried out to determine the relationship between the age structure and inflation in a panel of 24 OECD countries over the 1961-2014 period. A significant correlation is found between demography and inflation, consistent with the hypothesis that an increase in the share of working-age population causes deflationary pressures, while a larger scale of dependents and young retirees are associated with higher inflation rates. The results suggest that the potential impact of the global ageing process on inflation should be taken into consideration in the decision making processes of monetary policy.

Keywords: ageing, monetary policy, inflation.

JEL classifications: J14, E52, E31.

ACKNOWLEDGMENTS

First of all, I would like to express my sincere gratitude to my supervisor Paula Cristina Albuquerque for suggesting this topic, for all the invaluable comments and for the commitment devoted throughout the process of drafting this master thesis. It has been a privilege.

Secondly, I would like to thank my family and especially my mother, who always blindly believed in me. This paper is dedicated to her.

My greatest thanks to my best friends João Neto, Isabel Tavares, Mafalda Pereira and Catarina Gusmão for their unconditional friendship and endless support. Also, to my friend Zé Augusto who has always encouraged me throughout all of these years.

I thank my fellow classmates André Silva, Cristina Stresna, João Lucas and Rita Pereira for always being available to help me with all my questions, for sharing the study rooms with me during the long and though days of study and too for all the fun we had in the last few years.

In addition, I take this opportunity to thank FinSolutia, in particular Simão Lopes and my dearest CRM colleagues Joana Alves and João Duque, for the remarkable inputs to my professional enhancement and also contributions to this master thesis.

I will be forever grateful for your love and outstanding support.

All errors are mine.

CONTENTS

1. INTRODUCTION

In the last decade, issues related to population ageing have played an important role in international debates and amongst the general public, in recognition of the social and economic impact of demographic transition. Although ageing is occurring at a faster pace in developed countries, it is arising in almost all of the countries in the world (2015 Revision of World Population Prospects[1]). This phenomenon results from the combination of two critical factors: longstanding decrease of the birth rate and increased life expectancy, which incrementally lead to a decline of children and an increase of mature adults and elderly people. As a result, ageing is reshaping the distribution of various age groups in populations across the globe.

In light of changing age structures of populations and their implications, long term projections have been made on demographic changes and their macroeconomic effects. These projections raised awareness on effects of ageing fuelling a variety of policy debates, particularly on the sustainability of public finances, the impact of ageing populations on the labour market and the effects on economic growth. Although theoretical and empirical work is still scant, analysis of issues pertaining to monetary policy have recently gained relevance.

In accordance with the existing literature on the subject, this paper aims to present the mechanisms by which ageing is expected to affect monetary policy and assess its impact on inflation, a key variable taken into account by central banks when setting policy rates.

In principle, the direction of monetary policy depends on whether inflation is above or below its target. And, for a central committed to do whatever is necessary to anchor inflation expectations at its target, whether or not ageing exerts pressures on prices should

[1] Official United Nations population estimates and projections that have been prepared by the Population Division of the Department of Economic and Social Affairs.

be irrelevant (Anderson et al. 2014). However, if demographic changes affect other target variables such as the level of potential output or the equilibrium real rate, any incorrect specification in other parts of the economy can lead to unwanted inflation dynamics (Yoon et al. 2014).

The potential impacts on monetary policy are manifold. On the one hand, effects of ageing appear to be highly relevant, on the other hand, the repercussion of these effects should occur in a gradual way and their magnitude is surrounded by uncertainty. Nonetheless, it is with absolute certainty a matter worthy of attention.

This paper is organized in sections, which description is as follows. Section 2 presents the theoretical framework and main related literature. A brief explanation is given on how demographics has evolved and what future projections reveal. Subsequently, an analysis of the effects of ageing on the economy is undertaken, including the variables that may take centre stage in monetary policy decisions, as well as the implications for the conduct of monetary policy. Finally, we present the channels through which inflation is expected to be affected by ageing and the results of similar works, relating age structure with inflation. Section 3 presents the empirical specifications, namely the data, variables and econometric approaches used. In section 4, an empirical analysis is conducted based on estimation methods of panel data, followed by brief discussion of the found results. Section 5 showcases all conclusions, with some final remarks.

2. LITERATURE REVIEW AND THEORETICAL BACKGROUND

2.1. EVOLUTION OF DEMOGRAPHIC PATTERNS

An ageing population raises a variety of challenges. It not only impacts the culture and embedded organization of a society, but it extensively impacts the economy. Before extending our analysis to the effects of ageing on economy as well as financial markets, a brief description is given on the prospects about future demographic patterns.

The decline of fertility rates with lower mortality rates and increasing life expectancy has been causing a shift in the size of the world population and also an ageing phenomenon of its composition. An important result deriving from this combination is the gradual transformation of the overall age structure, from pyramid to rectangle, characterized by a decline in the share of children and an increase in the share of mature adults and elderly people.

Furthermore, demographics is expected to deteriorate during baby boomers retirement. The baby boomers refer to the generation born after the World War II when rapid economic growth was accompanied by high fertility rates. It has a significant size in the United States, but also in Europe, New Zealand, Australia and Canada. Actually, several countries are already super-aged[2] even before their baby boomers retire, namely Germany (21%), Greece (21%), Italy (22%) or Japan (26%). In addition, in countries where fertility rates have been rapidly declining, working-age[3] populations will possibly be considerably diminished.

Based on the 2015 Revision of the World Population Prospects released by the United Nations, the proportion of young people (0-14) in more developed regions[4] is projected to remain approximately constant by 2050 at around 16%, whereas those aged 15-64 will become less representative, from 66% to 58%. Population aged 65 and over is expected to

[2] If more than 7% of a country's population is 65 years of age or older, the country is considered to be ageing. When it exceeds 14%, the country is referred to as aged. Countries are referred to as super-aged when they reach the additional threshold of 21%.

[3] The working-age population is defined as those aged 15 to 64, measured as a percentage of total population.

[4] The more developed regions comprise Northern America, Europe, Australia, New Zealand and Japan. The definition is as stipulated by the United Nations.

increase from 18% to 27% and the percentage of those who are aged 80 and over is expected to double, increasing from 5% to 10%. As a result of these trends, the old-age dependency ratio, i.e. ratio of people older than 64 to the working-age population of 15- 64, will increase from 26.7% to 45.8%. The demographic structure of developed countries is projected to substantially change due to the dynamics of fertility, life expectancy and migration rates.

2.2. MACROECONOMIC EFFECTS OF DEMOGRAPHIC CHANGES

The analysis of the economic consequences of ageing populations can be pivotal in exploring appropriate policy responses. Given their implications, several studies have been assessing the impact of ageing on the economy. As stated in Yoon et al. (2014), two approaches are commonly used. The standard approach assumes a stable age-specific behaviour with respect to the key macroeconomic variables, being useful for evaluating the accounting effects of demographic changes. The second approach, more complex, intends to obtain a richer analysis including also the responses induced by those changes. This section covers the theoretical discussion of the impact of ageing on five main macroeconomic variables with implications for monetary policy: economic growth, savings, investment, real interest rates, and external balances.

The impact of demographic changes on economic growth can be perceived using different frameworks. For instance, Maddaloni et al. (2006) suggest that the growth accounting procedure, by not depending on particular assumptions as regards technology and individuals' behaviour, may be appropriate at an early stage of research. Under this perspective, real GDP growth is decomposed into the rates of change of labour utilization, of labour productivity, and the ratio of the working-age population to total population.

Considering the projected increase in the proportion of people with higher ages and the decrease of younger's, economic growth is expected to decline due to the reduction in the labour force growth. The net effect on economic growth depends also on the growth rates of labour productivity and labour utilization. However, to maintain the potential output growth at the current level by 2050, significant improvements in productivity and labour utilization are required (Papademos 2007).

To improve labour utilization, several actions can be undertaken. One possible solution is to increase the number of workers, which can, for example, be achieved through larger inflows from unemployment or by encouraging groups that have low participation rates to make part of the labour market (Albuquerque 2015). Other possible solutions are to stipulate longer working hours or to delay the retirement age. Also, increased migration offers a potential avenue to increase labour market participation and employment. Nonetheless, limits to these measures exist, restricting the possible compensatory effects over time (Maddaloni et al. 2006).

Regarding productivity, two consequences of demographic changes should be mentioned. First, a decrease in the working-age population, ceteris paribus, increases the capital density and consequently the labour productivity, which has a positive effect on economic growth. Second, workers with different ages exhibit different productivity profiles and the direction of the overall productivity level will depend on the productivity performance associated with the age cohorts more abundant. There is some consensus that some abilities tend to decline with age (Verhaegen & Salthouse 1997) and that a higher share of workers aged over 55 exerts a negative impact on output per worker (Tang & MacLeod 2006). Improvements in health care and higher investment in education, may sustain higher productivity levels and thus higher economic growth. Hence, the negative demographic impact on economic growth can be partially offset by other factors, making difficult to predict its dimension with precision.

Ageing is recognised to have a predominant role on national saving behaviour, decomposed into government saving and private saving. As the population ages, public savings are expected to be lower as a result of higher pensions and health expenditures. That decline, should be more conspicuous in countries where the major financing resources are taxation and debt financing.

When assessing the impact on private savings, two opposite views are often considered. Kinugasa & Mason (2007) argue that longer retirement periods would lead to higher savings, which is possible since a scarcer labour force (relatively to capital) increases the marginal productivity of labour and the corresponding wages. Likewise, lower fertility rates permit a larger wealth accumulation during working life period (Schultz 2005). Conversely, the view based on the life-cycle theory (Ando & Modigliani 1963) assumes that individuals' habits of spending and saving vary over the course of a lifetime: initial dissaving in young, proceeded by saving for retirement and dissaving in retirement, indicating that ageing will reduce private savings.

Several empirical evidence give support to the life-cycle pattern. Masson et al. (1995) confirm that the expected increase in old population will generate significant downward pressure on the savings of most industrial countries. Higgins (1998) projected that the decline in the saving rates between 2010 and 2025 will be above the three percentage points (p.p.) for the OECD as a whole.

If we assume that ageing will lead to a decline in economic growth, investment needs might reduce directly (Turner et al. 1998). The investment level of an economy is mainly determined by the expected real return. Thus, as the growth rate of the labour force falls, the production process becomes more capital-intensive and, consequently, investment rates will decelerate to reflect the relative lower productivity of capital, and to accommodate a scarcer work force (Trichet 2007).

According to Carvalho et al. (2015), the impact of demographic transition on real interest rates can be perceived through three channels. Firstly, if the increase of life expectancy leads to precautionary saving, due to the anticipation of a longer retirement period, real interest rate is expected to fall. Secondly, assuming that labour force will possible shrink, the increase in the capital per worker reduces the marginal productivity of capital and hence the real interest rate. Finally, accordingly to life cycle theory, retirees save less than the middle aged groups. This causes upward pressures on real interest rate, if the effect of more people entering retirement offsets the effect of the decrease in younger generations.

Since both savings and investment are expected to decline, the response of the equilibrium real interest rate largely depends on what is the dominant effect. If investment declines faster than domestic savings, the real interest rate that clears the market is expected to fall. If savings were to decline faster, the real interest rate will rise.

The result of a few works accounting for both investment and savings effects, suggests that real interest rates will decline. Carvalho et al. (2015) exploits the role of demographics in the current low and declining real interest rate. They found that, between 1990 and 2014, real interest rate dropped from 4% to 2.5% due to the demographic transition. Moreover, a simulation exercise predicts an additional 50 basis points fall over the next forty years. Miles (2002) highlights that the equilibrium real interest rate will fall for about 30 years, before marginally rising.

Along with real interest rates, national savings and investment imbalances have also implications for external balances, which may be reflected by pressures in exchange rates and balance of payments positions. In accordance with Turner et al. (1998), OECD economies record current account surpluses around 2-3 % of GDP up to 2025. While savings are boosted by a high proportion of net savers, and the economic growth along with investment rates start to decline, the weight of OECD imports relatively to non-OECD countries will reduce. As a result, OECD countries increase their net foreign assets positions. When the demographic transition towards a greyer society is completed (around 2040), the reversal in the trade balance may arise as a complement of the ageing process (Ewijk & Volkerink 2011). The deterioration in the trade balance is the net result of two effects: on the supply side, output growth is restrained by the decline in working-age population and, on the demand side, accumulated and repatriated savings keep up consumption. An increase in domestic prices may arise, leading to a higher real exchange rate.

The magnitude of the aforementioned effects depends on the openness degree of economies as the negative impact for a country can be partially offset by a benign outlook for other countries, namely through international factors mobility.

Assuming that a higher productivity of labour results in higher wages, countries where ageing is more acute can benefit from migration flows from countries with younger populations. However, there exist some legal restrictions to labour mobility, making difficult to gauge significant effects. Analogously, capital outflows to countries with higher rates of return could moderate the expected decline on real interest rates, caused by a shortfall of domestic investment.

2.3. IMPLICATIONS FOR THE CONDUCT OF MONETARY POLICY

Implications for the conduct of monetary policy arise because ageing influences three key aspects: the functioning of the real economy changing the equilibrium values of macroeconomic variables and their responses to policy shocks, the structure of financial markets leading to sources of financial instability, and the monetary transmission mechanism compromising the effectiveness of monetary policy.

Due to the gradual nature of demographic changes, the potential impact on monetary policy should be modest. Actually, it is likely that fiscal and structural policies will be in the forefront to tackle any adverse effects. Yet, in the absence of policy responses, central banks may face some challenges pursuing the main goals of monetary policy: promote sustained economic growth, maintain price stability, and safeguard the stability of financial markets.

Although monetary policy cannot directly contribute to the raise of long term growth, it can foster sustainable growth by promoting price stability. Notwithstanding, even if the price stability is not affected by ageing, monetary policy will be less effective in stabilizing output around its target. The monetary policy effectiveness depends on what causes the economic slowdown, but it may be more effective if the problems are perceived as short-lived (Papademos 2003). Considering ageing as an enduring process, economic growth along with living standards are likely to fall.

Savings are assumed to be the main transmission mechanism of the age effects into monetary policy (Lindh & Malmberg 2000). Foremost, changes in the saving rates induced by age structure influence aggregate demand and the price level, posing some threats to price stability. The well-known life-cycle theory suggests that individuals have different saving and investment preferences, leading financial markets to be affected by the demographic shift. Also, changes in saving and investment rates are expected to bring about adjustments in interest and exchange rates.

In relation to real interest rate, if the downward trend persists, central banks may be compelled to reconsider their inflation targets. As the equilibrium real interest rate approaches the zero bound, with a target inflation rate anchored for example at 2%, the response of central banks to contractionary shocks will become quite limited. Thus, a possible solution might be the raise of the target inflation rate.

The impact on exchange rates will depend on to which extent the international mobility of factors can mitigate the ageing process but, aside from interest rates and inflation, the exchange rate is one of the most important determinants of a country's economic performance.

As a consequence of the demographic transition, a more aggressive reaction function may be required to overcome deflationary or inflationary pressures and to maintain the economic growth.

The threats to financial stability can be inferred through the changes that may occur in the structure and development of financial markets, driven by the effects of ageing on households' portfolio allocation and asset prices, and its interaction with pension systems.

As mentioned previously, the increase of the elderly is expected to bring a change in saving behaviour, which may have an impact on the demand for almost all classes of assets. For instance, if older people are more risk averse, demand for fixed income assets such as bonds should increase relatively to riskier options.

Empirical evidence suggests that household portfolio allocation across asset types, in fact, vary with age. Bergantino (1998) argues that there is a divergence in stock and bond holdings for older individuals, i.e. the ownership of stocks tends to decrease faster than for bonds due to risk aversion. Bakshi & Chen (1994) support the idea of life-cycle risk aversion hypothesis, by finding that the average age of the population has a positive effect on the equity risk premium. Consequently, the demand for bonds is predicted to increase driving the price of riskless assets up (Brooks 2000).

The foundation of a connection between demographics and asset prices is also in the life-cycle hypothesis, which theorizes that the middle age cohorts (40-64) are involved in assets accumulation, while those over 65 start the decumulation of their wealth to support consumption in retirement. The main motivation for work in this area has been the sharp rise in stock market in the 1990s, coincident with the period in which baby boomers entered into the saving age. Hence, naturally emerges from this argument the aftereffect of falling asset prices when the baby boomers reach the retirement years (Davis & Li 2003). Nonetheless, the asset prices decline goes beyond the stock market. Tákats (2010) confirms that the impact of ageing populations extends to houses prices, but an asset price collapse as predicted in Mankiw & Weil (1989) is not foreseen.

Aside from the issues of asset allocations decisions, which can entail financial instability in terms of volatility of asset prices, the interaction of the ageing process with pension funds also poses additional challenges for central banks. In line with Davis (2005), the possible effects on financial stability can be drawn for countries where the pay-as-you-go (PAYG) remains dominant as well as where funding is inducted.

In the case of no-reform, where the PAYG is the prevailing system, the uncertainty about the pension system will lead to precautionary saving. Along with the expected increase for the next few years, high saving rates may lead banks to underprice risks and generate a financial bubble. In addition, if economic agents face high and distortionary taxes, credit losses are expected to occur as well as falls in asset prices unanticipated by lenders, due to adverse economic conditions. This may entail a fiscal-solvency crisis particularly in the case of governments using bond finance, where a rise in long term interest rates and loss of credit rating are to be expected.

On the other hand, the increasing importance of pension funds is likely to bring about new saving forms, leading to a shift in financial systems from a bank and loan basis to a securitized and institutional investor basis (Davis 1999 [as cited in Davis 2005]). The securitized financial systems exhibit several stabilizing features, since there are broader opportunities to diversify risks. However, the underlying disintermediation process increases competition and banks may be willing to take higher risks to avoid profitability losses. Extra challenges to central banks may arise in terms of adaptation of macro prudential analysis and response to crises.

The transmission mechanism of monetary policy is the process through which decisions taken by central banks affect the economy, and in particular the price level. The effects of ageing on the conduct of monetary policy depend on how younger and older cohorts are affected by those decisions through the different channels, thereby making monetary policy more or less effective. Following Imam (2015), we present some arguments behind the rationale that in an old society some channels would become relatively more important than others.

In principle, we expect young households to be more sensitive to interest rate changes since they are mostly debtors. Thus, assuming no other channels than the interest rate channel, monetary policy easily smooths consumption through changes in interest rates in a relatively young society.

The credit channel amplifies the interest rate channel by also impacting the risk premium of borrowing, which is inversely related to the borrowers' net worth. Older households might hold a large level of collateral, facing for this reason a lower cost of funding. Additionally, a larger net worth provides the means to finance consumption or investment, as an alternative to bank credit. This implies that the lower is the proportion of the population that is credit constrained, the lower is the sensitivity to monetary policy through this channel. Because credit constraints are likely to be more common amongst the young, in an old society the monetary policy will become less effective (Miles 2002).

Since elderly hold much of the stock of assets, following an unanticipated and permanent increase in interest rate that has a substantial impact on asset values, the negative impact on consumption is larger in a relatively old economy. Furthermore, if ageing leads to changes in pension systems, which increases the stock of financial assets, the expected effect should be bigger (Miles 2002). Therefore, the demographic shift tend to emphasize the increasing importance of the wealth channel and make monetary policy more effective.

As a higher inflation rate erodes the value of the wealth held by elderly, the risk aversion to inflation increases with age. The more sensitiveness of older adults to inflation lead the expectations channel to become relatively more important. However, the expectations channel should not be impacted as much by the demographic transition as it depends on the credibility of central bank that may remain unchanged (Imam 2015).

In order to conclude, we should mention that monetary policy decisions can also affect the economy through the exchange rate channel. The impact of ageing on current account balances and the consequences to exchange rates will largely depend on the relative declines in savings and investment. Since there is no consensus in the literature about this, the effect on this channel is said to be ambiguous.

Going beyond the importance of each channel, Imam (2015) confirms a weakening in monetary policy effectiveness with regards to inflation and unemployment. It was found that an increase in the old-age dependency ratio by 1 p.p is expected to lower the cumulative impact of a monetary policy shock on inflation by 0.1 p.p. and by 0.35 p.p. on unemployment. Also, the corresponding maximum impacts of monetary policy are lowered by 0.01 p.p. and 0.02 p.p., respectively.

2.4. AGEING AND PRICE STABILITY

Given the recognition of the benefits of price stability, as well as the advantages of controlling inflation relatively to GDP, many central banks believe that by maintaining price stability, monetary policy will make a broader contribution to the general welfare. Since monetary policy decisions require a comprehensive analysis of the risks to price stability, the former macro projections suggest that the impact of ageing should be, at least, included in its economic analysis.

To support the policy debate about the challenges that ageing can pose to price stability, few studies, mainly motivated by the experience of Japan, tried to find if there is a link between demography and inflation. Although it is not yet clear whether aging leads to deflationary or inflationary pressures, on the theoretical side there are some channels identified through which demographics can affect inflation, as reported by Anderson et al. (2014).

An almost certain effect from ageing is a shrinking in labour force, which may lead to changes in factor prices. While the productivity of labour is expected to increase resulting in higher real wages, the productivity of capital and the expected real return on new investments will in turn decrease. That change, but in particular the increase on real wages, affects wealth and thereby consumer behaviour leading aggregate demand to increase. Inflationary pressures may arise if aggregate supply adjusts in a sluggish manner. In addition, elderly's consumption preferences are quite different from those of the young, resulting in a demand shift from the manufacturing sector towards non-manufacturing sector (mainly services). Again, whether this shift affect inflation depends on how supply reacts. We should also notice that, if the productivity of the non-manufacturing sector is lower than the productivity of manufacturing sector, the aggregate demand shift reduces the total productivity growth (Katagiri 2012) causing further declines on output growth.

The change on private saving behaviour induces two movements on inflation dynamics in opposite directions. If as predicted by life-cycle theory, a higher fraction of elderly exerts downward pressures on savings, we would expect aggregate demand to be supported by retirees dissaving leading to inflationary pressures. On the other hand, the decline on savings may as well culminate on exchange rate appreciation and thus deflationary pressures.

Many advanced economies may observe higher government spending and lower tax contributions due to ageing. This fact, when combined with high debt levels, increases the risk premium and the need of fiscal consolidations. In order to stabilise their debt-to-GDP ratio, governments must be compelled to reining in spending which normally results in lower growth rates. If output growth is below its potential, then we have deflationary pressures. Nonetheless, unsustainable debt levels increases the chances of debt monetization and creates expectations of high inflation.

Besides economic factors, also different preferences about inflation can lead to changes in policy objectives. Central banks concerned with the redistribution of resources may opt for a relatively low inflation rate to ensure that the real value of savings and pension entitlements is maintained, preventing pensioners from an arbitrary distribution of income and wealth. Bullard et al. (2012) put emphasis on the ability of a relative ageing society to influence the intergenerational distribution in the economy. Since older cohorts work less or none, they would prefer higher rates from their savings and low inflation rates, given their creditor status. When the old have more influence over redistributive policy, the economy faces a lower level of capital, higher real rate of return and a lower rate of inflation.

On the empirical side, as noted by Aksoy et al. (2015), the main headwinds come from the difficulty in distinguishing changes in demographic structure from other low frequency phenomena and modelling age groups since they are highly collinear.

Reading the available empirical work, assessing the impact of ageing on inflation, the conclusions are not unanimous and seem to be sensitive to the measure of the age structure considered. While Yoon et al. (2014) opting for an aggregate measure, conclude that ageing will pose substantial deflationary pressures, Lindh & Malmberg (2000) and

Juselius & Takáts (2015) regress inflation on several age shares and found that ageing is inflationary. The methodologies and the main results are summarized as follows:

Yoon et al. (2014) investigate the impact of population dynamics on inflation using data of 30 OECD countries in the period 1960-2013. Demographic variables, summarized by the share of the 65 and over, share of 15-64 and population growth, are estimated through a fixed effects model, along with other relevant control variables: GDP growth, terms of trade change, M2 growth, and budget balance change. The results suggest that the share of elderly have a significant negative impact on inflation. The paper also reveals the individual results generated from the data on Japan. In stark contrast to the OECD sample, population growth is highly significant. Moreover, the effect of population growth is stronger than the effect from population shares.

Lindh & Malmberg (2000) estimate the relation between inflation and age structure. For 20 OECD countries, ranging from 1960-1994, inflation rates are regressed on the logarithms of five age shares (aggregated age groups that captures the most important phases of an individual's economic life cycle), also controlling for inflation expectations. Despite have been used four different estimation methods, the results are quite similar among them. Young adults (15-29) and young retirees (65-74) have a positive effect on inflation, while mature adults (30-49), middle-aged (50-64), and old people (over 75) exert deflationary pressures. A fairly mentioned point is the forecasting features of age distribution variables, since they are considerably exogenous to inflation and can be predicted with good precision. The projections made up to 2010 catch the downward inflation trend in OECD. The authors suggest that, as baby boomers begun to retire, inflation pressures will be similar to those in the 1970s.

Juselius & Takáts (2015) find a stable and significant correlation between demography and low-frequency inflation. The paper also considers OECD countries, more specifically 22 advanced economies, over the 1955-2010 period. The first model specifications, regress inflation on the total dependency ratio and population shares. It evolves to a finer age distribution in order to allow different age cohorts to have different effects, through a population polynomial. Young and old age cohorts have a positive impact on inflation and working-age population a negative impact, which means that ageing is expected to lead to higher inflation rates. The relationship between demographics and inflation remains intact after several robustness tests.

The empirical analysis of this paper is based on Juselius & Takáts (2015).

3. EMPIRICAL SPECIFICATIONS

3.1. DATA AND VARIABLES

Ranging from 1961 to 2014 (54 years of annual observations), our dataset is based on 24 OECD countries: Australia (AU), Austria (AT), Belgium (BE), Canada (CA), Denmark (DK), Finland (FI), France (FR), Germany (DE), Greece (GR), Iceland (IS), Ireland (IE), Italy (IT), Japan (JP), South Korea (KR), Luxembourg (LU), Netherlands (NL), New Zealand (NZ), Norway (NO), Portugal (PT), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK) and United States of America (US).

Countries' selection was supported by a double check analysis to see whether they are simultaneously OECD members and labelled by IMF as advanced economies. By doing that, we ensure that our sample covers all the countries where ageing is more acute and price stability is seriously taken into account by decision makers. Due to the lack of data before 1993, we exclude the countries from the ex – URSS, i.e. Czech Republic, Estonia, Slovak Republic and Slovenia. Israel inflation data are very volatile reaching a three digit inflation during the 80s. Because of that, Israel is also excluded.

The variables used are from several sources. Our variable of interest is the yearly inflation rate measured as the annual percentage change in consumer price index and is denoted as $inflation_{it}$, where $i = 1, \dots, N$ is a country index and $t = 1, \dots, T$ the time index. Data on inflation for the majority of the countries were gathered from the World Development Indicators (WDI). Data for Germany were taken from Worldwide Inflation Data and for United Kingdom from World Economic Outlook (IMF dataset).

Demographic data were obtained from the 2015 Revision of World Population Prospects (United Nations). From here, we collected population data by five-year age groups and computed a *P*:th degree population polynomial, where D_{pit} are the transformations to be considered in our estimations. Further details about the transformations can be found on section 4.1..

M2 growth data ($m2growth_{it}$), defined as the average annual growth rate in money and quasi money, were based on WDI database and extended in terms of time coverage using the IMF International Financial Statistics, the Economic Research Division of Federal Reserve Bank of St. Louis, Data Market, National Bank of Greece and the data platform Knoema. GDP growth ($gdpgrowth_{it}$) corresponds to the annual percentage growth rate of GDP converted at Geary Khamis PPPs[5] and were obtained from The Conference Board Total Economy Database (TED). The Terms of Trade change (ΔTOT_{it}) is the log difference of goods and services terms of trade index, calculated as the ratio of exports prices to import prices, and data are based on WDI values. We also include one period lagged inflation as a proxy for inflation expectations[6] ($inflation_{it}^{e}$).

[5] Hypothetical unit of currency that has the same purchasing power parity that the U.S. dollar for a given year, in this case 1990.

[6] Motivated by the empirical work of Lindh & Malmberg (2000).

In order to address concerns about endogeneity, we define instrumental variables for inflation expectations and M2 growth that will be included in our regressions as well. Inflation expectations is instrumented by a function of the third and fourth lags of inflation ($inflation_{IV}$) as Lindh & Malmberg (2000) applied. The instrument for M2 growth is the variable lagged by one period ($m2growth_{IV}$) as suggested in Yoon at al. (2014).

Table I in the Appendix presents the descriptive statistics for the full sample. All variables are in percentage.

3.2. METHODOLOGY

There are several advantages of using panel data that we can emphasize as being relevant for our empirical analysis. For instance, Balgati (2005) argues that panel data allow for more information, more variability, less collinearity, more degrees of freedom and more efficiency. In addition, with a larger sample we can obtain more reliable parameter estimates.

Linear panel model estimates can be obtained using the Ordinary Least Squares (OLS) method. However, to avoid estimates that are biased and/or inefficient and thus inappropriate for statistical inference, three assumptions are required: the exogeneity of explanatory variables, uncorrelated, and homoscedastic errors. Another concern is the endogeneity problems that can arise due to several reasons such as omitted variables, simultaneity or measurement error.

A reasonable assumption taken when analysing panel data is that, each entity has its own individual characteristics that may influence either the dependent or independent variables and we should control for it. Nonetheless, many factors as political and pension systems, labour policies or other institutional practices might be hard to control for and thus they are considered in the model as unobserved factors. Consequently, we can associate panel data with two types of unobserved factors: those that are constant (country specific effects) and those that vary over time (the error term).

For pooled OLS to produce unbiased and consistent estimators, we have to assume that country specific effects are uncorrelated with explanatory variables. Therefore, if we wrongly assume that, the resulting bias is called heterogeneous bias.

One way to address this question is to use the fixed effects (FE) model, since it allows the country effects to be correlated with explanatory variables. This method, applies a transformation that removes the effect of those time-invariant characteristics prior to the straight OLS estimation, so we can assess the net effect on our dependent variable. One important assumption in fixed effects is that both unobserved factors and the error term for a particular entity should not be correlated with others. Other assumptions needed for estimates to be valid are that the errors are homoscedastic and serially uncorrelated (across *t*).

A second method to deal with unobserved effects in panel data, as common as fixed effects, is the random effects (RE) model, which is more efficient when we believe that the unobserved effect is uncorrelated with all the regressors.

To verify which of the two methods is the most appropriate, we perform the Hausman test. The test compares an estimator known to be consistent (FE) with an alternative estimator that, under the hypothesis being tested, is efficient and consistent (RE). The null hypothesis is that the unobserved effects and the independent variables are not correlated. For a p-value less than 0.05, the null hypothesis is rejected and the fixed effect model is preferable since it remains unbiased and consistent.

In essence, fixed effects subtract from all variables the corresponding time averages eliminating all the between-subject variability and analyses what causes individual's values to change across time. The random effects transformation subtracts only a fraction of the time average, let's say λ. The random effects is then the GLS estimator obtained from estimating an equation with the quasi-demeaned data through OLS. Relating the three, pooled OLS is obtained when λ=0, fixed effects when λ=1 and random effects when 0 < λ <1.

Similarly to random effects, pooled OLS also requires the unobserved effects to be uncorrelated with the explanatory variables. Under this hypothesis, they seem to produce both consistent estimators. However, OLS ignores that the composite error will be serially correlated across time because the unobserved effects or country heterogeneity is present in the error term in each time period (see Wooldridge 2002). Therefore, OLS standard errors will be incorrect. Given that, pooled OLS will not be included in our analysis. We are left with OLS-FE and OLS-RE.

The third method we use is the Two-Stage Least Squares (2SLS) to overcome any endogeneity problems that can arise in our estimations. It require first to specify the instrumental variables, i.e. explanatory variable uncorrelated with the error term. If the defined variables are not poor, then 2SLS is a more suitable method than OLS. The regressions with instrumental variables are also estimated through fixed (2SLS-FE) and random (2SLS-RE) effects.

When OLS-FE is considered, the error structure is assumed to be heteroscedastic, autocorrelated and possibly correlated between the countries. The standard errors are computed from Discroll & Kraay (1998) estimates. For the remaining methods, the standard errors are heteroscedasticity and autocorrelation consistent as in Rogers (1993).

The asymptotics of large N and large T panels are different from the asymptotics of conventional panels with large N but small T. As T gets large, the sample variance would tend to diverge and the second moment-converge condition is likely to fail. Thus, with 54 time series observations, our empirical analysis also requires to address the concern of nonstationarity, which is the basis for the spurious regression problem. Following that, the variables are differentiated to achieve stationarity and said to be cointegrated. We rewrite the equation to be estimated in an error correction model (ECM), in which the short run dynamics of the variables are influenced by the deviation from equilibrium.

According to Blackburne III & Frank (2007), one of the main findings related to large T literature is that the homogeneity of the parameters slope could be inappropriate. Bearing this in mind, we apply three alternative methods related to the estimation of nonstationary panels: the dynamic fixed effects (DFE), the mean group (MG) estimator of Pesaran & Smith (1995) and the pooled mean group (PMG) derived by Pesaran et al. (1999). The DFE allow only the intercepts to differ across countries and produces consistent estimators when the slopes are identical. The MG and the PMG should be preferred when the homogeneity assumptions are not satisfied. While with the MG estimator, the intercepts, the short run and long run coefficients, and the error variances are allowed to differ, the PMG constraints the long run coefficients to be equal across countries. Again, the Hausman test can be performed to check which estimator should be considered.

The estimation outputs are obtained through the Stata econometric software package.

4. EMPIRICAL ANALYSIS

4.1. PURE AGE MODELS: METHODOLOGICAL ISSUES

According to Lindh & Malmberg (2000), most macro variables are endogenous to inflation as they are simultaneously determined by economic equilibrium mechanisms and expected to be correlated with age structure as well. For this reason, reduced form regression models, where inflation is regressed only on age group shares, are more likely to meet the exogeneity assumptions than the macro model is. This argument, is the main motivation for the estimation of pure age models, despite the coefficients obtained from reduced form models cannot be subjected to a rigorous structural interpretation.

Regression models with age variables differ in the way the age effects are specified. To represent the age distribution, three approaches are often used. The first one, represents age distribution by an aggregate measure, such as the old-age dependency ratio or the total dependency ratio[7]. A related disadvantage is that we are accounting only for a small part of the total variation in the age distribution. Ideally, we would like to include changes in all age groups since it represents important changes in economic behaviour. An econometric approach, proposed by Fair & Dominguez (1991) and already applied by Higgins (1998), Arnott & Chaves (2012), and Juselius & Takáts (2015), allows the inclusion of the entire age distribution through a polynomial restriction. Then, only few parameters need to be estimated and the perfect collinearity between the constant and the age shares should be removed. In turn, Lindh & Malmberg (1999) argue that the polynomial restriction generates strong multicollinearity among the compounded age variables and suggest that we can obtain more reliable estimates including only a limited number of broad age groups[8].

As following the methodology applied by Juselius & Takáts (2015), we intend to specify the age effects in our regressions through a population polynomial, allowing 17 age cohorts to have distinct effects on inflation. Thus, for each country and year, we divide the number of people in cohorts 0-4, 5-9, 10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79 and 80+ by total population. The share of each

[7] The total dependency ratio is the ratio of dependents, i.e. people younger than 15 or older than 64, to the working-age population, those ages 15-64.

[8] To use the population shares as regressors, the authors had to drop one group due to perfect collinearity with the intercept. The youngest age group, children aged 0-14, is often considered as the most likely group to be simultaneously determined with several macroeconomic variables and, for this reason, excluded. According to Arnott & Chaves (2012), this highlights the need for an approach that uses all the information available and that defines demographic variables less arbitrarily and more systematically.

cohort is denoted by n_{kit}. k is the index for cohort, i for country, and t for year. We want to estimate a regression like:

$$inflation_{it} = \alpha_i + \sum_{k=1}^{17} \beta_{1k} n_{kit} + \varepsilon_{it} \ , \quad (1)$$

where α_i is a country specific fixed effect, β_{1k} denote the 17 implied coefficients to be estimated and ε_{it} the error term. Since all population shares sum to one, the constant is not included in (1).

Estimating the previous equation arises some econometric problems: a large number of coefficients are included when compared to the number of time periods and the results may exhibit strong multicollinearity. In order to overcome such methodological issues, we restrict the coefficients β_{1k} to lie along a low-order polynomial of the form $\beta_{1k} = \sum_{p=0}^{P} \gamma_p k^p$ with $P < K$ and require that $\sum_{k=1}^{17} \beta_{1k} = 0$. While the low order polynomial involves that the relationship between inflation and age shares changes smoothly, the second restriction ensures that the constant term is not affected if population does not affect inflation (recall that population shares sum to one and are collinear with the intercept). Constraining β_{1k} in this fashion, leads to the new variables $D_{pit} = \sum_{k=1}^{17} (k^p n_{kit} - \frac{k^p}{17})$. The variables D_{pit} are included in equation (2) and there are only p coefficients to be estimated (γ_p: s). Then, the β_{1k}: s and the respective standard errors can be easily obtained. The formal derivation is available in the Appendix. The equation relating demographics with inflation comes as:

$$inflation_{it} = c + \alpha_i + \sum_{p=1}^{P} \gamma_p D_{pit} + \varepsilon_{it}. \quad (2)$$

The choice of the polynomial degree should reflect the trade-off between parsimony and statistical power. Since each polynomial degree contains the same terms as the previous plus an additional item, we perform the Wald test for nested models to determine which order of polynomial is most appropriate. We limit the test to the 3rd, 4th, 5th, and 6th order polynomials[9]. As can be seen in Table II (Appendix), the F statistic for the 3rd and 4th polynomials degree show that the variables are jointly significant at 1%, indicating that the choice must be between the two[10]. As the R squared is higher with a 4th degree polynomial, it was considered as the benchmark model.

In addition to demographic variables, we also include time dummy variables for the years 1974 (d_{74}), 1980 (d_{80}), and 2009 (d_{2009}) to control for special events that may had affected the inflation rate. While the two oil crises are associated with high inflation rates, and thus d_{74} and d_{80} control for huge positive outliers, d_{2009} controls for the recent financial crisis that resulted in a steep contraction with a sharp decline in inflation. Our equation of interest is:

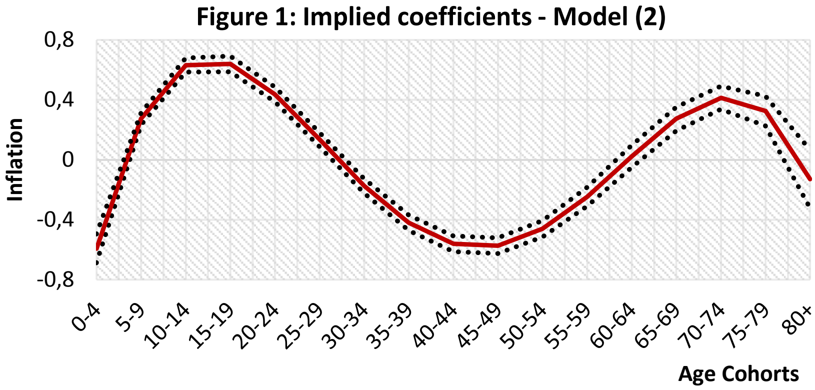
$$inflation_{it} = c + \alpha_i + \gamma_1 D_{1it} + \gamma_2 D_{2it} + \gamma_3 D_{3it} + \gamma_4 D_{4it} + \partial_1 d_{74} + \partial_2 d_{80} + \partial_3 d_{2009} + \varepsilon_{it} \ . \quad (3)$$

Equation (3) is estimated through fixed and random effects and the results are displayed in Table III in the Appendix.

As expected, the differences between the two methods are not meaningful. The population variables are all significant at 1% level. The dummy variables are also significant and with expected signs. Equation (3) explains over 30% of inflation variation. The result of the Hausman test does not allow rejecting the null hypothesis, suggesting that the estimators obtained from the random effects regression model are consistent and efficient. In Figure 1, we plot the implied coefficients associated with model (2). The solid line in the graph, shows the implied coefficients linking the size of each age cohort in the population with the corresponding inflation impact.

[9] 1st and 2nd polynomials degree are somewhat flat making difficult the distinction of effects for different cohorts.

[10] The F Test for the 5th order degree polynomial reveal that variables are not jointly significant. In the case of the 6th, the variables are significant only at the 10% level.

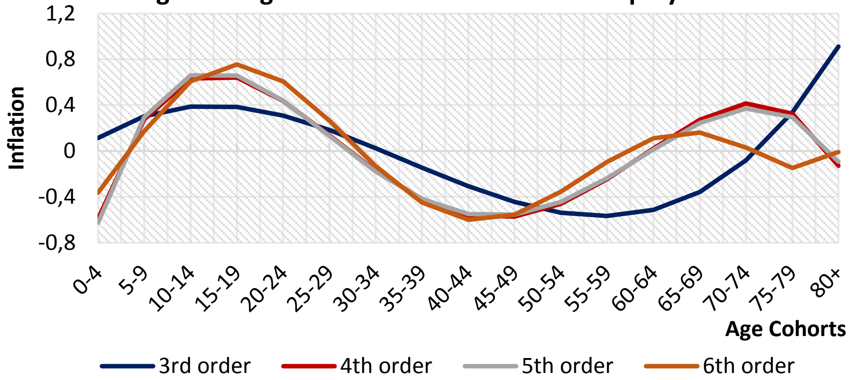


Inflation is positively associated with children and young retirees and the working-age groups are deflationary. A 1% higher concentration in the cohort 65-69 results in an inflation rate 0.27% higher. Considering a 1% increase in the 70-74 cohort, the respective impact on inflation will be around 0.41%.

The effects of very young (0-4) and very old (80 and over) age cohorts are however a bit surprising, since both exhibit a negative impact on inflation. According to the argument presented by Juselius & Takáts (2015), the data might be meaningless at the endpoints, i.e. for the very young and very old, due to curtailed child mortality rate and increased life expectancy, which may has changed the economic impact of these groups over time. Lindh (1999) also obtained a negative impact on inflation from the very old, suggesting that they consume less than expected from life cycle theory. For curiosity, we regress the share of 65 and over ($share\ 65+$) on inflation. The results displayed in Table III revealed the same negative impact on inflation as in Yoon et al. (2014).

To confirm whether the fourth degree polynomial is appropriate, we regress equation (3) using random effects for alternative polynomial specifications. From Figure 2, we can verify that the age cohort effects in the fifth and sixth degree polynomials are similar to those of the fourth. When comparing the third and the fourth degrees, the last should be chosen in the sense that the age cohort effects can be better perceived from its fit.

Figure 2: Age cohort effects with different polynomials



4.2. ADDITIONAL CONTROLS

In order to make a more complete analysis, additional controls which may be relevant explaining low frequency inflation are added to the model: M2 growth, GDP growth, change in terms of trade, and inflation expectations. The real interest rate could also be relevant, but the variable is clearly endogenous and including it would make inflation appears on both sides of the econometric equations.

The demographic structure is again represented through a fourth degree polynomial. After the inclusion of these variables, the specification yields:

$$inflation_{it} = c + \alpha_i + \sum_{p=1}^{4} \gamma_p D_{pit} + \delta_1 m2growth_{it} + \delta_2 gdpgrowth_{it} + \delta_3 \Delta TOT_{it} + \delta_4 inflation^e + \partial_1 d_{74} + \partial_2 d_{80} + \partial_3 d_{2009} + \varepsilon_{it}. \quad (4)$$

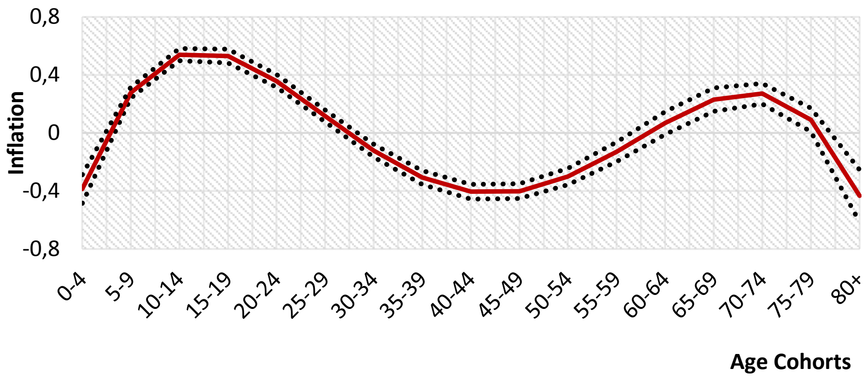
In Table IV (please consult it in the Appendix) are presented several estimation outputs related to Equation (4). Again, each specification is estimated twice allowing for fixed and random effects. The inclusion of controls is made in a gradual way. Models (5) and (6) do not include inflation expectations. Since when controlling for inflation expectations is expected to see the effect of the other variables weakening, we include it on models (7) and (8) to perceive the changes occurred. Models (9) and (10) illustrate one last concern relatively to the endogeneity problem that can arise due to the inclusion of lagged inflation (recall that it is the proxy for inflation expectations) and M2 growth, motivated by the correlation that the variables may have with the contemporaneous error term. Here, inflation expectations and M2 growth are substituted by the defined instrumental variables and estimated using 2SLS.

Based on the results obtained from the Hausman test, when other controls are added, fixed effects is preferred to random effects. In turn, the random effects model should be chosen when the instrumental variables are included. Further analysis will focus on the selected approaches.

In model (5), the inclusion of other variables changes somewhat the magnitude of the coefficients of demographic variables, but still are statistically significant at 1%. Comparing Figures 1 and 3, the impact of young cohorts does not change much, but there are less impact on inflation from working-age groups and young retirees. Inflation rate will be 0.22% and 0.27% higher following a 1% increase in the 65-69 and 70-74 cohorts, respectively. The impact of very old increased its magnitude, remaining the negative effect.

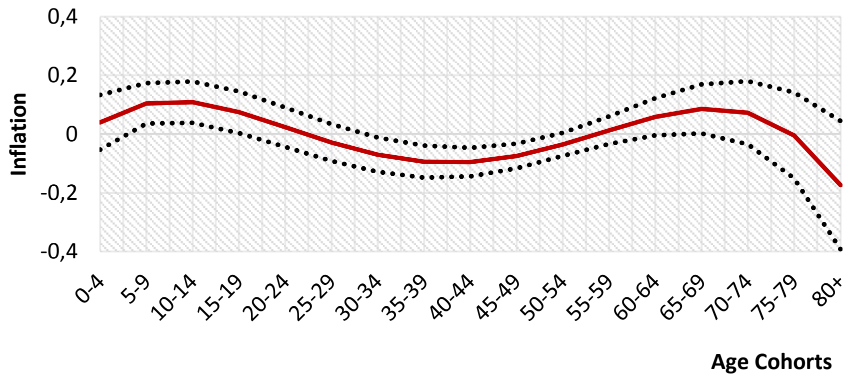
M2 and GDP growth are both significant and with the correct signs. This interpretation is based on the Quantity Theory of Money upon the equation of exchange, MV = PY. Thus, an increase in money growth will lead to higher prices, while an increase in real GDP growth, interpreted as an increase in supply, will cause prices to fall. The variable terms of trade is significant only at the 10% level and has a positive sign. To assess the impact of an increase in terms of trade on inflation, is often taken into account the exchange rate regime and if that improvement results from an increase in export prices or from a decline in import prices. Nonetheless, Gruen & Dwyer (1995) noted that when the exchange rate floats, whether the change in terms of trade arises from changes in the prices of exportable or importable goods is immaterial, since the resultant movement in nominal exchange rate delivers the same change in domestic prices. This leads us to assume that the coefficient exhibits the correct sign.

Figure 3: Implied coefficients - Model (5)



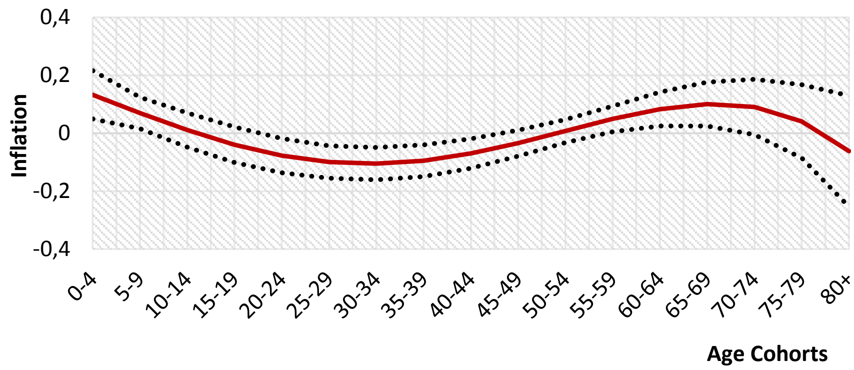
Adding inflation expectations in model (7) increases the explained variation from 48% to 77% and, as expected, the magnitude and significance of others variables is weakened. For instance, demographic variables are still significant but the cohort effects on inflation almost dissipated, as shown in Figure 4. M2 growth, GDP growth, and the terms of trade change are no longer significant. Inflation expectations is the main driver of actual inflation.

Figure 4: Implied coefficients - Model (7)



In model (10), the impact of M2 growth with a lag is bigger than the one obtained with M2 growth, suggesting that the link between this variable and inflation is stronger in the long run. The demographic effects are only jointly significant and the variables GDP growth and terms of trade change turn now to be significant and with the correct signs.

Figure 5: Implied coefficients - Model (10)



The additional controls do not remove the demographic impact and the pattern across age cohorts seem to be stable. Along with demographics, the monetary aggregate, GDP growth and inflation expectations seem to be the most relevant variables for explaining low frequency inflation.

4.3. MODEL DYNAMICS

When nonstationary series are present in a regression model, it is possible to obtain allegedly significant links from two or more variables that have no direct connection. This is called the spurious regression phenomenon. One classical approach to deal with nonstationary variables is to differentiate the series in order to achieve stationarity and analyse the true relationship between them. However, by doing that any evidence about the long run relationship between the variables is lost. Then, the estimation of an error correction model is more appropriate, since it combines both short and long run behaviours.

Aside from inflation expectations, included in the dynamic panel through lagged inflation, the other relevant variables to explain inflation are the demographic variables, M2 growth, and GDP growth. Therefore, a possible long run inflation equation is:

$$inflation_{it} = c + \alpha_i + \sum_{p=1}^{4} \theta_{1pt} D_{pit} + \theta_{2t} m2growth_{it} + \theta_{3t} gdpgrowth_{it} + \varepsilon_{it}. \quad (5)$$

If the variables are $I(1)$ and cointegrated, then the first difference will be required to obtain a covariance stationary series. Since the demographic effects are gradual, we do not allow population terms to have any short term effects on inflation. The dynamic panel specification associated to (5) is then an ARDL(1,1,1)[11] of the form:

$$inflation_{it} = c + \alpha_i + \sum_{p=1}^{4} \beta_{11pi} D_{pit-1} + \beta_{20i} m2growth_{it} + \beta_{21i} m2growth_{it-1} + \beta_{30i} gdpgrowth_{it} + \beta_{31i} gdpgrowth_{it-1} + \lambda_i inflation_{it-1} + \varepsilon_{it} \quad (6)$$

and the respective error correction parameterization comes as:

$$\Delta inflation_{it} = c + \alpha_i + \emptyset_i \big(inflation_{it-1} - \sum_{p=1}^{4} \theta_{1pi} D_{pit-1} - \theta_{2i} m2growth_{it-1} - \theta_{3i} gdpgrowth_{it-1} \big) + \beta_{21i} \Delta m2growth_{it} + \beta_{31i} \Delta gdpgrowth_{it} + \varepsilon_{it}, \quad (7)$$

where $\emptyset_i = -(1 - \lambda_i)$, $\theta_{1pt} = \frac{\beta_{11pi}}{1-\lambda_i}$, $\theta_{2t} = \frac{\beta_{20i}+\beta_{21i}}{1-\lambda_i}$ and $\theta_{3t} = \frac{\beta_{30i}+\beta_{31i}}{1-\lambda_i}$.

In equation (7) inflation is stationary and only stationary independent variables can be pertinent for explaining it. The term in parentheses is called the cointegrating vector and it captures the deviations from a long run relationship between M2 growth, GDP growth and the population polynomial. The coefficient $\emptyset_i$ is the speed adjustment parameter and illustrates how fast any deviation from the dynamic equilibrium will be reflected into inflation growth. We would expect $\emptyset_i$ to be negative and significant if the variables exhibit a return to long-run equilibrium. If the previous regressions were spurious, then $\emptyset_i$ should be zero. Long run elasticities are given by the coefficients θ_{1pi}, θ_{2i} and θ_{3i}. The remaining terms capture short run dynamics.

In Table V in the Appendix, we present the estimated results for equation (7) based on three methods, DFE, PMG, and MG. Regardless of the specification, the speed of adjustment estimates are always negative and significant suggesting that demographic

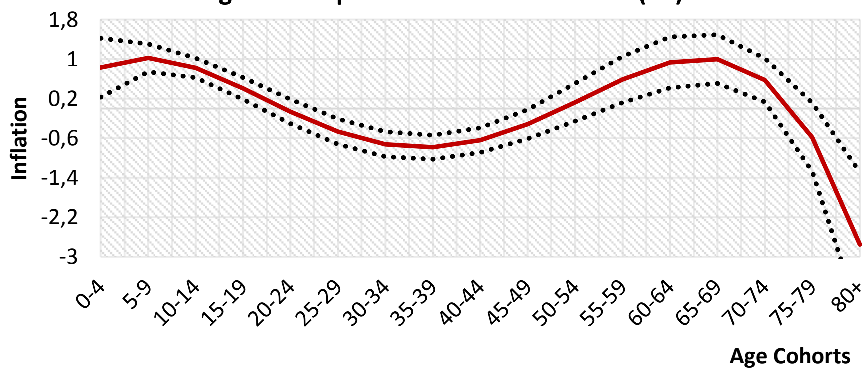
[11] Autoregressive Distributed Lag Model that includes the lagged value of the dependent variable and current and lagged values of the explanatory variables M2 growth and GDP growth.

effects are not spurious. Using the DFE or the PMG specifications, the demographic variables are individually and jointly significant. However, when allowing for full heterogeneity with the MG estimator they are only jointly significant.

Once again, the Hausman test can be performed to test the differences between the models. While the PMG estimator constraints the long run parameters to be equal across countries, the MG estimator allows for complete heterogeneity of the parameters. The MG estimator will be consistent in either situations, but the PMG is inconsistent if the true model is heterogeneous or efficient if it is homogeneous as regards long run elasticities. In our case, we reject the homogeneity assumption and the MG estimator is preferred to the PMG. We also test the DFE specification against the MG. The concern about using DFE often relies on the bias[12] that arises from the endogeneity between the error term and lagged inflation. Here, the Hausman test is used to measure the magnitude of this endogeneity. The result obtained suggests applying DFE, instead of MG, once the bias is minimal.

The homogeneity assumptions related to prior estimations have been satisfied. In addition, any country heterogeneity does not significantly affect the demographic impact on inflation, as can be observed in Figure 6. Again, the impact of very young and very old can be less precisely estimated.

Figure 6: Implied coefficients - Model (13)



[12] Generally known as dynamic panel bias or Nickell's bias (1981).

Regarding the remaining coefficients displayed in model (11), the estimated long run elasticity to M2 growth has the correct positive sign and is highly significant. However, in the short run the magnitude of the coefficient is much smaller and has the opposite sign. In turn, GDP growth seems not to belong to the long run relationship having only significant short term effects on inflation dynamics.

4.4. COUNTRY HETEROGENEITY

The country specific long run coefficients can be obtained from the MG estimator. In order to understand any differences between the countries in our sample, in Table VI in the Appendix can be found the individual estimates of population polynomial along with the adjustment coefficients.

The demographic coefficients are jointly significant at 10% level in the majority of countries, except for Germany, Ireland, Luxembourg, Netherlands, and United Kingdom. To some extent, this may suggest that in countries with a stronger commitment to price stability, such as Germany, Luxembourg, and Netherlands, the demographic effects on inflation are weaker. Conversely, Ireland inflation rate has been extremely volatile as a consequence of adverse economic conditions. With regard to the United Kingdom, the results displayed can suffer from a lack of interpretation, since we do not have data on inflation before 1980.

The adjustment coefficients are not significant only in two countries: France and Ireland. Thus, the deviations from the equilibrium are mean reverting in most cases.

The results obtained in this section are somewhat different from the ones in our reference paper, possibly because we are using different controls. Also, for some countries the demographic coefficients are quite bigger. At this point, we should bear in mind that when considering individual estimates the degrees of freedom are severely limited, resulting in inflated coefficients.

5. CONCLUSIONS

This paper has the purpose to establish a relation between ageing and monetary policy theoretically and empirically. One of the most prevailing ways to conduct monetary policy is through a reaction function that relates the policy rate with a couple of variables that best capture the main trends of the economy. The most well-known is the Taylor rule, under which central banks set the nominal interest rate in response to real interest rate, output gap, and deviations from target inflation rate. The current demographic changes are expected to affect several macroeconomic variables, including those in the reaction function with repercussions to the conduct of monetary policy and price stability objective.

The main goal of our literature review was then to provide a solid background on the linkages between demographic changes and monetary policy that undoubtedly evidence the economic value of demographic information.

Given the relative importance of price stability, our empirical work was dedicated to examine if there is a statistically and economically significant relationship between demographics and inflation, focused on 24 OECD economies.

By adopting a population polynomial technique, first applied by Fair & Dominguez (1991) we found a significant correlation between age structure and inflation. The working-age groups have a negative impact on inflation, whereas children and young retirees have a positive effect. This pattern holds in the pure age models and when other controls are added to the model. In addition, the relation between demographics and inflation is not spurious and not affected by country heterogeneity.

Further research will be needed to accurately estimate the impacts of very young and very old. Since the share of the population over 80 is expected to double by 2050, precisely determine the impact from this group is particularly relevant. Unfortunately, we were not able to draw any solid conclusion at this point.

The result that an ageing population will lead to inflationary pressures in OECD is the main conclusion of this thesis and is in line with the findings of related works, namely with Juselius & Takáts (2015) and Lindh & Malmberg (2000).

It was however unaddressed in this paper, an empirical relation between demography and the conduct of monetary policy per se, in a way to understand if central banks have accommodated or mitigated the demographic pressures on inflation. Due to the existence of different policy regimes and complexity of the decision process faced by central banks we decided not to pursue this investigation at this initial stage. Nonetheless, it should be the future extension of this work.

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APPENDIX

1. Polynomial Representation of the Age Structure taken from Juselius & Takáts (2015)

Consider the regression specification for the K age shares:

$$inflation_{it} = \alpha_i + \sum_{k=1}^{K} \beta_{1k} n_{kit} + \varepsilon_{it}. \quad \text{(A1)}$$

As mention earlier, there are several difficulties associated with the estimation of this regression. The polynomial of the age structure allows to overcome such problems by imposing two restrictions. The first one constraints the coefficients of the population shares β_{1k} to lie along a P:th degree polynomial with $P < K$ of the form:

$$\beta_{1k} = \sum_{p=0}^{P} \gamma_p k^p = \gamma_0 + \gamma_1 k^1 + \cdots + \gamma_p k^p. \quad \text{(A2)}$$

Substituting β_{1k} into (A1) and rearranging the equation, we obtain:

$$inflation_{it} = \alpha_i + \sum_{k=1}^{K} \sum_{p=0}^{P} \gamma_p k^p n_{kit} + \varepsilon_{it}$$

$$= \alpha_i + \sum_{p=0}^{P} \gamma_p \sum_{k=1}^{K} k^p n_{kit} + \varepsilon_{it}$$

$$= \alpha_i + \gamma_0 \sum_{k=1}^{K} k^0 n_{kit} + \sum_{p=0}^{P} \gamma_p \sum_{k=1}^{K} k^p n_{kit} + \varepsilon_{it} \quad \text{(next step uses } \sum_{k=1}^{K} k^0 n_{kit} = 1\text{)}$$

$$= \alpha_i + \gamma_0 + \sum_{p=1}^{P} \gamma_p \sum_{k=1}^{K} k^p n_{kit} + \varepsilon_{it}. \quad \text{(A3)}$$

The second restriction by imposing $\sum_{k=1}^{K} \beta_{1k} = 0$ allow us to determine γ_0. For that, we substitute (A2) in the sum $\sum_{k=1}^{K} \beta_{1k}$ and set the expression to zero, as follows:

$$\sum_{k=1}^{K} \beta_{1k} = \sum_{k=1}^{K} \sum_{p=0}^{P} \gamma_p k^p = \sum_{p=0}^{P} \gamma_p \sum_{k=1}^{K} k^p = \gamma_0 \sum_{k=1}^{K} k^0 + \sum_{p=0}^{P} \gamma_p \sum_{k=1}^{K} k^p = \gamma_0 K + \sum_{p=0}^{P} \gamma_p \sum_{k=1}^{K} k^p, \quad \text{(last step uses } \sum_{k=1}^{K} k^0 = K\text{) (A4)}$$

setting (A4) equal to zero, yields:

$$\gamma_0 = -\sum_{p=1}^{P} \gamma_p \sum_{k=1}^{K} (k^p / K). \quad \text{(A5)}$$

We then need to substitute γ_0 in (A3) to get our equation of interest:

$$inflation_{it} = \alpha_i + \sum_{p=1}^{P} \gamma_p \sum_{k=1}^{K} (k^p n_{kit} - k^p / K) + \varepsilon_{it}, \quad \text{(A6)}$$

where $\sum_{k=1}^{K} (k^p n_{kit} - k^p / K)$ corresponds to D_{pit}. Given the estimates of $\gamma_p : s$, the implied regression coefficients can be calculated directly from (A2):

$$\beta_{1k} = \sum_{p=1}^{P} \gamma_p \left(k^p - \sum_{k=1}^{K} k^p / K\right). \quad \text{(A7)}$$

The specification above shows that β_{1k}:s are linear transforms of the γ_p: s. Rewriting (A7) in a vector format:

$$\beta_1 = \omega\gamma, \quad \text{(A8)}$$

where ω is a K × P matrix with elements $\omega_{kp} = k^p - \sum_{k=1}^{K} k^p / K$.

Using the expression given in (A8), the variance of β_1 is:

$$Var(\beta_1) = Var(\omega\gamma) = \omega\, Var(\gamma)\omega'. \quad \text{(A9)}$$

The standard errors are simply the square root of the variances calculated.

2. Estimation Outputs

Table I
Descriptive Statistics: 1961 – 2014

	$Observations$	$Mean$	$Std. Dev.$	$Min.$	$Max.$
$inflation$	1271	5.495	6.445	-4.480 (IE, 2009)	84.222 (IS,1983)
$m2growth$	1108	10.926	11.519	-28.630 (UK,1992)	121.924 (CA,2001)
$gdpgrowth$	1296	3.199	3.022	-8.864 (GR, 2011)	16.921 (KR,1973)
ΔTOT	1270	0.120	3.186	-15.729 (JP,1970)	21.289 (KR, 1964)

Table II
Wald test for nested models

$Block$	F	$Block\ df$	$Residual\ df$	$Pr > F$	R^2	$Change\ in\ R^2$
$(D_{1it}\ D_{2it}\ D_{3it})$	128.83	3	1267	0.000	0.234	
(D_{4it})	108.05	1	1266	0.000	0.294	0.060
(D_{5it})	0.28	1	1265	0.598	0.294	0.000
(D_{6it})	3.06	1	1264	0.081	0.296	0.002

Note: With the Wald test we simply run Equation (2) four times, adding a block of predictors to the model for each run. The F statistic is the test of joint significance for each block.

Table III

Dependent variable is $inflation_{it}$

	(1) OLS-FE	(2) OLS-RE	(3) OLS-FE	(4) OLS-RE
c	0.063***	0.064***	0.129***	0.127***
	(0.012)	(0.020)	(0.030)	(0.016)
D_{1it} $(\times 1)$	1.985***	1.973***		
	(0.432)	(0.497)		
D_{2it} $(\times 10)$	-4.520***	-4.490***		
	(0.906)	(1.065)		
D_{3it} $(\times 10^2)$	3.660***	3.640***		
	(0.711)	(0.832)		
D_{4it} $(\times 10^3)$	-0.973***	-0.963***		
	(0.186)	(0.216)		
$share\ 65+_{it}$			-0.342***	-0.337***
			(0.115)	(0.056)
$d74$	0.078***	0.078***	0.101***	0.101***
	(0.010)	(0.011)	(0.010)	(0.011)
$d80$	0.066***	0.066***	0.094***	0.095***
	(0.008)	(0.013)	(0.009)	(0.017)
$d2009$	-0.010***	-0.010*	-0.030***	-0.030***
	(0.002)	(0.005)	(0.007)	(0.005)
Obs	1271	1271	1271	1271
R^2	0.341	0.333	0.176	0.157
$Adj. R^2$	0.337	0.329	0.173	0.154
$F-Test$	0.000	0.000	-	-
$Hausman\ Prob$	0.987	-	0.990	-

Notes: *, ** and *** represent significance at 10, 5 and 1 percent level, respectively. Robust standard errors are in parentheses. Obs represents the total number of observations. $F-Test$ is the test of joint significance for demographic variables. The $Hausman\ Prob$ refers to the probability reached in the Hausman test.

Table IV
Dependent variable is $inflation_{it}$

	(5) OLS - FE	(6) OLS - RE	(7) OLS - FE	(8) OLS - RE	(9) 2SLS - FE	(10) 2SLS - RE
c	0.037**	0.043***	0.009**	0.011**	0.007	0.007
	(0.008)	(0.014)	(0.005)	(0.005)	(0.007)	(0.005)
D_{1it} $(\times 1)$	1.547***	1.571***	0.210	0.087	0.027	-0.054
	(0.301)	(0.369)	(0.138)	(0.071)	(0.159)	(0.136)
D_{2it} $(\times 10)$	-3.590***	-3.660***	-0.607*	-0.331**	-0.254	-0.060
	(0.599)	(0.775)	(0.309)	(0.158)	(0.362)	(0.310)
D_{3it} $(\times 10^2)$	2.970***	3.030***	0.570**	0.339***	0.319	0.152
	(0.463)	(0.609)	(0.260)	(0.129)	(0.311)	(0.265)
D_{4it} $(\times 10^3)$	-0.807***	-0.822***	-0.168**	-0.104***	-0.108	-0.0609
	(0.123)	(0.163)	(0.074)	(0.361)	(0.089)	(0.075)
$m2growth_{it}$	0.187**	0.195**	0.071	0.074		
	(0.071)	(0.0936)	(0.044)	(0.0512)		
$gdpgrowth_{it}$	-0.479***	-0.483***	-0.148	-0.129*	-0.254**	-0.205**
	(0.145)	(0.073)	(0.101)	(0.073)	(0.110)	(0.095)
ΔTOT_{it}	0.145*	0.144	0.056	0.049	0.081**	0.066*
	(0.076)	(0.093)	(0.064)	(0.085)	(0.041)	(0.037)
$d74$	0.072***	0.071***	0.068***	0.068***	0.071***	0.070***
	(0.008)	(0.014)	(0.003)	(0.015)	(0.008)	(0.008)
$d80$	0.054***	0.053***	0.044***	0.044***	0.046***	0.049***
	(0.010)	(0.011)	(0.003)	(0.009)	(0.008)	(0.008)
$d2009$	-0.028***	-0.028***	-0.029***	-0.028***	-0.025***	-0.026***
	(0.006)	(0.009)	(0.004)	(0.004)	(0.008)	(0.007)
$inflation_{it}^{e}$			0.693***	0.743***		
			(0.089)	(0.036)		
$inflation_{IV}$					0.625***	0.705***
					(0.113)	(0.094)
$m2growth_{IV}$					0.257**	0.208**
					(0.123)	(0.099)
Obs	1067	1067	1064	1064	1033	1033
R^2	0.476	0.482	0.765	0.809	0.687	0.731
$Adj. R^2$	0.471	0.477	0.763	0.807	0.684	0.728
$F - Test$	0.000	0.000	0.009	0.000	0.007	0.003
$Hausman\ Prob$	0.000	-	0.000	-	0.937	-

Notes: *, ** and *** represent significance at 10, 5 and 1 percent level, respectively. Robust standard errors are in parentheses. Obs represents the total number of observations. $F - Test$ is the test of joint significance for demographic variables. The $Hausman\ Prob$ refers to the probability reached in the Hausman test.

Table V

Dependent variable is $\Delta inflation_{it}$

	(11) DFE	(12) PMG	(13) MG
Long Run			
c	0.012*	0.012***	-0.011
	(0.006)	(0.002)	(0.080)
$\emptyset_i$	-0.283***	-0.252***	-0.576***
	(0.023)	(0.033)	(0.101)
$D_{1it-1}(\times 1)$	1.351***	1.479***	1.228
	(0.450)	(0.296)	(1.512)
$D_{2it-1}(\times 10)$	-3.600***	-3.580***	-4.460
	(1.010)	(0.649)	(3.370)
$D_{3it-1}(\times 10^2)$	3.260***	3.080***	4.700
	(0.875)	(0.550)	(3.090)
$D_{4it-1}(\times 10^3)$	-0.941***	-0.859***	-1.510
	(0.253)	(0.157)	(0.964)
$m2growth_{it-1}$	0.281***	0.049	0.087
	(0.044)	(0.032)	(0.068)
$gdpgrowth_{it-1}$	0.156	0.837***	0.230
	(0.189)	(0.179)	(0.153)
Short Run			
$\Delta m2growth_{it}$	-0.026**	0.001	-0.040
	(0.011)	(0.017)	(0.028)
$\Delta gdpgrowth_{it}$	-0.286***	-0.313***	-0.255***
	(0.041)	(0.043)	(0.037)
Obs	1047	1047	1047
$F-Test$	0.000	0.000	0.000
$Hausman\ Prob$	1.0000	0.000	-

Notes: *, ** and *** represent significance at 10, 5 and 1 percent level, respectively. Standard errors are in parentheses. Obs represents the total number of observations. $F-Test$ is the test of joint significance for demographic variables. The $Hausman\ Prob$ refers to the probability reached in the Hausman test.

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Table VI
Dependent variable is $\Delta inflation_{it}$

	D_{1it} $(\times 1)$	D_{2it} $(\times 10)$	D_{3it} $(\times 10^2)$	D_{4it} $(\times 10^3)$	$\emptyset_i$	$F-Test$
Australia	4.579**	-11.250**	10.400*	-3.190	-0.376***	0.002
	(2.162)	(5.450)	(5.710)	(1.980)	(0.124)	
Austria	0.620	21.300	-4.540*	1.960**	-0.799***	0.061
	(1.201)	(23.700)	(23.600)	(0.824)	(0.297)	
Belgium	-28.65***	54.780***	-41.400***	10.600***	-2.760***	0.000
	(6.848)	(12.510)	(8.990)	(2.250)	(0.669)	
Canada	2.936***	-7.740**	8.410*	-3.000	-0.344**	0.000
	(0.959)	(3.340)	(4.840)	(2.070)	(0.144)	
Denmark	-1.923	2.850	-2.650	0.991	-0.529***	0.000
	(1.273)	(2.440)	(2.090)	(0.646)	(0.141)	
Finland	3.661***	-7.090***	5.030**	-1.180	-0.517***	0.013
	(1.295)	(2.700)	(2.320)	(0.724)	(0.149)	
France	9.488*	-2.168*	0.184*	-0.00514*	-0.360	0.009
	(5.198)	(1.185)	(0.104)	(0.00307)	(0.232)	
Germany	0.727	-1.930	1.840	-0.565	-0.473***	0.163
	(0.971)	(2.030)	(1.710)	(0.496)	(0.148)	
Greece	2.469	-8.440	7.280	-1.830	-0.427*	0.004
	(3.395)	(9.480)	(10.200)	(3.470)	(0.231)	
Iceland	-0.353	-0.513	-1.350	1.330	-0.749***	0.006
	(5.458)	(12.320)	(11.600)	(3.770)	(0.138)	
Ireland	2.969	-9.810	11.600	-4.330	-0.210	0.273
	(9.634)	(23.770)	(22.700)	(7.250)	(0.140)	
Italy	12.38***	-38.150***	41.000**	-13.600**	-0.278**	0.038
	(4.210)	(13.880)	(16.000)	(5.630)	(0.117)	
Japan	-2.623*	5.220**	-4.070	1.080	-0.533***	0.022
	(1.353)	(2.540)	(2.850)	(1.010)	(0.149)	
Korea	3.551	-1.044	0.107	-0.00348	-0.584***	0.001
	(4.022)	(1.129)	(0.116)	(0.00386)	(0.155)	
Luxembourg	-4.158	10.890	-11.800	4.070	-0.332*	0.573
	(5.372)	(13.290)	(12.800)	(4.090)	(0.177)	
Netherlands	-0.440	0.874	-0.980	0.385	-0.429***	0.365
	(2.039)	(4.860)	(4.730)	(1.550)	(0.140)	
New Zealand	5.917***	-13.690***	12.600***	-3.950***	-0.620***	0.000
	(1.071)	(2.630)	(2.870)	(1.070)	(0.151)	
Norway	1.417***	-3.790***	3.260***	-0.872***	-0.852***	0.000
	(0.542)	(0.992)	(0.838)	(0.248)	(0.154)	
Portugal	6.396	-26.070	32.000	-1.140	-0.522***	0.002
	(8.756)	(26.140)	(28.500)	(9.700)	(0.160)	
Spain	-2.064	3.710	-4.120	1.650	-0.368**	0.088
	(5.110)	(13.880)	(16.000)	(5.840)	(0.146)	
Sweeden	4.142***	-9.710***	7.640***	-1.910***	-0.630***	0.000
	(1.046)	(2280)	(1.910)	(0.520)	(0.174)	
Switzerland	1.141	-2.620	1.480	-0.129	-0.291**	0.074
	(1.578)	(3.180)	(2.830)	(0.923)	(0.128)	
United Kingdom	1.754	-3.470	2.290	-0.441	-0.493***	0.527
	(2.178)	(3.600)	(2.210)	(0.510)	(0.155)	
United States	5.525***	-10.990***	9.830***	-3.190**	-0.348**	0.003
	(2.005)	(4.010)	(3.790)	(1.300)	(0.147)	

Notes: *, ** and *** represent significance at 10, 5 and 1 percent level, respectively. Standard errors are in parentheses. $F-Test$ is the test of joint significance for demographic variables.