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Secular Stagnation and the Demographic Transition: A Factor Model Approach

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Abstract

Secular stagnation is a tale of ageing economies permanently constrained in a below full-employment steady-state due to aggregate demand shortfalls. Using a factor model combined with a VAR for seven key macro-series augmented with demographics, we investigate the link between the demographic transition and macroeconomic trends. We find that, while a single variable offers an insufficient representation of the recent population dynamics, two factors can account for almost the entire variance of the five variables that best describe the demographic transition. Our results indicate that demographics have exerted significant deflationary and contractionary pressures in the Euro Area and Japan since 1970.

Keywords: Demographics, Secular Stagnation, Effective-Lower Bound, Factor Model, VAR.

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1 Introduction

Since the Great Recession, many of the world's advanced economies have been experiencing extended periods of subpar growth, delaying the recovery and exacerbating some of the erstwhile trends. Short and long-term interest rates have been on a downward path for almost thirty years. Both have plunged into negative territory in the aftermath of the financial crisis and remained there since then. In addition, low growth rates, below target inflation, dwindling unemployment and sluggish productivity growth prompted concerns over a new normal characterised by a binding effective-lower bound (ELB) and persistent stagnation. These low-frequency phenomena have several implications, constraining macro-policy, and particularly the scope of monetary policy to respond to recessionary shocks. Hence, central banks were forced to thoroughly reconsider their mandates, ensued the pursue of once dubbed unconventional monetary policies and a call for further fiscal support to complement its decisions (Draghi, 2019).

Developed economies are as well undergoing a severe ageing process. In the last decades, the age profile of these countries changed at a dramatically rapid pace, utterly shifting the demographic structure. Steady gains in life expectancy, combined with a decay in infant mortality and in fertility, caused population growth to shrink significantly, even becoming negative in some cases (e.g. Japan), and a steeply rise in the number of old dependents (population aged over 64). Furthermore, the aforementioned population variables should not suffer any deviation in the foreseeable future from their ongoing trends. Changes on the age cohorts, as Hansen (1939) suggested in his secular stagnation hypothesis which was recently revived by Summers (2014), play an important structural role, acting as a key determinant of economic growth and progress. Different agents decide differently, with their preferences being heterogeneously distributed given the age group to which each one belongs. According to their age, individuals differ in their life-cycle consumption-saving decisions, labour supply, productivity level or contribution to innovation. Therefore, demographics emerge as a natural possible explanation for the current anemic economic environment.

Despite the increasing interest in studying precisely the outlets through which demographics affect economic activity, there is still a lack of econometric evidence, namely due to some difficulties that arise when estimating the impact of the age structure. Cohorts are rather complex and highly collinear. Moreover, it is as well quite challenging to separate the boundaries between demographics and other structural movements that might be the predominant forces behind economic time series. Thus, it is common to impose strong restrictions and rely upon a single variable to describe the demographic transition, specially the age dependency ratio (ratio between the population aged over 64 years and the working population). The frequent usage of this variable in the literature is motivated by its capability to best capture, under certain conditions, movements in population growth and in longevity (Ferrero et al. (2017) and Carvalho et al. (2016)).

Nevertheless, we argue that the demographic transition is a tale of two factors, not just a single one. The age dependency ratio is a straightforward proportion measure that simply illustrates which fraction of the population grew or faltered faster. As an example, between 1960 and 1980 in the United States, both working age and old age population increased significantly, 43% and 66% respectively. As a consequence, the latter outstripped the former, meaning a 2.4 percentage points surge in the age dependency ratio. To take just another example, in spite of registering population dynamics similar to other developed countries, Japan has nowadays the steepest slope in terms of age dependency ratio trends.

Given this setting, we propose a two-step estimation method that combines factor analysis with a standard Vector Autoregressive model (VAR) to decompose the effect of the demographic transition upon last decades' macroeconomic dynamics in the United States, Japan and the Euro Area. Using a Dynamic Factor Model (DFM), we start by extracting two factors from a set of five demographic variables that best represent the shifting population trajectories in the advanced world. Then, a VAR for a vector of seven key macro-variables is assembled, where we incorporate the two "demographic factors" as well as the age dependency ratio in an alternative specification, in order to assess the impact of demographics via these two distinct measures. Finally, we compare the responses to a shock in each "demographic factor" with the ones for the age dependency ratio.

Our results contribute to the literature by showing that a single variable is not sufficient to describe the demographic transition. Responses obtained for the age dependency ratio specification did not represent precisely recent dynamics and were on average smaller than the responses to an equivalent shock in our factors. However, our two factors jointly are able to explain virtually the entire variability of the data (up to 95%). Results from the model augmented by the unobservable factors indicate that the demographic transition has statistically significant impacts on GDP, inflation, interest rate, savings, investment and hours worked. We also find that the magnitude of demographic changes upon economies is large, having exerted deflationary and contractionary forces based on data since 1970. Therefore, we provide further empirical evidence of the link between the demographic outlet and the secular stagnation hypothesis.

The remainder of this thesis proceeds as follows. Section 2 presents a brief review on relevant literature. Section 3 explains the theoretical framework employed. Section 4 describes the dataset used, followed by Section 5 which provides the estimation results. Section 6 illustrates our main results. Finally, Section 7 concludes this study.

2 Related Literature

The economic impact of demographics has always been a widely acknowledged and recurrent topic in economic literature. Nonetheless, its role is not completely consensual, with many economists diverging in through which channels and how it affects concretely economic dynamics. Interestingly, this debate was acutely common amid the very first economists centuries ago, as it still is nowadays. Therefore, this analysis is of first-rate importance since it provides granular quantitative evidence to the ongoing debate on the structural effects of demographics in the developed world for the last five decades.

Adam Smith perceived population growth as simultaneously a consequence and a cause of economic progress. Labour division, crucial element in Smith's theory, generates greater productivity, that in turn, bolsters growth by augmenting revenues, labour demand and wages. Thus, the role of population growth was nothing but positive as it supported and created in a sort of cycle, favourable conditions for expansion and prosperity. On the other hand, economists such as Thomas Malthus or David Ricardo argued that flourishing population growth depressed wages due to the labour market incapability to absorb the soaring labour supply. Additionally, this surge would depress capital accumulation per capita, a crucial driver of the standard of life.

These aforementioned effects would ultimately exert upward pressure on the limited natural resources, rising rents and costs of cultivating, bound to reduce economies to subsistence.

Later, in the twentieth century, John Maynard Keynes, in a notorious lecture conducted at the *Eugenics Society*, recognized the benefits of a relatively stable population and defended that dwindling population growth implies more unemployment (Keynes, 1937). In the Keynesian world, shrinking populations mean less aggregate demand and savings, thereby reducing capital accumulation, hence generating higher unemployment levels. Although his view did not materialize, he contradicted the consensus and warned that a declining population had indeed numerous undesirable consequences. Less than two years after Lord Keynes' speech, Alvin Hansen, in his presidential address at the Annual Meeting of the *American Economic Association*, proposed the secular stagnation hypothesis. Secular Stagnation (Hansen, 1939) is a theory of permanently constrained ageing economies, dragged by shortfalls in aggregate demand and excess savings to a below full employment steady-state.

Summers (2014) resurrected this idea and suggested that we now live in a world where the equilibrium real interest rate has declined significantly to a chronic zero-lower bound. According to his view, these remarkably low interest rates are the outcome of excess leveraging associated with periods of unsustainable growth that masked some structural stagnation syndromes in the pre-crisis era, namely diminishing populations and fast technological progress. Other closely related contribution is the global saving glut characterized in Bernanke (2005), who considered that US current account deficits in the beginning of the century were financed by increasing desired saving in developing countries and partially in some ageing industrial economies. In the long-run, however, advanced economies would fully return to its international lender status due to their ageing populations, which because of the soaring number of retirees and the limited domestic investment opportunities, will have higher saving propensities. Concerning secular stagnation, Eggertsson, Mehrotra, & Robbins (2019) were the first to formalize this hypothesis through the development and calibration of several complex overlapping generation models (OLG). Authors present quantitatively how the slowdown in population growth and the increase in life expectancy alongside sluggish productivity growth have exerted downward pressure on the natural interest rate since 1970, causing it to range between -1.5 and -2 percent in 2015.

The interest rate outlet is precisely the one that has been studied the most, given the undisputable importance that life-cycle saving and consumption decisions imply to its dynamics. Carvalho et al. (2016) depict two main effects on the interest rate of a reduction in population growth: higher capital per-worker leads to a reduction in the marginal product of capital hence lowering the rate of interest; and given the steeply rise in the age dependency ratio (i.e. number of retirees per workers), because this group has a smaller propensity to save, aggregate savings are inferior, thus driving the interest rate up. Considering this setting, authors find that capital deepening outstrips the "consumption" effect with an overall 1.5 percentage points negative outcome on the interest rate. In addition, Ferrero et al. (2017) produce various counterfactual scenarios for the dependency ratio, arriving at similar conclusions. Others, such as Gagnon et al. (2016), Cooley & Henriksen (2018) and Jones (2018) emphasize this same mechanism not only for the interest rate, but also for economic growth and productivity.[1] In contrast to these findings, although Favero & Galasso (2015) show that aged economies tend to generate less long-term growth, authors project real rates to revert to their historical mean by following an ascending path in the forthcoming twenty years.

The transmission channels of demographic shifts, however, are far broader than the ones we mentioned above. For instance, Aksoy et al. (2019) add the impact on innovation to their study regarding the long-term impacts of changes in age cohorts, as Feyrer (2007) suggested. Their analysis demonstrates significant effects for a panel of OECD countries on output, savings, investment, hours worked per capita and inflation. Beyond these results, they found a negative relationship between the number of dependents and patents applications per capita, a proxy for innovation, while the number of middle-aged workers affected it positively. Following this technological intuition, Acemoglu & Restrepo (2017) explore the negative developments in output since the nineties and associate them with burgeoning automation and the rise of artificial intelligence rather than with adverse age structure changes. Albeit not inferring any causal connection between the two, they argue that countries experiencing faster ageing pro-

[1] See Gordon (2012) and Galor & Weil (2000) for further discussion on innovation, productivity and growth.

cesses have adopted more rapidly solutions towards automation, such as implementing robots in their industries. Alternatively, Basso & Jimeno (2020) and Eggertsson, Lancastre, & Summers (2019) re-examine Acemoglu & Restrepo (2017) evidence reaching opposite conclusions, instead supporting secular stagnation.

3 Empirical Strategy

Dynamic Factor Models are largely used in economic literature being particularly popular in macro-policy. Initially proposed in the seventies by Geweke (1977), the idea behind this approach is that fluctuations in the business cycle are driven by few unobservable latent factors and idiosyncratic disturbances. Sargent & Sims (1977) seminal contribution showed that two dynamic factors are able to explain a large proportion of the variation of fundamental macroeconomic variables, such as output and prices. More recently, Bernanke et al. (2005) influential work on monetary policy shocks departs from the conventional factor model analysis and develops a factor-augmented VAR model (FAVAR), which includes both observable and unobservable series. Nevertheless, so far DFMs have been studied mainly in a stationary framework. Often in macroeconomics we aim to model non-stationary series. Since we are interested in studying demography and its acutely persistent movements, we can not exclude the non-stationary components of the series from our assessment. Hence, to incorporate the various long-term trends that compose the demographic transition, we follow the methodology proposed by Barigozzi et al. (2020), that performs factor estimations in a non-stationary setting, in our first estimation step depicted in Section 3.1.

We propose a DFM in order to avoid heavy parametrization, given its appealing dimensionality reduction logic, and also to capture any country specific unobservable dynamics that otherwise would not have been explicitly considered.

Afterwards, we construct a VAR model to analyse empirically the effect of demographics upon key macroeconomic variables. In Section 3.2, we will conduct two separate approaches: first, we include factors extracted in the previous analysis, and second, an alternative specification is built including the age dependency ratio.

3.1 Non-Stationary Dynamic Factor Model

We undertake our factor analysis following essentially Barigozzi et al. (2020) methodology for non-stationary DFMs, although with a slightly different notation.

Let X_t represent a vector of n non-stationary demographic series $X_t = (X_{1t}, ..., X_{nt})'$ which is a linear combination of latent common factors (F_t) and idiosyncratic disturbances (e_t), both can be assumed to be at least I(1):

$$X_t = \Lambda F_t + e_t \tag{1}$$

where F_t is an r-dimensional column vector of unobserved factors, Λ is a $n \times r$ matrix of factor loadings and $e_t = (e_{1t}, ..., e_{nt})'$ is a vector with dimension n that contains the idiosyncratic components. Factors are driven by a VAR process, formally:

$$F_t = \Phi_1 F_{t-1} + ... + \Phi_k F_{t-k} + \eta_t \tag{2}$$

equivalently, we can rewrite (2) in lag-polynomial notation as

$$\Phi(L) F_t = \eta_t \tag{3}$$

where $\Phi(L)$ is a $k \times r$ matrix of lag polynomials and η_t is an orthonormal r-dimensional vector white noise, that is, $\eta_t \overset{i.i.d.}{\sim} (0, I_r)$. Moreover, it holds that loadings obtained for the model in first differences i.e. $\Delta X_t = \Lambda \Delta F_t + \Delta e_t$ are exactly the same as those in equation (1) when the model is estimated in levels.[2] This equivalence allows us to overcome the difficulties posed by the non-stationary framework without having to impose any heavy restrictions regarding the model. As such, the unobserved factors can be extracted from the differentiated series (ΔX_t) by means of non-parametric averaging methods such as principal components. The usage of this cross-sectional method cleans the influence of the idiosyncratic disturbances given that its weighted averages will converge to zero, hence leaving only the variation associated with the factors.

[2] See Barigozzi et al. (2020) for further details.

The solution hinges upon retrieving the r largest eigenvectors of the variance-covariance matrix of X_t subject to an arbitrary $r \times r$ matrix. This condition can be simply solved by imposing the normalization $n^{-1}\Lambda'\Lambda = I_r$. Note that due to this restriction, factors entail no possible interpretation nor economic reasoning, thus implying some difficulties that we will address in Section 6. Once the loadings have been estimated, one can obtain the unobserved components F_t through the projection of X_t onto the space spanned by the loadings at any moment in time. It follows the least squares estimator of F_t:

$$\hat{F}_t = n^{-1}\hat{\Lambda}' X_t \tag{4}$$

Hence, after obtaining the loadings in first differences, one can easily get factor estimates in levels given the estimator (4) by construction. Whilst other authors have come up with different approaches, the common practice in modelling non-stationary DFMs consists precisely in first differentiating X_t so that stationary series are obtained, and then apply principal components on ΔX_t as it ensures consistent estimates for Λ.

3.2 Unrestricted VAR

After estimating the factors, our second step is to incorporate them in a VAR model. VAR models are the most widely used econometric tool in macroeconomics. This framework will allow us to explore and identify the impact of exogenous demographic shocks, represented by our factors F_t, on a set of macro-variables. Within this context, consider a standard VAR(p) as our benchmark:

$$y_{it} = \alpha_i + A_1 y_{it-1} + ... + A_p y_{it-p} + \beta_1 F_{it-1} + ... + \beta_p F_{it-p} + \epsilon_{it} \tag{5}$$

where y_{it} is a set of macro-variables for country i at time t, p is the number of lags included, α_i is a time-invariant country specific intercept, ϵ_{it} is the reduced-form error term and F_{it} are the unobserved factors estimated in the previous section, which represent the demographic channels as mentioned above.

Alternatively, we build an additional specification where we account for demographics using the age dependency ratio instead. This alternative equation offers the possibility to establish an empirical comparison between the results when the demographic transition is described through our unobserved factors and the ones originated from the usage of the age dependency ratio. We define:

$$y_{it} = \alpha_i + A_1 y_{it-1} + ... + A_p y_{it-p} + \phi_1 DR_{it-1} + ... + \phi_p DR_{it-p} + \varepsilon_{it} \quad (6)$$

where the unique difference to equation (5) is the inclusion of DR_{it} rather than F_{it}, which stands for the age dependency ratio in country i at period t.

Our main interest here, however, is assessing how shocks in each "demographic factor" F_t and in the age dependency ratio affect macro-variables y_t. Therefore, our goal is to estimate the impulse response functions (IRF) for y_t to shocks in η_t and ε_{it}, that, given the standard invertibility assumption in VAR literature, can be interpreted as linear combinations of the structural shocks.

Once we are dealing with non-stationary factors, we can not exclude the possibility of having cointegration relationships within our setting. Sims et al. (1990) proved that an unrestricted VAR in levels is an equivalent representation to a Vector Error-Correction model (VECM), yielding consistent parameters estimates, which in turn allow us to conduct impulse response exercises. In this way, we do not need to address explicitly orders of cointegration among our variables because the unrestricted VAR alone is able to capture any existing cointegration relationships. The unique assumption we have to impose lies upon the stationarity of the VAR residuals. If residuals are stationary, the equivalence between the two representations holds and one can proceed without further assumptions.

4 Data

As previously mentioned, we are interested in decomposing the demographic transition. Given that this is essentially a phenomenon that has been mostly affecting developed countries, we focus on the effects for Japan, the country with the largest share of elderly dependents in the world; the United States; the Euro Area as a block; as well as Portugal and Germany individually, two of the "older" economies in Europe as to their number of old dependents. The inclusion of the latter two countries aims to provide a more precise description of the individual demographic developments within the Eurozone and distinguish possible aggregate trends from country specific dynamics in our sample.

In the first part of our empirical approach, where a factor analysis is performed, we use five demographic variables that best describe the demographic transition. The series span from 1961 to 2018, combining annual data, collected from the Eurostat and the World Bank's World Development Indicators for the age dependency ratio, infant mortality, life-expectancy at birth, fertility rate and population growth.[3] Note that these population variables consider all residents regardless of their legal status or citizenship, thus accounting for immigration. Additionally, by using annual data rather than five-year averages, our representation permits a granular assessment of the concrete interactions between demographics and macro-variables.

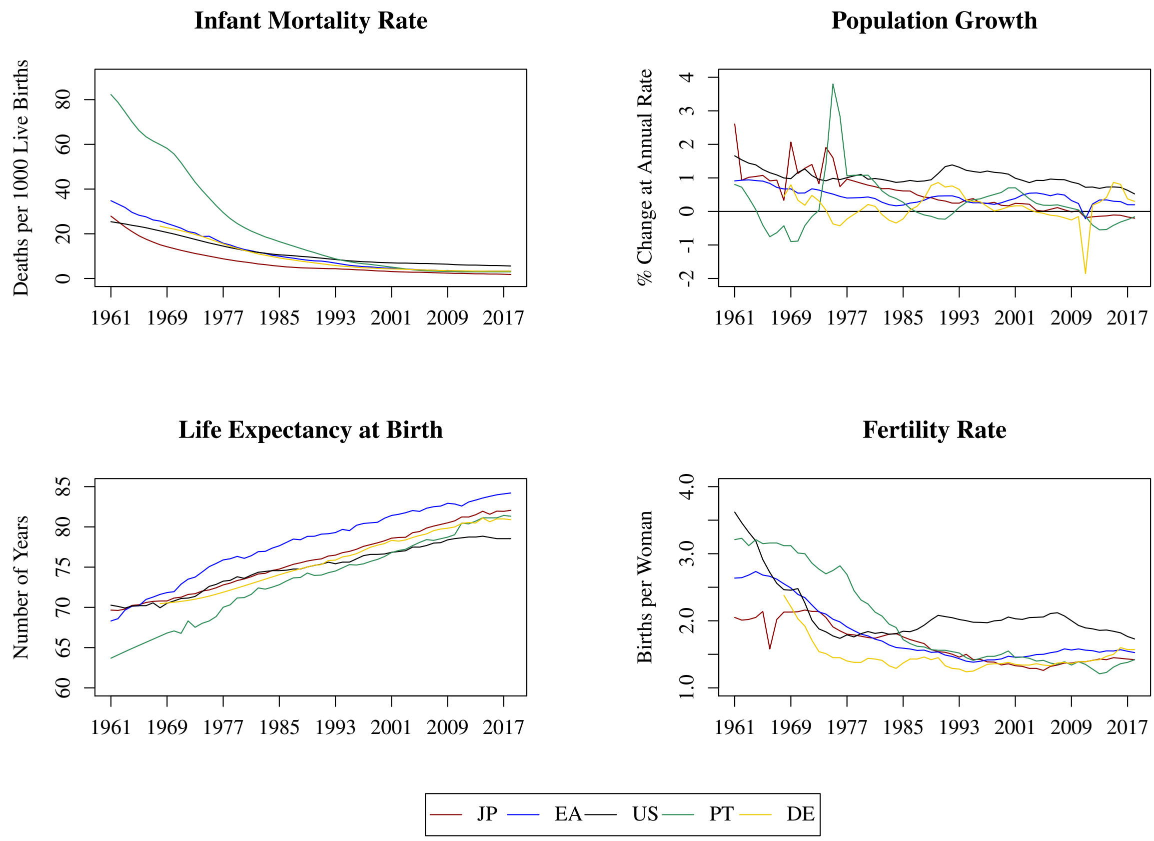

Figure 1: Variables used to describe the Demographic Transition

The years covered in our dataset accompany the evolution of various social processes that contributed to the current ageing trajectories. Children of the 1945 baby-boom started to enter in the job market around the seventies. During this decade, economic and health con-

[3] See data Appendix for further details.

ditions were immensely improved. For example, the steady gains in life expectancy illustrate concretely those improvements. The abundance of labour supply supported by the entrance of the baby-boom generation on economic maturity and by the higher labour-force participation of women, combined with a decay in fertility rates, led to a sharp fall in the number of dependents, ultimately favouring aggregate capital formation and growth. Moreover, Bussolo et al. (2015) argue that dwindling child mortality was the igniting force behind the decline in fertility, later reinforced by the remaining aforementioned developments. Together, these phenomena formed a sort of "demographic snowball" effect that culminated in decades of waning populations and swelling age dependency ratios (Figure 2). Our timespan will be able to capture all these movements in each of the selected variables throughout the years, without being constrained upon a single measure.

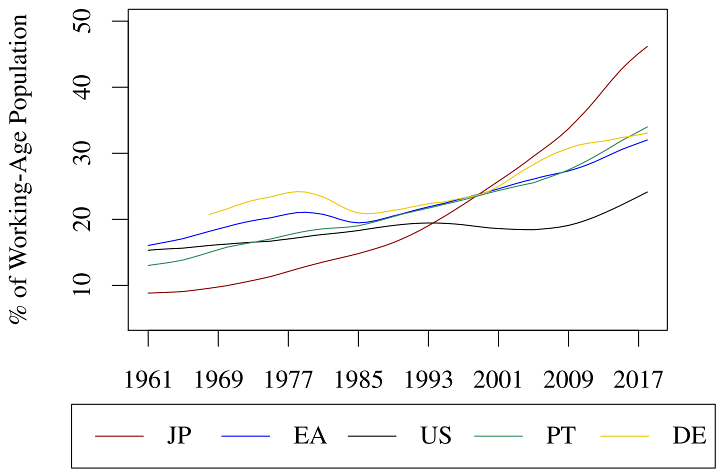

Figure 2: Age Dependency Ratio

With respect to the VAR model, similarly to Aksoy et al. (2019) and Ferrero et al. (2017), we have a vector of seven macro-variables, augmented by demographics as described in equations (5) and (6). For most of the sample, annual data from 1971 to 2018 is used, however, in some cases, data availability forced us to consider a narrower time interval. The variables used are: real GDP growth rate, investment growth rate, short-term interest rate, inflation rate, savings, average hours worked per worker, and finally, to control for global shocks, oil prices per barrel.[4] Apart from oil prices and short-term rates that were retrieved from the Federal Reserve

[4]All series that are not growth rates or shares were logarithm-transformed and then multiplied by one hundred. See Table 3 in Appendix for further details.

of St. Louis' database and the Eurostat, respectively, all data for the VAR was extracted from the OECD.

5 Estimation

Concerning the principal components analysis, we choose two common factors r as our baseline specification. Jointly, these factors account for up to 95% of the total data variance (Table 1). As such, the selection of r did not rely on any formal information criterion given that two factors explained almost the entire data variability. Similarly to what Corsetti et al. (2018) do, Figure 9 in Appendix compares the actual demographic data and the fitted series derived from the extracted factors. Our intuition is reinforced by these predicted series as they closely trace the majority of the movements in demographics. For some variables, the prediction is nearly perfect.[5] Moreover, considering that it takes two factors to capture the bulk of the variance in the data, our reasoning regarding the age dependency is confirmed. If a single variable were sufficient to explain the demographic transition, one would expect the first factor to account for the largest proportion of the series variance.

Besides, Table 2 in Appendix presents the R-squared obtained from regressing the demographic series on each factor. Despite the impossibility of a direct factor interpretation, this table offers a decent correlation measure between factors and the concrete demographic variables behind them. In general, Factor 1 seems to be more related with life expectancy, infant mortality and the age dependency ratio. Factor 2, on the other hand, is linked with population growth in Germany and Portugal, with infant mortality in Japan and the Euro Area and with the age dependency ratio in the US, Euro Area and Portugal. Note that, albeit both factors showed substantially different correlations across variables and countries considered, individually they are able to explain a sizeable fraction of the five variables. We will address factor interpretability more in depth in Section 6.

Regarding the Vector Autoregressive model, it is important to note that we have annual data at best from 1971 until 2018. In some cases, such as the Euro Area, data is only available from 1997 onwards. Hence, our narrow time horizon will not allow the inclusion of several

[5] See Figure 9 in Appendix.

lags. Notwithstanding this constraint, we analysed the optimal number of lags for our model following Akaike, Hannan-Quinn and Bayes Information criterion. Across our panel of countries, criteria indicated for each of the two specifications either four or five lags. Thus, due to sample time restrictions, we implement a model of order one for both specifications, similarly to Aksoy et al. (2019) and Ferrero et al. (2017).

Additionally, in the VARs for the Eurozone at aggregate level, we excluded savings as its first observation was in 2002. Because of this further observational reduction, our model could not be properly estimated. In this way, we refrained from imposing such a heavy time restriction and run our model without data for savings, which in turn, allowed us to use a wider timespan.

Finally, we tested the stationarity of the residuals, using the Augmented-Dicky Fuller test. All residuals are stationary at a 5% threshold level. Therefore, we can proceed without formally testing for cointegration since the equivalent representation between a VAR and VECM holds.

	Factor 1	Factor 2	Cumulative
Japan	0.5369	0.3132	0.8501
United States	0.6782	0.1714	0.8497
Euro Area	0.8188	0.1296	0.9485
Portugal	0.8827	0.05873	0.9414
Germany	0.4690	0.2442	0.7132

Table 1: Proportion of the variance explained by two factors

6 Results

In this section we present our empirical findings, starting with the benchmark VAR where demographics were defined by means of our two estimated factors, and subsequently inspecting the alternative specification for the age dependency ratio. Note that factors do not have any straightforward meaning nor any possible interpretation. This issue, however, poses no difficulties in terms of analysis. We overcome this interpretability constraint by scaling shocks in each factor to the age dependency ratio. Then, we measure how our set of five demographic variables reacted individually to a shocks in the unobservable latent factors. These solutions allow us to identify and relate factor variations to deviations in concrete variables, therefore providing a clear and accurate measure to unravel demographic shocks in our baseline model. Due to the persistence of demographics, cumulative IRFs were computed for every specification. Shocks were defined to a one standard deviation, with its 68% confidence bands being obtained via bootstrapping.

6.1 Benchmark VAR

We undertake our result description by presenting the impulse responses for Germany, Portugal, Japan and the United States. Since the model for the Euro Area as a block was built without savings, we present its main results separately in Figure 7. Our initial assessment focus is on shocks in the first of the two extracted factors for five variables selected from the VAR.

Figure 3 shows the percentage responses to a one standard deviation shock in Factor 1 for the interest rate, inflation, GDP growth, savings and investment.[6] At a first glance, shocks generate heterogeneous reactions within our sample and no variable reacts contemporaneously. Inspecting the interest rate outlet, overall cross-country effects are negative. Germany registers at maximum a 1.5 percentage points drop, whereas Portugal denotes a neutral response in this channel. Notably, Japan has the sharpest drop in inflation as well as in terms of GDP growth, about 1.5 and 0.8 percentage points respectively. These results prove empirically how demographics have exerted deflationary and contractionary pressures upon the Japanese economy.

Apart from the rate of interest, Japan exhibits the largest falls in the considered set of macro-variables, thus confirming its long-standing stagnant trends. It is noteworthy that when compared with the United States and Germany, the Japanese responses largely exceeded the reactions of its peers among the world's largest economies. Nevertheless, even though estimates here depicted are asymmetrically distributed, primarily they illustrate the importance and influence of demographic shocks in the economy. Our estimation demonstrates statistically and economically significant effects originated by these unexpected shocks in the age structure. Regarding savings and investment, there is a remarkably clear disparity between Germany, which reveals after an initial decrease, a surge in these two variables, and the remaining countries, that

[6] See Figure 10 for all the impulse responses of average hours worked.

display negative outcomes. In the Portuguese case, investment denotes a moderate response, not differing very much from what occurs with respect to the interest rate. Average hours worked, shown in Figure 10, decline in every country.

Finally, the first row of Figure 7 presents the main findings for the Euro Area. Here, broadly speaking, responses are more irregular than the ones described above. Overall effects are identical, we highlight particularly the significant movements caused upon GDP, investment and interest rate. The unique difference lies on the rise of inflation, which in turn, tends to zero after six periods.

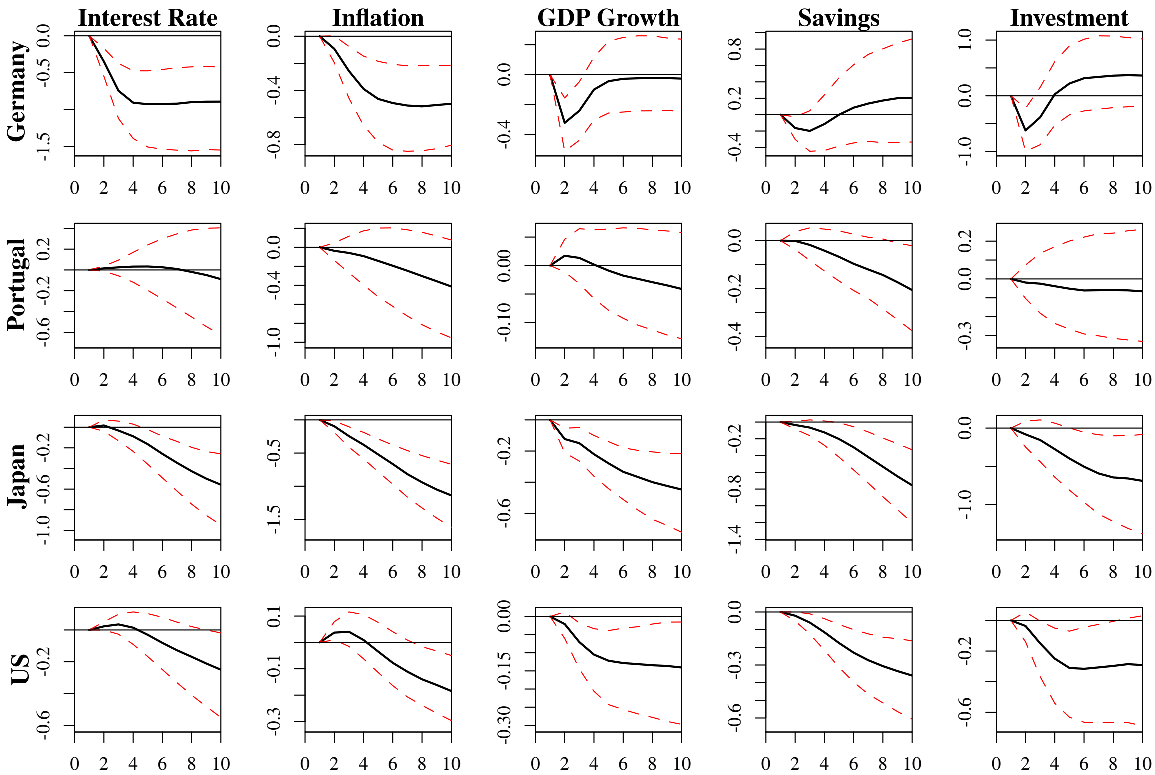

Figure 3: Percentage responses to a one standard deviation shock in Factor 1. Note: dashed lines report the 68% bootstrap confidence bands.

Given this setting, we complete our reasoning following the responses of the demographic variables resulting from the shock in Factor 1. Figure 4 contains the demographic reactions associated to a shock in Factor 1. As we stressed before, this approach solves the interpretability issue created by the inclusion of latent factors.

This figure features several surprising results, namely the neutrality of the age dependency ratio in the United States and its downward trajectory for Japan. Furthermore, population growth for the Euro Area, the United States and Portugal remains almost unchanged. Common to every country, however, is the steady increase in life expectancy and the decline in infant mortality. These two indicators were very responsive to the shock, similarly to the estimates in Table 2. Also, aside from the Euro Area, fertility rate also describes a dwindling response.

Results shown here decompose the demographic transition, thereby simulating the demographic movements behind this factor. As can be observed, the substantial deflationary and contractionary pressures outlined in Figure 3 are mostly related across our sample to steeply rises in life expectancy and decaying infant mortality alongside fertility rates. Therefore, this intuition is in accordance with recent literature on the gloomy consequences of the demographic transition and supports the secular stagnation hypothesis. Besides, the age dependency ratio exhibits as well significant upward responses, yet for Japan and the United States its role is contrary to what we expected. Hence, this latter result reinforces our reasoning regarding it. Notwithstanding its importance, some evident limitations prevent it to capture properly all the population developments. If that was the scenario, one would expect to see promptly soaring age dependency ratios in Figure 4 as a consequence of, for instance, an increase in longevity.

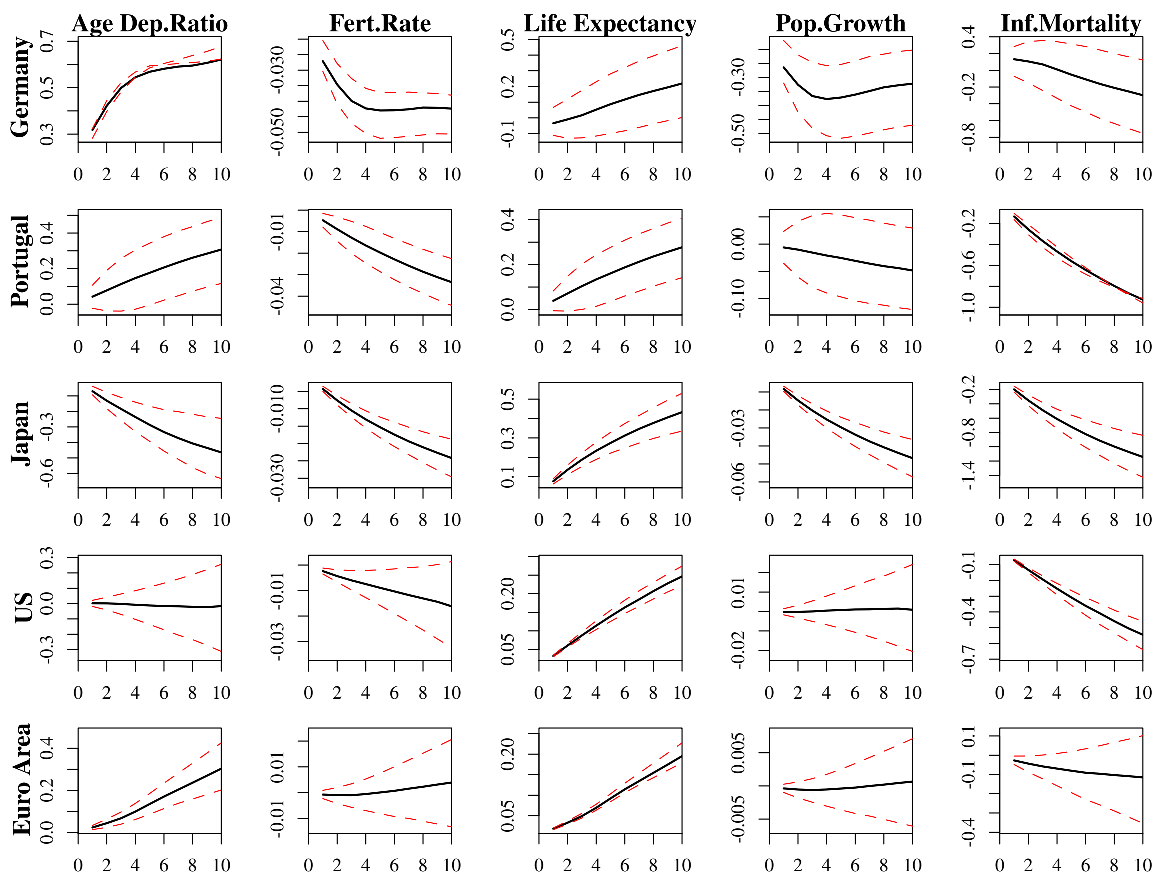

Figure 4: Demographic responses to a one standard deviation shock in Factor 1. Note: dashed lines report the 68% bootstrap confidence bands.

Moving on to the results of Factor 2, Figure 5 presents the responses to a shock in our second "demographic" factor. Taking a closer look, once again there is a considerable degree of heterogeneity among the sample. Denote as well the significant contrasts when comparing with the reaction derived from Factor 1. Firstly, opposite trajectories depending on the factor that is being shocked proves the idea that these demographic phenomena may provoke contradictory forces in various economic outlets.

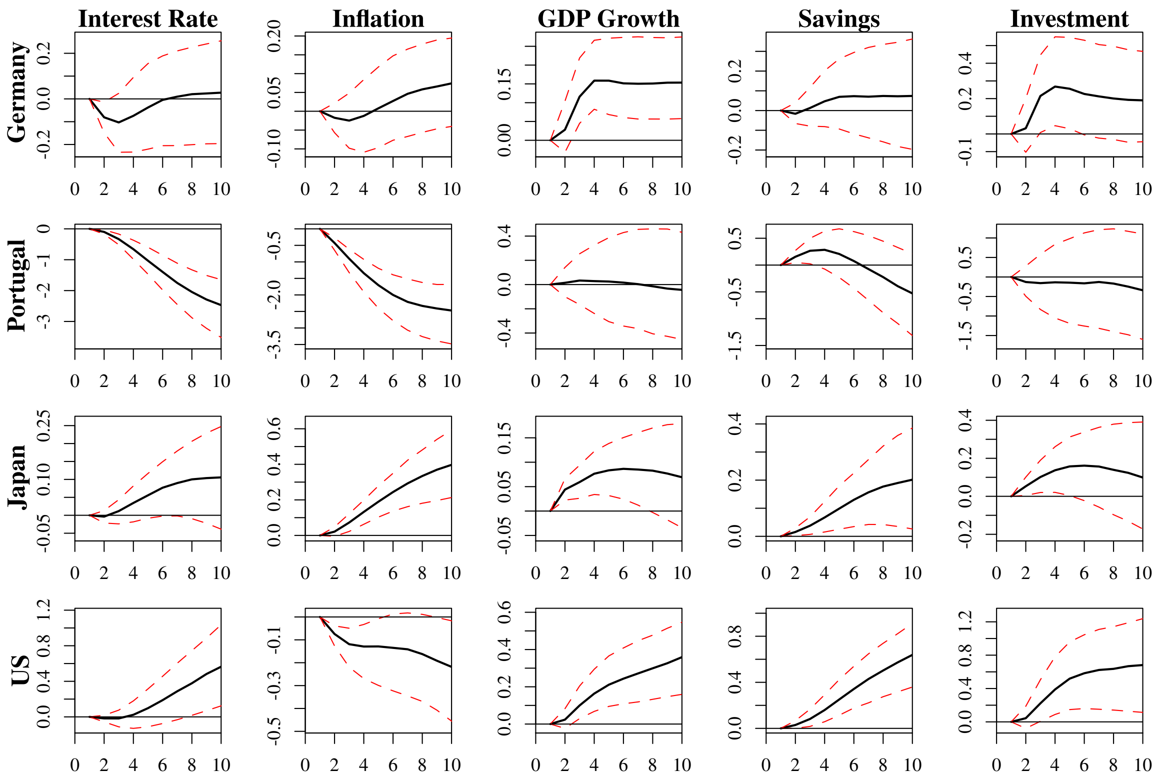

Figure 5: Percentage responses to a one standard deviation shock in Factor 2. Note: dashed lines report the 68% bootstrap confidence bands.

Concerning interest rates, the response is positive for the United States. Japan also exhibits an increasing effect despite smaller, while Germany shows very little deviations, converging to zero after four periods. Portugal, on the other hand, outlines an enormous 3 percentage points plunge into negative territory. Inflation decreases in the US and in Portugal, in spite of the upward response in Germany, and curiously, in Japan. In terms of GDP growth, shocks affect output positively in all countries except for Portugal, which does not suffer any considerable variation. We emphasize particularly the maximum 0.5 percentage points response in the United States. Looking at savings and investment, depicted in the final two columns, both reveal an inverse reaction in comparison with the scenario where we analysed a shock in Factor

1. These variables indicate positive effects, with Portugal being the unique exception. Here, let us underscore the large reactions in the United States and the stable path registered in Germany after an initial surge. Lastly, hours worked for this case, increased in Germany and in the US, denoting small deviations in the remaining countries after ten periods.

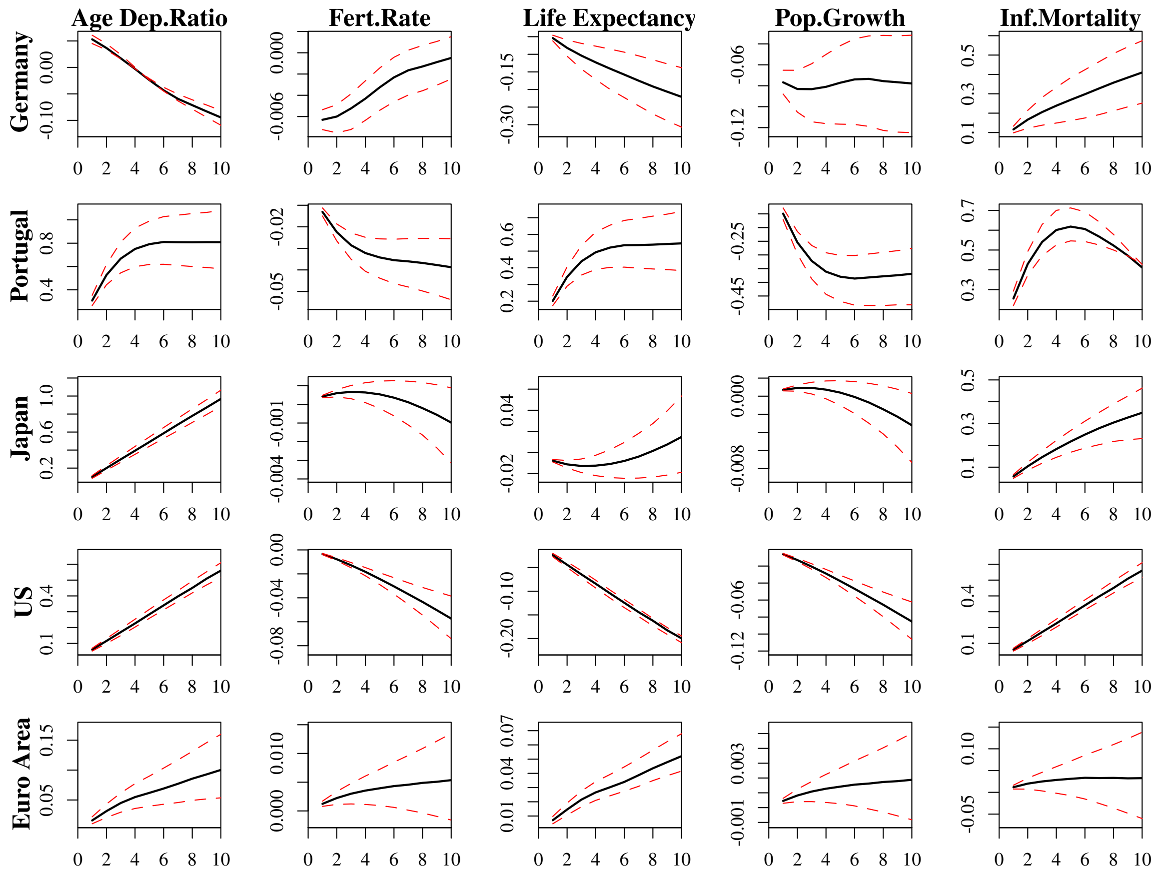

Figure 6: Demographic responses to a one standard deviation shock in Factor 2. Note: dashed lines report the 68% bootstrap confidence bands.

Looking at the second row of Figure 7, once again, one can observe irregular responses to a shock in Factor 2 for the Euro Area as a block, relatively to impulse responses assessed above. On top of this, the rate of interest remains almost unchanged whilst inflation drops by a maximum of 0.15 percentage points. With respect to GDP growth and investment, responses are nearly indistinguishable. Nevertheless, the latter points to larger effects.

Analysing the demographic framework, Figure 6 illustrates variations associated with shocks in Factor 2 for our set of five demographic variables. In this setting, the age dependency ratio is more responsive, even though in the case of Germany the response is negative. Indeed, results for Germany are quite surprising given that they show opposite signs to what one would expect to see. Identically unexpected estimates are obtained for life expectancy in the United States as well as for infant mortality in our sample, excluding just the Euro Area case. Fertility ratio decays in Portugal, Japan and in the United States and life expectancy increases for Portugal, Japan and the Eurozone. In general, this factor seems to be mostly linked with a fall in population growth and a surge in the age dependency ratio. Hence, from these results, we can relate these population changes to expansionary economic trajectories.

It is noteworthy that the resulting effects from a shock in Factor 1 exceed the responses caused by a shock in our second factor. Contractionary forces as a direct consequence of population shifts seem to prevail across our sample. This finding is in line with recent literature, proving that the demographic transition contributed to a decline in the interest rate, inflation, output growth and average hours worked. Only the United States appears to have avoided these pressures, denoting combined increases in the interest rate, GDP growth and investment resulting from the two shocks. From our findings, we observe that shrinking active populations and more old dependents due to higher longevity reflected into the negative responses on average hours worked. The overall decline in investment and in the interest rate is also particularly remarkable, since it is consistent with the lack of investment and the consequent lower natural rate pointed by Hansen (1939) and more recently by Summers (2014). Savings, on the other hand, do not evidence any clear saving glut as Bernanke (2005) and Summers (2014) suggested. Nevertheless, our estimates are aligned with Aksoy et al. (2019) projected long-term slump in savings. In addition, some of these changes appear to be modestly correlated with the age dependency ratio, therefore sustaining our reasoning that long-standing demographic trends are a conjunction of several social developments.

As a validation of this method, and given that countries such as Germany and Portugal experienced extraordinary events during the years covered in our sample that might have inducted structural breaks (e.g. German reunification, adherence of the Euro etc.), we included time dummies in our model to address for endogeneity concerns. This robustness check reassured the validity of our results. Responses for Germany exhibited a slight decrease. Contrarily, in Portugal the effects were amplified.

Additionally, we run the model including just the first factor and then conduct the respective impulse responses to assess whether this factor alone would describe adequately the link between demographics and macroeconomic trends. Responses yielded were acutely identical as those in Figure 3, only their magnitude revealed minor changes.

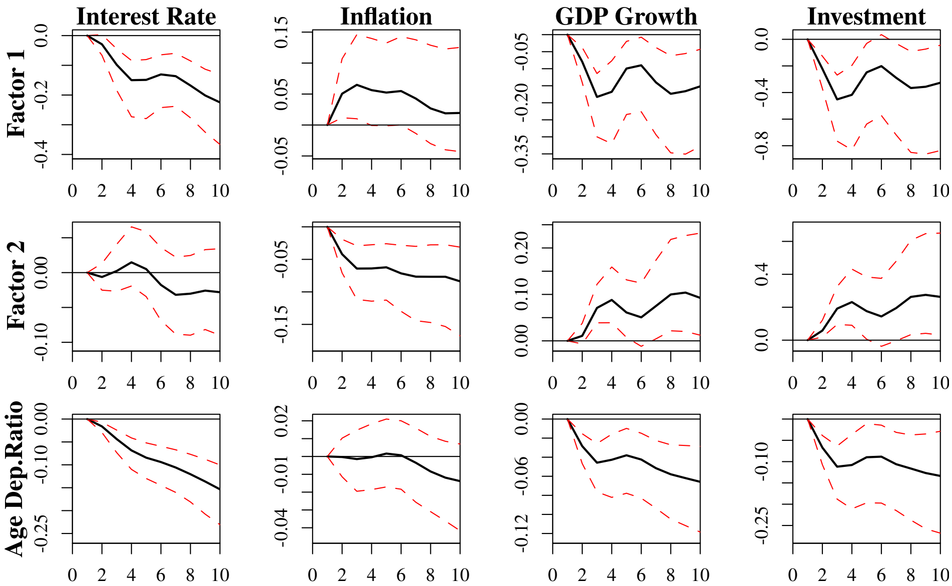

Figure 7: Percentage Responses for the Euro Area to a one standard deviation shock in Factor 1, Factor 2 and in the age dependency ratio. Note: dashed lines report the 68% bootstrap confidence bands.

6.2 Alternative Specification: Age Dependency Ratio

At last, we analyse our second specification where the age dependency was introduced to describe the demographic transition rather than our unobservable factors. We point out that if this variable were the silver bullet to represent recent population developments, we would expect it to illustrate precisely current economic dynamics.

Figure 8 contains the impulse response functions for the same variables assessed before, but now to a shock in the age dependency ratio. Responses feature high levels of cross-country heterogeneity. Note as well that for the Euro Area (third row of Figure 7) the reactions are smoother and more stable than in the earlier analysis. The reaction upon the interest rate is negative in all countries. Looking at inflation, Germany and Japan show positive responses, though in the case of the latter, the effect was quite modest. GDP reflects minor changes in the United States and Portugal, whilst Germany and Japan describe descending paths. Similarly, investment demonstrates rather identical movements as GDP. Regarding hours worked (Figure 10), the United States and Germany are the only two exceptions to a general fall in this labour market indicator. Lastly, savings rise significantly in Germany and fall in the rest of the sample.

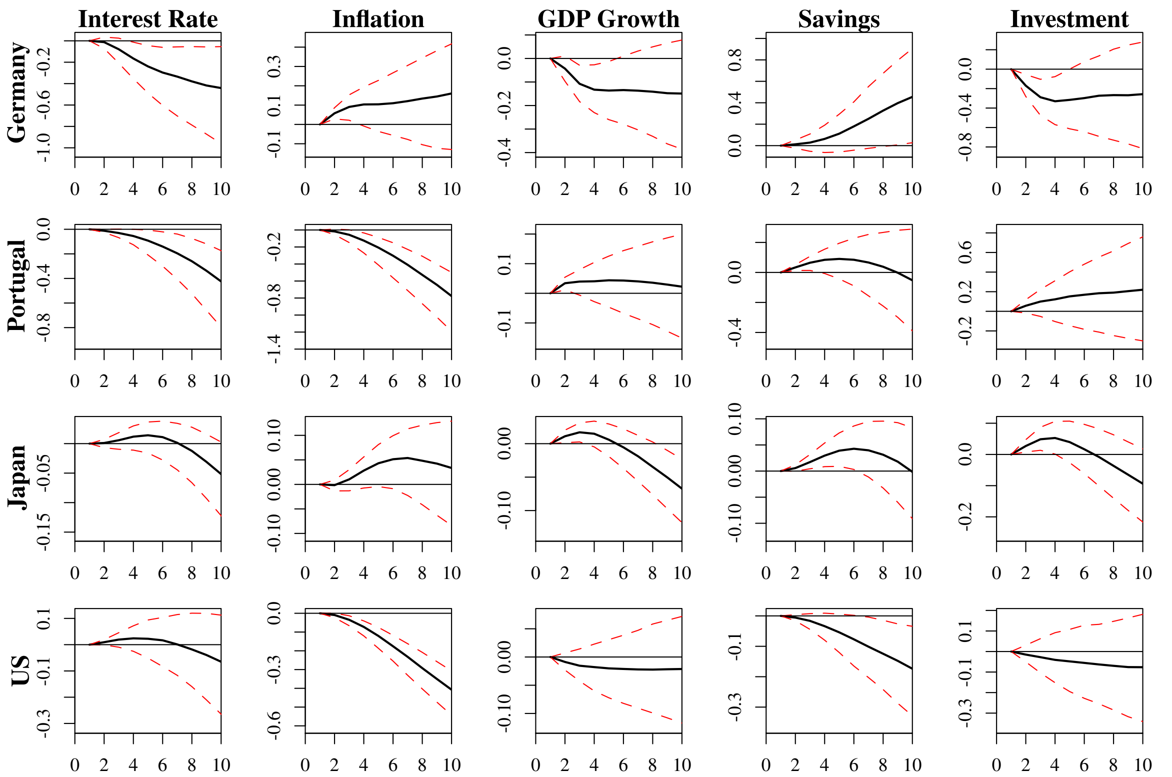

Figure 8: Percentage responses to a one standard deviation shock in the Age Dependency Ratio. Note: dashed lines report the 68% bootstrap confidence bands.

In order to compare these responses with those derived from our factors, we run our benchmark model again and obtain the impulse responses normalised by the size of the shock in the age dependency ratio, that is, one standard deviation as depicted in Figure 8. Since shocks will be equivalent, this solution allows us to relate explicitly age dependency ratio responses implied by a shock in our factors with the ones estimated for the dependency ratio specification, thus permitting a clear interpretation between the two measures. To do so, we selected the factor most correlated with the age dependency ratio for each country,[7] and then estimate its responses considering the size of interest.

Figure 11 and 12 in Appendix illustrate the responses implied by shock in the selected factor, equivalent to the shock in the age dependency ratio model (i.e. one standard devia-

[7]We chose Factor 1 for every country apart from the US, where we used Factor 2 due to the implicit neutral age dependency ratio response of Factor 1 shown in Figure 4.

tion). Demographic changes here projected are very identical, but smaller when compared with the results from our first specification. More importantly, we note that these effects did not match the responses for the age dependency ratio VAR, shown in Figure 8. For instance, when the response in the age dependency ratio associated with a factor shock has the same size as when we shock the dependency ratio alone, interest rate and GDP in Japan dropped respectively by a maximum of 1 and 0.8 percentage points for the first scenario. Whereas on the second, responses for both variables fell just 0.12 percentage points. Identical gaps between the two measures were estimated for the remaining countries and variables. As stressed above, responses are substantially different in terms of magnitude and sign from the ones estimated in the model for the age dependency ratio. We quantified the average difference between the these two scenarios for our sample in Table 4 in Appendix. Broadly speaking, reactions to factor shocks outstripped on average the responses in the age dependency ratio case, ranging from -0.13 to 0.64 percentage points.

With that being said, the age dependency seems to offer an insufficient measure for the demographic transition. Consequently, our intuition as well as our previous findings for the baseline VAR are validated by these results. Although one variable is not enough to describe recent population trends, our analysis shows that two variables, more specifically the two estimated unobservable components, are able to quantify and characterize much more appropriately the effects of the demographic transition.

7 Conclusion

The aftermath of the Great Recession has been unanimously anemic in the advanced world. The crisis itself only aggravated some previous chronic trends that were already dragging developed economies towards a secular stagnation steady-state, characterised by subpar output growth, binding effective-lower bound and persistent below target inflation. Even though this "new normal" is still positive, it carries unmitigated undesirable implications, namely for monetary policy. At the same time, these economies are undergoing a severe five-decade long demographic transition. Given the importance of the age structure in determining life-cycle consumption-saving decisions, demographics emerge as a natural possible explanation for the slowdown in growth. This outlet was particularly underlined in Hansen's seminal hypothesis and whereas other structural trends may be difficult to forecast, demographic developments are acutely persistent, hence easily predictable.

In spite of this wide recognition, the role of demographics upon economic progress remains unclear. Over the last few years, there has been a remarkable increasing interest and effort in studying accurately the transmission channels of population shifts, however, empirical evidence is still less compelling. Moreover, it is common to rely on a single measure to describe changes in age cohorts, while these phenomena are a combination of various asymmetric developments. Thus, our aim was to provide further evidence and decompose the outlets through which demographics might contribute to secular stagnation.

Our results contribute to the literature by demonstrating that there are necessary two factors to explain virtually the entire variance of the demographic data, therefore proving that a single variable is not sufficient to trace recent demographic movements. Among our findings, we emphasize that the demographic transition has significant impacts upon GDP, inflation, interest rate, savings, investment and hours worked across our entire sample. Moreover, based on data since the seventies, we show that demographic changes have exerted strong deflationary and contractionary forces in Japan, Euro Area, Portugal and Germany. These findings support empirically the secular stagnation hypothesis and are consistent with recent literature on the influence of ageing on long-run growth. Only the United States seems to have avoided large overall depressing effects. This conclusion is not surprising because of the panel of countries analysed, the US were and are expected to be the least affected by ageing and tumbling population growth. Results obtained are robust to both global shocks and various time effects, namely historical events that could have constituted a source of endogeneity to our model.

To conclude, we would like to stress the necessity for further research regarding the effects of ageing. Our results offer an entirely different perspective for assessing the contribution of demographics to macroeconomic trends. Hence, our analysis can be widely applied in future research to adequately inspect demographic outlets. Particularly, we consider that the influence of ageing on technological progress and on labour markets should be precisely decomposed in order to better understand how demographics affect economic trajectories. In addition, it would be interesting to investigate how different economic theories on the impact of population shifts relate to our two factors. This analysis is of utmost importance given that these trends are not easily reverted. Beyond constraining our capacity to respond to future cyclical downturns and ensure macroeconomic stabilization, demographic changes pose a serious structural conundrum for policymakers, putting at stake the sustainability of fiscal policy decisions, thus leaving a heavy burden for future generations.

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Appendix

Factor Predictions

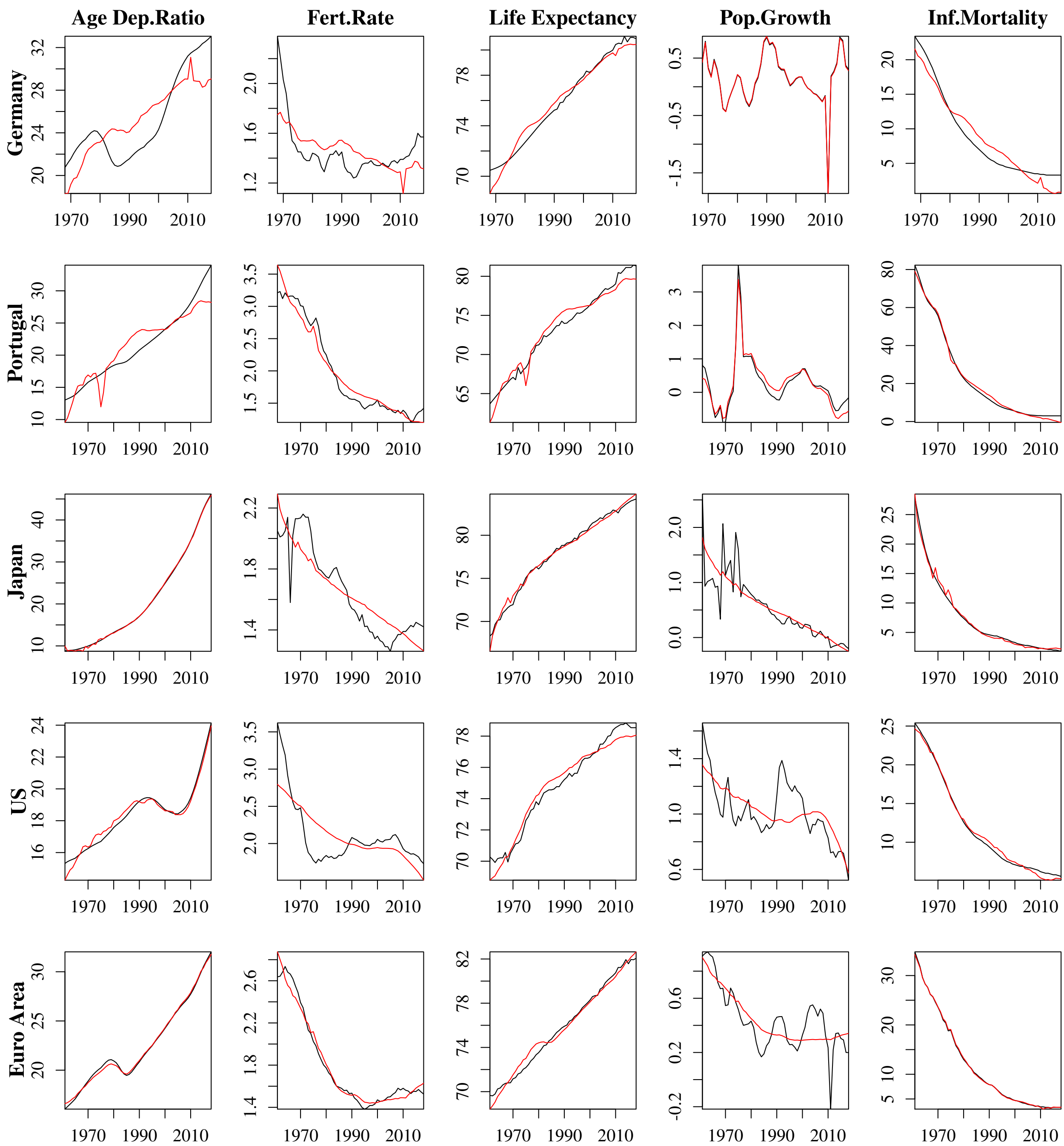

Figure 9: Factors explanatory power. Comparison between the demographic variables (black lines) and the predicted series (red lines) fitted from the two extracted factors for our sample.

Factor Interpretation (R-squared)

	Germany		**Portugal**		**Japan**		**United States**		**Euro Area**	
	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2
Age Dependency Ratio	0.61	0.02	0.77	0.52	0.85	0.00	0.80	0.77	0.80	0.98
Fertility Rate	0.34	0.05	0.94	0.39	0.76	0.15	0.54	0.27	0.85	0.34
Life Expectancy	0.96	0.00	0.92	0.49	0.99	0.20	0.95	0.29	0.94	0.86
Population Growth	0.02	0.99	0.00	0.68	0.75	0.14	0.41	0.38	0.60	0.27
Infant Mortality	0.92	0.00	0.99	0.27	0.85	0.48	0.98	0.28	0.98	0.55

Table 2: R^2 retrieved from the linear regression of the demographic series on each factor.

Dataset

This section of the Appendix contains a complete and detailed description of the dataset used. All series are annual and span from 1961 to 2018. Demographic data for Germany starts in 1968. Data used in the VAR for the United States and the Euro Area is respectively available from 1973 and 1997 onwards.

Transformation code:

1-No transformation

2-First difference

4-Logarithm

5-First difference of logarithm

Note: logarithmized series were multiplied by one hundred.

Description	Source	Transformation	Start	End
Demographic Variables				
Age Dependency Ratio, % of working age population	World Bank	1	1961	2018
Fertility Rate, births per woman	World Bank	1	1961	2018
Life Expectancy at Birth, number of years	World Bank	1	1961	2018
Population Growth, % change at annual rate	World Bank	1	1961	2018
Infant Mortality, number per 1,000 live births	World Bank & Eurostat	1	1961	2018
Macroeconomic Variables				
Investment (Gross Fixed Capital Formation), % annual growth rate	OECD	1	1971	2018
Savings, % of GDP	OECD	1	1971	2018
Hours Worked per Worker, annual average	OECD	4	1971	2018
GDP at market prices (2015=100), annual growth rate	OECD	1	1971	2018
Inflation (CPI), % annual change	OECD	1	1971	2018
Nominal Short-Term interest rate % annual change	Eurostat	1	1971	2018
Oil Price (WTI), average annual price per barrel	FRED	4	1971	2018

Table 3: Data description.

Impulse Responses for Average Hours Worked

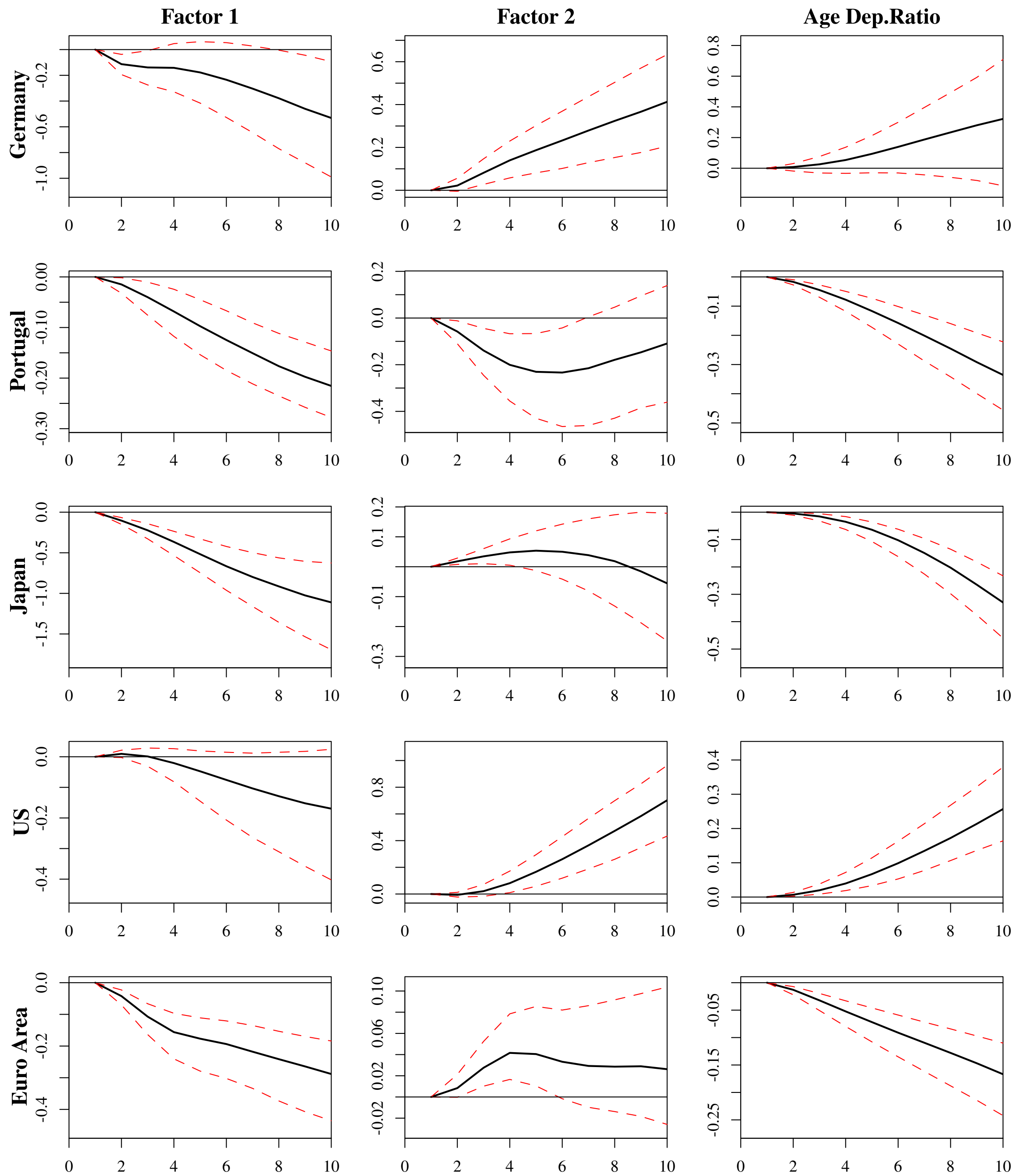

Figure 10: Percentage responses in the average annual hours worked per worker to a one standard deviation shock. Note: dashed lines report the 68% bootstrap confidence bands. Columns represent respectively the responses to a shock in Factor 1, Factor 2 and in the age dependency ratio.

Normalised Responses

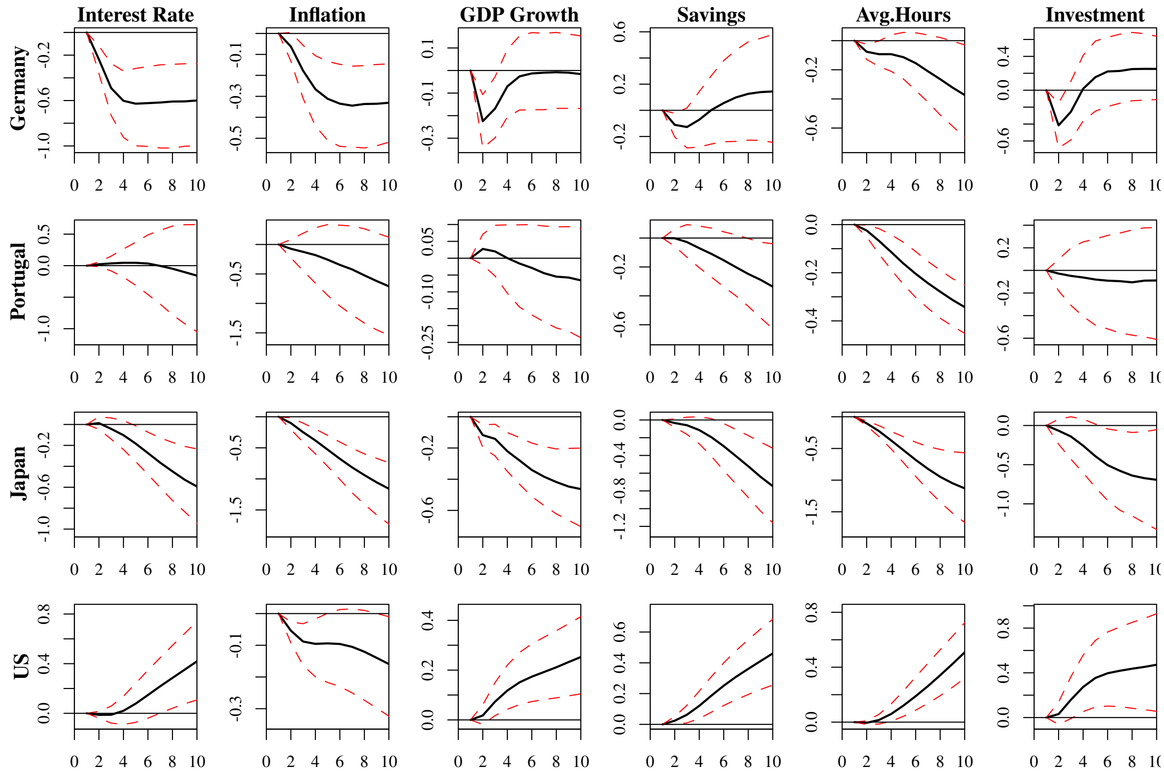

Figure 11: Percentage responses normalised by the size of the age dependency ratio shock. Note: dashed lines report the 68% bootstrap confidence bands.

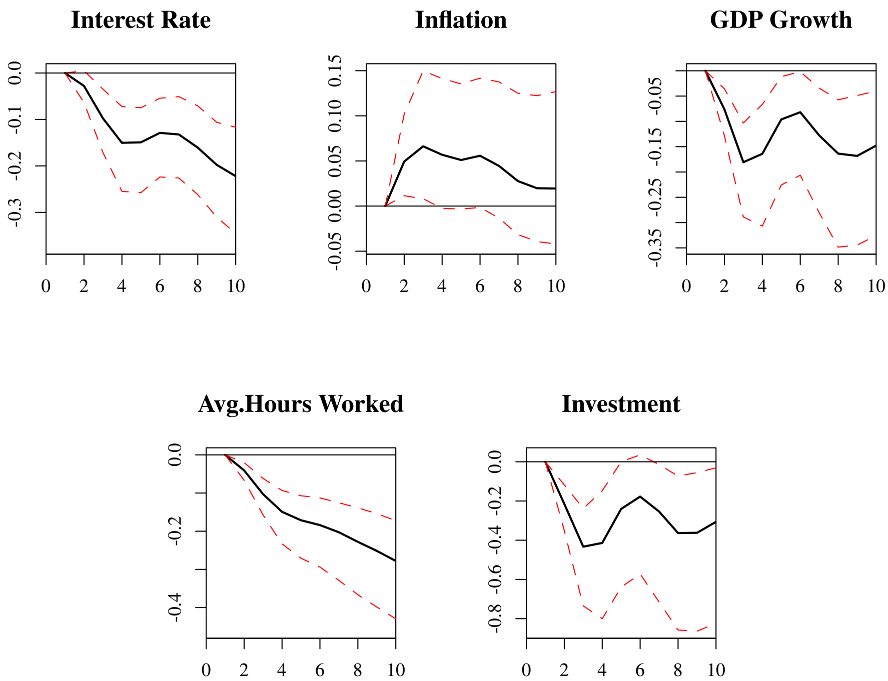

Figure 12: Percentage responses normalised by the size of the age dependency ratio shock for the Euro Area. Note: dashed lines report the 68% bootstrap confidence bands.

Variable	Germany	Portugal	Japan	US	Euro Area
Interest rate	0.251	-0.133	0.278	0.161	0.042
Inflation	0.153	0.004	0.641	-0.099	0.035
GDP Growth	-0.073	0.002	0.273	0.131	0.081
Savings	-0.101	0.113	0.334	0.164	—
Hours Worked	0.049	0.368	0.500	0.108	0.084
Investment	-0.054	-0.080	0.375	0.244	0.193

Table 4: Average absolute difference between an equivalent shock in one of our factors and the age dependency ratio.
Note: we chose Factor 1 for every country apart from the US, where we used Factor 2 due to the implicit neutral dependency ratio response of Factor 1 shown in Figure 4.