Population Ageing and Future Demand for Old-Age and Disability Pensions in Germany - A Probabilistic Approach

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Comparative Population Studies
Vol. 47 (2022): 87-118 (Date of release: 22.03.2022)

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Abstract: Industrialised economies are experiencing a decline in mortality alongside low fertility rates – a situation that puts social security systems under severe pressure. Population ageing is associated not only with longer periods of pension claims but also smaller cohorts eventually entering the labour market. This threatens the sustainability of pay-as-you-go social security systems for implementing or further improving appropriate reform measures; adequate forecasts of the future population structure are needed.

We propose a probabilistic approach to forecast the number of pensions in Germany up to 2040. Our model considers trends in population development, labour force participation, and early retirement, as well as the effects of pension reforms. Principal component analysis is used to manage the high degree of complexity involved in forecasting trends in old-age and disability pension claims, which arises because of cross-correlations between old-age and disability pension rates, different age groups, and gender. Time series methods enable the inclusion of autocorrelations of the pension rate time series in the model. Monte Carlo simulation is used to quantify future risk. The latter is an important feature of our model, as the future development of the population and, eventually, the pension claims and the financial burden resulting from those claims, are highly stochastic.

The model predicts that, in the median trajectory, the number of old-age pensions will increase by almost 5 million between 2017 and 2036, alongside increases in the number of disability pensions by 2036. These numbers take account of the increase in legal retirement ages as part of the 2007 pension reform. After the mid-2030s, however, a moderate decrease can be expected. The results show a clear need for further reforms, especially in the medium term.

Keywords: Population ageing · Stochastic forecasting · Principal component analysis · Time series analysis · Applied econometrics · Public pension systems · Social policy

Federal Institute for Population Research 2022

URL: www.comparativepopulationstudies.de
DOI: https://doi.org/10.12765/CPoS-2022-05
URN: urn:nbn:de:bib-cpos-2022-05en6

1 Introduction

Countries with low fertility and decreasing mortality rates struggle with an ageing population structure and negative natural population growth (*OECD* 2018). Decreasing mortality means longer periods of pension claims as long as retirement ages are not adjusted proportionally to the increases in life expectancy. *Ceteris paribus*, low fertility results in a smaller workforce in the long run (*Zuchandke et al.* 2014). In Western Europe, for instance, mortality has been decreasing almost monotonically since the 1970s (*Vanella* 2017); throughout the same period, fertility has been rather low (*Vanella/Deschermeier* 2019). For countries applying a Bismarck-type pension system (pay-as-you-go),[1] such as Germany, the financial distress resulting from this particular demographic development is twofold: the elderly are at increased risk of suffering from old-age poverty, while a growing share of labour income generated by the working population has to be transferred to the elderly (*Goffart* 2018). Demographic ageing, combined with pay-as-you-go schemes, thus affects the financial sustainability of pension systems if such a trend is not averted by policy reforms.

At approximately 63 percent, public pension payments constitute the largest share of retirement income in Germany (*Federal Ministry of Labour and Social Affairs* 2019). Therefore, future old-age income will depend heavily on changes in the size and structure of the population, which are essential for the financial stability of German Pension Insurance (Deutsche Rentenversicherung, DRV). The DRV should ensure a certain living standard for its pensioners while not overburdening the working population with excessively heavy contributions to the pension system (*Vogt* 2017).

Since potential pension reforms should be based on new and adequate forecasts of the future development of the DRV (*Zuchandke et al.* 2014), this paper provides a stochastic forecast of the year-end old-age and disability pensions for Germany up to 2040. We define the notion of age- and sex-specific pension rates (ASSPRs) by dividing age- and sex-specific pension numbers by the corresponding official population estimates for people living in Germany. We use principal component analysis (PCA) for dimensionality reduction and consideration of cross-correlation between the ASSPRs, and the connections with retirement, disability, and legal retirement age are covered as well. Time series models include autocorrelation of the ASSPRs. Combined with a fully probabilistic population forecast model developed in earlier studies (*Vanella* 2017; *Vanella/Deschermeier* 2018, 2019, 2020), a forecast of the future numbers of pensions is drawn up. The model takes trends in labour force participation and early retirement, along with demographic trends such as decreasing mortality and morbidity, into consideration implicitly by time series analysis. The effects of previous pension reforms are captured by an econometric model in the forecast. The simulation returns distributions of

[1] Pension payments are redistributed from the labour force to pensioners within the same period (see, for example, *Graf von der Schulenburg/Lohse* 2014).

the old-age and disability pensions by age and sex of the recipients. Predicting the future distribution of pensions (instead of relying on specific scenarios under predefined conditions) allows for additional insights, as we derive a large number of possible future outcomes from the historical data available and then quantify the probabilities of these outcomes taking place (*Vanella/Deschermeier* 2020). This allows readers, such as pension experts and policy-makers, to tailor necessary reforms to the specific needs of German pensioners as well as future pensioner cohorts.[2] Deterministic approaches, in contrast, only present a limited number of scenarios without knowing their expected probability (*Keilman et al.* 2002). *Vanella* and *Deschermeier* (2020), for instance, show that a stochastic forecast of the population in Germany in the median scenario is not necessarily more accurate than an informed deterministic approach, but is more likely to also cover the real, perceived population development.[3]

The remainder of this paper is structured as follows. The next section presents an overview of German pension reforms since the 1980s. We will then describe the method and data used for our analysis and present a selection of the results generated by our forecast. The model is applied to Germany but is in principle applicable to other countries as well, especially those that adopt a Bismarck-type social security system. The paper will conclude with a discussion of the results and limitations, and provide an outlook regarding opportunities for further research.

2 German pension insurance and its demography-related reforms

Demographic ageing puts pension systems under pressure. This is not solely a problem of the German economy but is also recognised by other industrialised countries which are hit similarly hard or even harder than Germany by demographic trends. Countries with low fertility and decreasing mortality, such as Italy (*Baldacci/Tuzi* 2003), Spain (*Spijker et al.* 2020), Japan (*Ogawa* 2005), Finland (*Koissi* 2006), China (*Wang et al.* 2019), and Croatia (*Tomaš* 2020),[4] have recognised the need for, and have been discussing the possibility of pension reforms. Indeed, many countries have already introduced demography-related parameters in their pension schemes. For instance, Denmark, Finland, France, Greece, Italy, the Netherlands, and Portugal have already introduced automatic or semi-automatic adjustments of retirement ages to changes in life expectancy. Overall, OECD countries have introduced pension reforms that will raise the respective standard retirement ages over the next four decades by about two years, on average (*OECD* 2021).

2 For instance, decision-makers would have the option to specify reforms under which the statutory pension payments made by the working population are 75 percent likely to cover all pension claims (to state a simple example).

3 The authors illustrated in a backcast that, even when adjusting for census errors and taking the limits of the extreme scenarios into account, the Federal Statistical Office's deterministic projection did not cover the eventual population in any of the years.

4 List is non-exhaustive.

The timing of pension claims is an individual decision. However, there is strong evidence supporting the effects of policy reforms on social security and retirement decisions or expectations (*Börsch-Supan* 1992, 2000; *Coppola/Wilke* 2014; *Buchholz et al.* 2013). Moreover, social policy can try to influence retirement decisions by bonus-malus systems in order to affect retirement behaviour as well as labour force supply (*Gruber/Wise* 2000).

Since the late 1980s, the German Government has passed a series of pension reforms as countermeasures to the demographic ageing process. In 1989, the *Rentenreformgesetz 1992* (*RRG* 1992) was the first reform with a clear demographic agenda: it raised the legal retirement age for female and unemployed persons from 60 years to 65 (the latter being the standard legal retirement age for men at that time, i.e. the normal retirement age in the absence of any factors allowing for an earlier retirement) by 2008 and was one important measure for containing the number of future retirees. Moreover, the exceptional early retirement age of 63 years for persons who had been employed for at least 35 years was abolished[5] (*RRG* 1992). Furthermore, whereas early retirement without monetary "sanctions" had previously been possible, the reform introduced a financial bonus-malus system for the individual retirement decision. Since that reform, every month of premature pension claims reduces the monthly pension payments by 3‰. In contrast, each month of delayed pension claims beyond the individual legal retirement age[6] is rewarded with an increase of 5‰ in monthly pension payments (*Wilke* 2009).

The *Wachstums- und Beschäftigungsförderungsgesetz (WFG)* in 1996 (*WFG* 1996) accelerated the increases in the legal retirement ages for the unemployed and females even further, underlining the urgency of policy measures. Due to *RRG* 1992, the increase in the retirement age of these two groups would have ended at the target age of 65 in 2018 (*RRG* 1992, §41 I). However, the WFG required the introduction of this target age in 2007 for unemployed men and in 2010 for women. The legal retirement age for severely disabled persons increased from 60 to 63 years between 2000 and 2006 following *Rentenreformgesetz 1999* (*RRG* 1999).

Even though the RRG reforms introduced actuarial adjustments into the benefit calculation and harmonised statutory retirement ages across groups, a more fundamental reform was necessary to cope with the demographic changes. The Riester reform of 2001 brought such a fundamental change. While the statutory pension as the first pillar had alone secured the standard of living of pensioners in Germany until then, the Riester reform transformed the German pension system into a multipillar system – this meant that the statutory pensions from the first pillar should be partially replaced in the long term by additional retirement income from the second (occupational) and third (private) pillars. This led to the introduction of a

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5 In 2014, the German Government returned to a similar measure, with a legal retirement age of 63 years for persons who have 45 years of social security payments (*Bundesregierung* 2013). This change is considered in our model as well.

6 The legal retirement age corresponding to an individual's personal circumstances, as defined by gender, field of work, birth cohort, and absence or presence of disabilities.

new pension formula that linked individual pension benefits not only to the overall development of labour income but also to the predetermined growth in private old-age saving rates in society over time (*Wilke* 2009).

In 2004, this new pension formula was enhanced once more by adding the so-called *sustainability factor,* which is directly connected to the system dependency ratio.[7] The sustainability factor links the amount of pension payments to the annual change in the ratio between pension recipients and pension payers, thus including the demographic developments in the pension payments. Consequently, this adjustment directly considers the overall demographic and labour market development when determining pension payments (*Wilke* 2009). The effects of including the system dependency ratio in the benefit calculation, as opposed to considering the life expectancy as alternative reform options, were analysed in a simulation study (see *Fehr/Habermann* 2006).

The *RV-Altersgrenzenanpassungsgesetz* from 2007 was the most recent reform designed to address the demographic ageing process in Germany. The standard legal retirement age will now increase gradually to 67 years by 2031. The legal retirement age for severely disabled individuals will be adjusted accordingly, from 63 to 65 years, while for mineworkers, which make up a small group, the change will be from 60 to 62 years (*RV-AltAnpG* 2007). These differing retirement ages are directly reflected in our forecast model. The average annual retirement ages for different retirement groups are shown in Appendix A for historical, current, and future time horizons.

3 Method and data

In this section, we propose a joint probabilistic forecast model for the number of old-age pensions and disability pensions by sex and age of the pensioners. We estimate past ASSPRs for old-age and disability pensions. The data have been accumulated from three sources: the German Federal Statistical Office (Destatis), the Deutsche Rentenversicherung (DRV), and the Federal Health Reporting Service (gbe-bund) provided by Destatis and the Robert Koch Institute (RKI). Thus, we used the year-end sex-specific stocks of old-age pensions by age (in years)[8] for the years 1992-2009 from the gbe-bund database (*Destatis* 2018).

It is not advisable to use data before 1992 because the integration of pensions for citizens from the former German Democratic Republic (DDR) into the DRV after German reunification did not happen until 1992 (*RÜG* 1991). Therefore, data up to 1991 are available for West Germany only. Furthermore, the DRV was reformed in 1992, transforming disability pensions for persons who had already passed their individual legal retirement age into old-age pensions (*RRG* 1992). The data for 2010-

7 The ratio of the number of persons exceeding a certain age (mostly 65 years) to the number of persons in the assumed working age bracket, e.g. 15-64 years (*Wilke* 2009).

8 Ages 60-99 annually, over 99 grouped.

2017 were downloaded from the statistics portal of the DRV (*Statistikportal der Rentenversicherung* 2020a). Because the gbe-bund data originate from the DRV as well, we ensure that our datasets are consistent.

We estimate the age-specific pension rates by year for ages 60 to 64 for both genders. For instance, the ASSPR for old-age pensions of females aged 64 years in 2015 is computed by dividing the stock of old-age pensions on 31 December 2015 paid to females aged 64 by the population estimate of this demographic group. Old-age pensions for persons above 64 years of age are cumulated, as there are no time series data for persons aged 66 and above available for the past. Instead, our data only contain cumulative pension numbers paid to individuals aged 65 or older. Those numbers are then divided by the estimate of the population residing in Germany in that particular age group and for that particular gender. In other words, the old-age ASSPR of females aged 65 and above in the year 2015, for instance, is computed as

$$a_{65+,f,2015} = \frac{A_{65+,f,2015}}{P_{65+,f,2015}},$$

with $A_{65+,f,2015}$ being the number of old-age pensions on 31 December 2015, paid to females aged 65 years or older, and $P_{65+,f,2015}$ being the estimated number of female residents in Germany on that same date.[9] For each gender and year, the population aged 65 and above is cumulated and used as the denominator of the quotient. That way, trends in pension claims in the 64 and over age group are covered by the historical data. Population estimates are computed annually by updating the estimates for the previous year, i.e. births and migration inflows are added and deaths and migration outflows are subtracted (*Vanella/Deschermeier/Wilke* 2020). However, there is still some difference due to the undercounting of international migration (*Vanella/Deschermeier* 2018), but the grouping reduces the dimensionality of the data and mitigates the error that naturally results from updating in the old-age population, since individuals who have emigrated in the past without notice continue to be counted in the population. In relative terms, these errors are of a larger magnitude than for the younger population, as the elderly population is smaller (*Vanella/Heß/Wilke* 2020).

Disability pensions are not differentiated by age but simply by sex and type of disability (full or partial). The data for the years 2010-2017 were downloaded from the statistical database of the DRV (*Statistikportal der Rentenversicherung* 2020b), and the data for 2000-2009 are available at the DRV research homepage (*Forschungsportal der Deutschen Rentenversicherung* 2018). The data for 1992-1999 were provided by the DRV upon request (*Deutsche Rentenversicherung Bund* 2018). Year-end population estimates for 1992-2017, broken down by sex and age based on the 2011 census, were downloaded from the *Human Mortality Database* (2019).

9 The data give annual estimates of the age- and sex-specific population by age in years (0-109, 110+), the reference for the data is described below.

The pension numbers are divided by the population estimates, allowing us to calculate annual ASSPRs for the 1992-2017 period. The resulting data matrix has 16 columns as conglomerates of 16 time series of ASSPRs. Basing the model on the ASSPRs has the advantage of including the possibility of a return to the labour force indirectly in our data. Another advantage of our approach is that we take into account the numbers of persons receiving pension payments from the DRV while residing abroad, which, to our knowledge, previous studies did not. As stated above, earlier approaches tend to estimate labour force participation rates first and derive pension rates from those rates.

We apply PCA (see, for example, *Chatfield* and *Collins* 1980; *Handl* 2010; *Vanella* 2018 for a comprehensive description and application of the method) to the matrix of the logistically transformed ASSPRs with 1.03 as the upper limit, which is approximately the historical maximum rate for Germany.[10] This transformation prevents the simulations for the ASSPRs from taking unrealistically high values (see *Vanella/Deschermeier* 2019 for a similar application for age-specific fertility rates). The PCA approach allows us to minimise the effective dimension of the data while also covering the correlations between the time series in our model (*Vanella* 2018). The Principal Components (*PCs)* are linear combinations of all logistically transformed ASSPRs, which are correlated with these while being uncorrelated with each other (*Chatfield/Collins* 1980; *Vanella* 2018). For example, the i^{th} PC is a linear combination of all original J ASSPRs as:

$$p_{i,t} = \sum_{j=1}^{J} \lambda_{j,i} a_{j,t}, \tag{1}$$

where

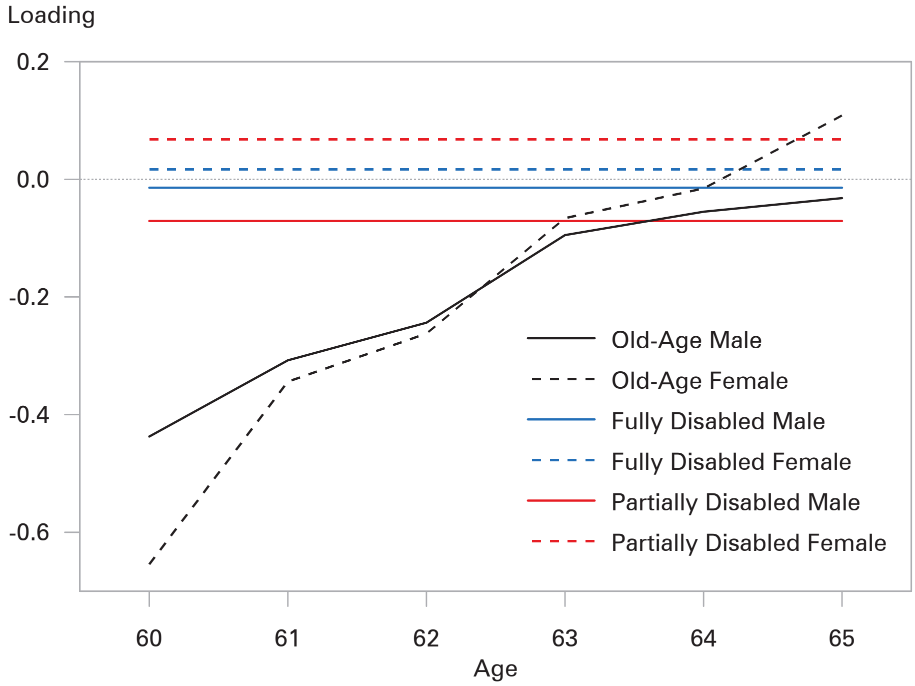
- $a_{j,t}$ is the observation of the j^{th} ASSPR in year t,
- $\lambda_{j,i}$ is the loading (i.e. coefficient) of the j^{th} ASSPR on the i^{th} PC.

The loadings between the first PC and the logistically transformed ASSPRs are illustrated in Figure 1.

Principal Component 1 (PC1) is negatively correlated with the rates of old-age pensions in pre-legal retirement ages and with the rates of disabled males. Moreover, its loadings are positive for disabled females. *Ceteris paribus,* positive trends in PC1 are therefore associated with decreases in retirement rates in the pre-legal retirement age groups. Likewise, disability pension rates of males decrease with increases in retirement rates, while the disability pension rates of females increase instead. PC1 explains approximately 91 percent of the total variance in the logistically transformed ASSPRs. Figure 2 shows the historical course of PC1, as derived from (1). The years 1996 and 2011 are marked by vertical lines to stress that

10 The value of 1.03 shows that the number of pensions in the specific age groups exceeds the official population estimate by 3 percent, which is due to individuals living abroad while receiving pension payments from Germany.

Fig. 1: Loadings of the first Principal Component



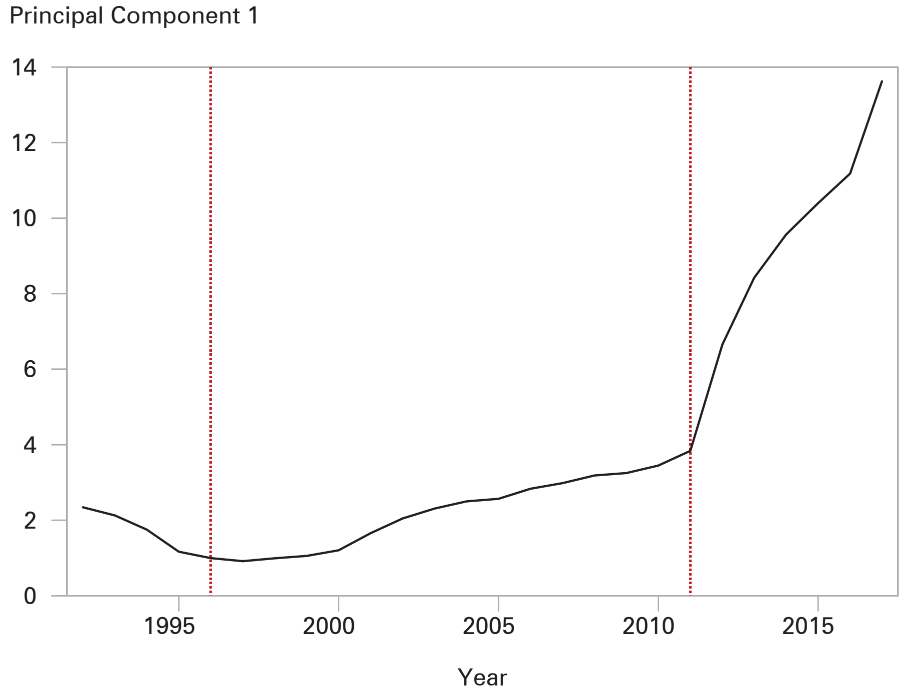
Source: Own calculation and design

in the following years, the effects of RRG 1992 and *RV-AltAnpG* 2007 started to kick in (see Appendix A).

The trend in PC1 decreases until the late 1990s. It increases almost monotonically shortly after 1997 and has done so even more sharply since 2012, strongly implying a connection of PC1 to the past pension reforms that introduced increases in the legal retirement ages, as explained in Section 2.

To test our hypothesis of connections between PC1 and legal retirement ages and to integrate effects in their adjustment on future pension numbers, we iteratively fit an explanatory model for PC1 with the mean annual retirement ages as exogenous variables. These variables are derived from the legal texts presented in Section 2. The individual retirement age does not address the period but rather the birth cohort of said person. Our forecast, however, has a period perspective. As a result, we need to approximate the average legal retirement age of persons who are eligible to retire in a certain year. For instance, the standard legal retirement age of persons born before 1947 is 65 years. For each cohort born after 1947, the legal retirement age will increase, depending on the year and month of birth (*RV-AltAnpG* 2007). Consequently, we would need a more detailed estimation of the individual legal retirement age for all groups eligible for legal retirement in each year. We therefore assumed births to take place uniformly for a year and approximated the average individual retirement age for persons eligible to retire in a certain year, which is a

Fig. 2: Past course of Principal Component 1



Source: Own calculation and design

composition of different cohorts. The estimates for these average retirement ages by period are given in Appendix A. We estimate the impact of increasing retirement ages on PC1 by regressing its past time series on the set of different legal retirement ages in the corresponding years, according to Appendix A. We follow a stepwise estimation procedure to identify the best possible model for predicting the course of PC1 based on the current retirement regulation. The results of the different iterations are given in Table 1, with standard errors for the coefficient estimates in brackets. For informative purposes only, we also report the R^2 and adjusted R^2 for each model.

The models all show a high degree of joint significance. For the standard legal retirement age and the legal retirement age of mineworkers, the natural logarithms are put into the model since the scatterplots suggest a logarithmic connection between the two variables and PC1. We optimise the model iteratively by omitting the variable with the smallest individual significance in each iteration. We finally choose the model that minimises Akaike's information criterion (AIC) and the Bayesian information criterion (BIC). Both are minimised by Model 1.3. Omitting more variables leads to worsening model fits, as indicated by increases in the AIC and the BIC in Model 1.4. The final model accentuates the effects on PC1 of the standard legal retirement age, the earlier legal retirement age for persons with 45 years of social insurance payments, as well as the legal retirement ages of females

Tab. 1: Model estimates for Principal Component 1[a]

Retirement Age	Model 1.1	Model 1.2	Model 1.3	Model 1.4
Intercept	- 4,426***	- 4,326***	- 4,551***	- 3,907***
	(709)	(625)	(555)	(474)
ln(Standard)	711**	669***	732***	579***
	(258)	(218)	(202)	198)
Insured for 35 years	0.52	0.37	-	-
	(0.65)	(0.46)	-	-
Insured for 45 years	0.31	0.3	0.41*	-
	(0.26)	(0.25)	(0.21)	-
Severely disabled	- 0.21			
	(0.63)	-	-	-
Unemployed	- 0.43*	- 0.44*	- 0.32*	- 0.14
	(0.23)	(0.22)	(0.16)	(0.14)
Women	0.64***	0.58***	0.58***	0.58***
	(0.21)	(0.14)	(0.14)	(0.15)
ln(Mineworkers)	344***	363***	356***	358***
	(107)	(88)	(86)	(92)
R^2	0.9912	0.9911	0.9908	0.9891
Adj.R^2	0.9878	0.9883	0.9885	0.9870
AIC	34.51	32.66	31.54	34.06
BIC	45.83	42.73	40.35	41.60

[a] One asterisk means statistical significance on a 10 percent level against $H_0 : \beta_x = 0$, with β_x being the x^{th} coefficient. Two asterisks indicate a 5 percent significance level and three asterisks mean 1 percent.

Source: Own calculation and design

and mineworkers. It stresses developments in very early retirement between ages 60 and 63, an age group in which most retirement stems from mineworkers. We see this from the high negative loadings for these age groups, as illustrated in Figure 1. For example, in 2016, over 70 percent of the pension numbers among male 60-year-olds were mineworkers (*Deutsche Rentenversicherung Bund* 2017). The coefficient for the legal retirement age of unemployed persons is negative, which appears strange at first. One possible explanation might be that increasing the legal retirement age for unemployed individuals might create incentives for them to retire early instead of applying for welfare services for longer periods (*Brussig* 2012).

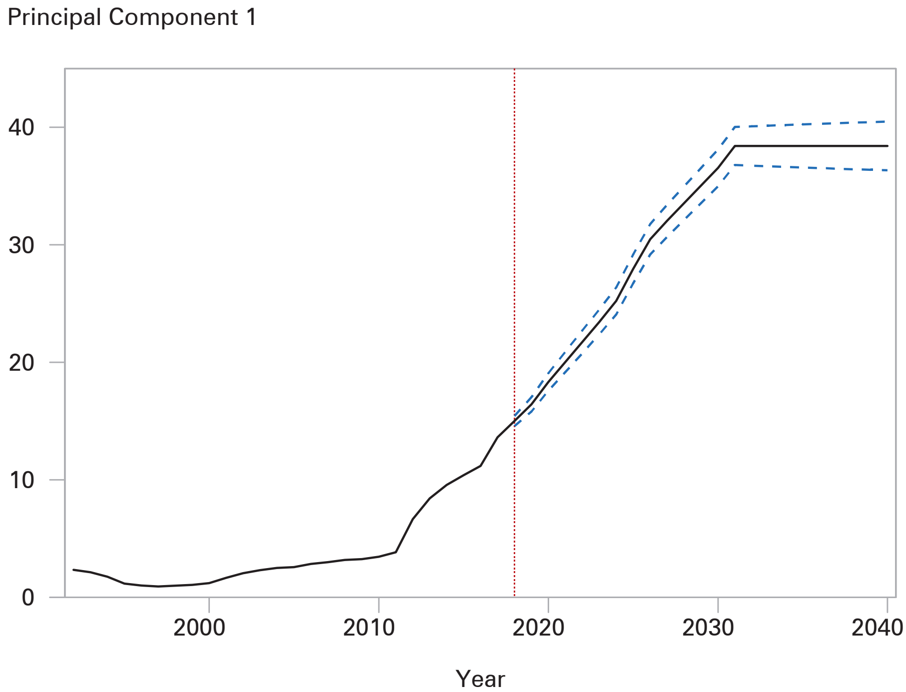
After fitting the data to the quantified model, we fit a Box-Jenkins time series model to the data (see *Box et al.* 2016). Based on the autocorrelation function (ACF) and the partial autocorrelation function (PACF), we identify a random walk as the most appropriate model for the error term (see, for example, Shumway and Stoffer 2016 on ARMA processes, ACFs and PACFs). The forecast model for PC1 is therefore

$$p_1(y) = -4{,}551.43 + 731.96\ln(s_y) + 0.41l_y - 0.32u_y + 0.58f_y + 355.66\ln(b_y) + r_y + \varepsilon_y, \quad (2)$$

with $\varepsilon_y \sim NID(0,0.37^2)$, $\ln(s_y)$ being the natural logarithm of the mean standard legal retirement age l_y being the mean legal retirement age after being insured 45 years, u_y being the mean legal retirement age for unemployed persons, f_y being the mean legal female retirement age and b_y being the mean legal retirement age of mineworkers in year *y*, as calculated in Appendix A. r_y is the difference between the actual value of PC1 in period *y* and its mean estimate according to Model 1.3, therefore covering prediction errors in the independent variables.

The forecast of PC1 with 75 percent PI is illustrated in Figure 3.

Fig. 3: Forecast of Principal Component 1 with 90 percent PI



Source: Own calculation and design

After an expected sharp increase up to the early 2030s and associated age-specific pension rates induced by the pension reforms and connected retirement age increases, illustrated in Appendix A, we expect stagnation once the retirement ages have reached their maxima.

The remaining 15 PCs[11] are assumed to be random walk processes, as they show no clear trending behaviour. This allows the surplus risk generated by them to be reasonably well included. The fitted PC models are used for future simulation of

[11] We have 16 PCs overall, as the number of PCs is equal to the number of ASSPRs.

the 10,000 trajectories up to 2040 via Wiener processes (see, for example, *Vanella* 2018). In this way, the stochasticity of all variables is considered in the forecast model (*Vanella* 2017). The trajectories of the PCs can easily be retransformed into trajectories of the ASSPRs (*Vanella* 2018):

$$\Phi_\tau = \Pi_\tau \Lambda^{-1}, \quad (3)$$

where

- Π_τ is a 10,000x16 matrix of 10,000 trajectories for each PC in year τ,
- Λ^{-1} is the inverse of the loading matrix,
- Φ_τ is a 10,000x16 matrix of 10,000 trajectories for all logit-ASSPRs in year τ.

These are multiplied by the trajectories resulting from the probabilistic population forecast for Germany conducted by *Vanella* and *Deschermeier* (2020). In this way, trajectories of the pension numbers are derived up to 2040.

4 Results

According to *Vanella* and *Deschermeier* (2020), which forms the basis of the pension forecast conducted in the present paper, there is a high probability that the total population will increase over the forecast horizon. The population in the median forecast, for 31 December 2040, will be slightly below 85 million. In light of the pension fund, the population structure is highly relevant.

Table 2 gives a selection of the simulation results of *Vanella* and *Deschermeier* (2020), by three age groups.

Obviously, the increase in the population is the result of clear growth in the population in the pension age group, whereas the population in the typical labour age group is expected to decrease by 2040. In our context, the forecasts of the working-age population[12] and the old-age population[13] are of major interest. There is a high probability that we will observe a sharp increase in the old-age dependency ratio due to a decrease in the working-age population[14] up to the late 2030s, together with an increasing population in the pension age group.

Our modelling approach provides more insight into the actual pension numbers because the predicted population at this stage is multiplied by the age- and sex-specific risks of pension claims estimated by our PC time series method. The trajectories of the PCs are transformed back into trajectories of the ASSPRs, as mentioned above. The trajectories can be used to estimate the quantiles of the forecast to construct PIs. Figure 4 illustrates the ASSPRs for old-age pensions at

[12] Defined by *Vanella* and *Deschermeier* (2020) as persons aged 20-66 years.

[13] The old-age population here is defined as the population aged 67 years and above.

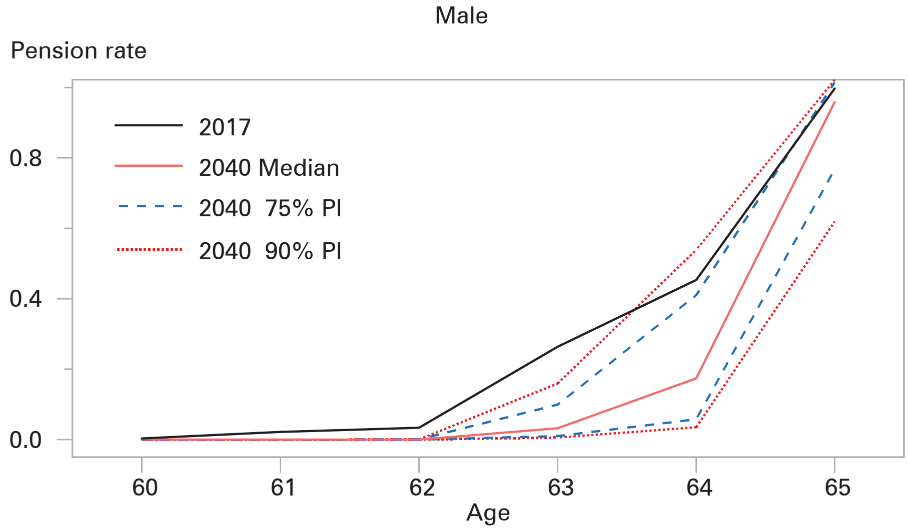
[14] It should be noted that this does not even include labour force participation (see, for instance, *Fuchs et al.* 2018), but simply refers to the age group.

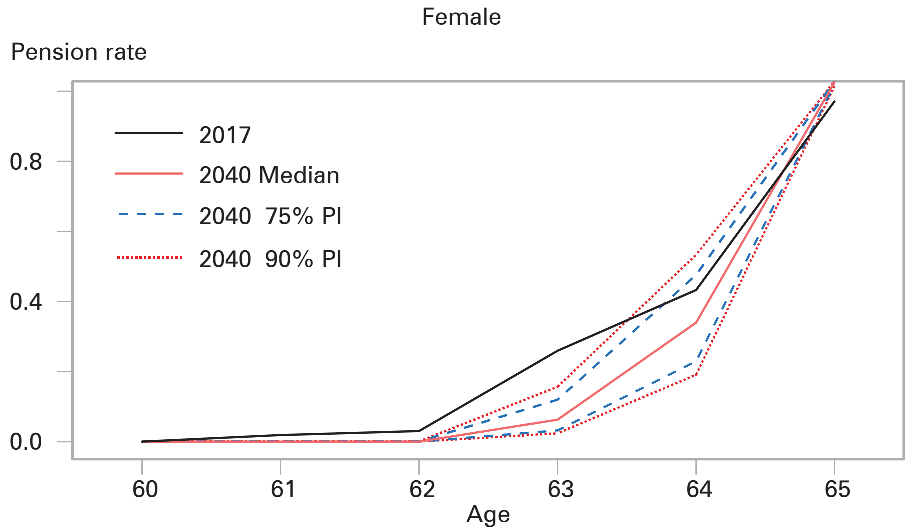
Tab. 2: Forecast population (in millions) for selected years and three age groups with 75 percent PIs

Year	Young Median	Young 75% PI Lower Bound	Young 75% PI Upper Bound	Working Age Median	Working Age 75% PI Lower Bound	Working Age 75% PI Upper Bound	Old Median	Old 75% PI Lower Bound	Old 75% PI Upper Bound
2017	15.252			51.804			15.736		
2021	15.573	15.354	15.799	51.588	51.178	52.012	16.428	16.357	16.500
2025	16.122	15.675	16.563	50.755	49.958	51.568	17.233	17.064	17.398
2029	16.642	15.948	17.337	49.396	48.224	50.559	18.446	18.181	18.715
2033	17.031	16.065	17.985	47.845	46.346	49.325	19.812	19.439	20.188
2037	17.086	15.853	18.311	47.065	45.233	48.871	20.630	20.127	21.118
2041	16.974	15.510	18.481	47.352	45.211	49.513	20.389	19.744	21.013
2045	16.835	15.124	18.609	47.829	45.340	50.382	19.844	19.020	20.603

Source: *Vanella/Deschermeier* 2020; own design

Fig. 4: Age- and sex-specific pension rates in 2017 and 2040





Source: *Statistikportal der Rentenversicherung* 2020a; *Human Mortality Database* 2019; Own calculation and design

year-end 2017 in comparison with the predicted ASSPRs in the median trajectory with 75 percent and 90 percent PIs at the end of the forecast horizon.

For the age group of people under 65 years, a decrease in the prevalence of old-age pension claims is probable as a result of the pension reform of 2007 described in Section 2, as these reforms push the standard legal retirement age to 67 years.

For the age group of people over 65 years, the changes for the males will be subtle, whereas the ASSPRs of the females will almost certainly increase. This stems from the high labour force participation rates among the female population born since the baby boom years (*Fuchs et al.* 2018). The preceding generations participated less in the labour market because their primary profession was mostly motherhood and housekeeping (*Hertrampf* 2008). Increased labour force participation is associated with higher pension entitlements in a pay-as-you-go system, eventually leading to a higher share of persons receiving pension payments associated with labour income.

Figures 5 and 6 give the past and future overall rates of disability pensions by sex and type of pension. Please note that for Figure 6, the scales on the vertical axes are not the same due to illustrative purposes.

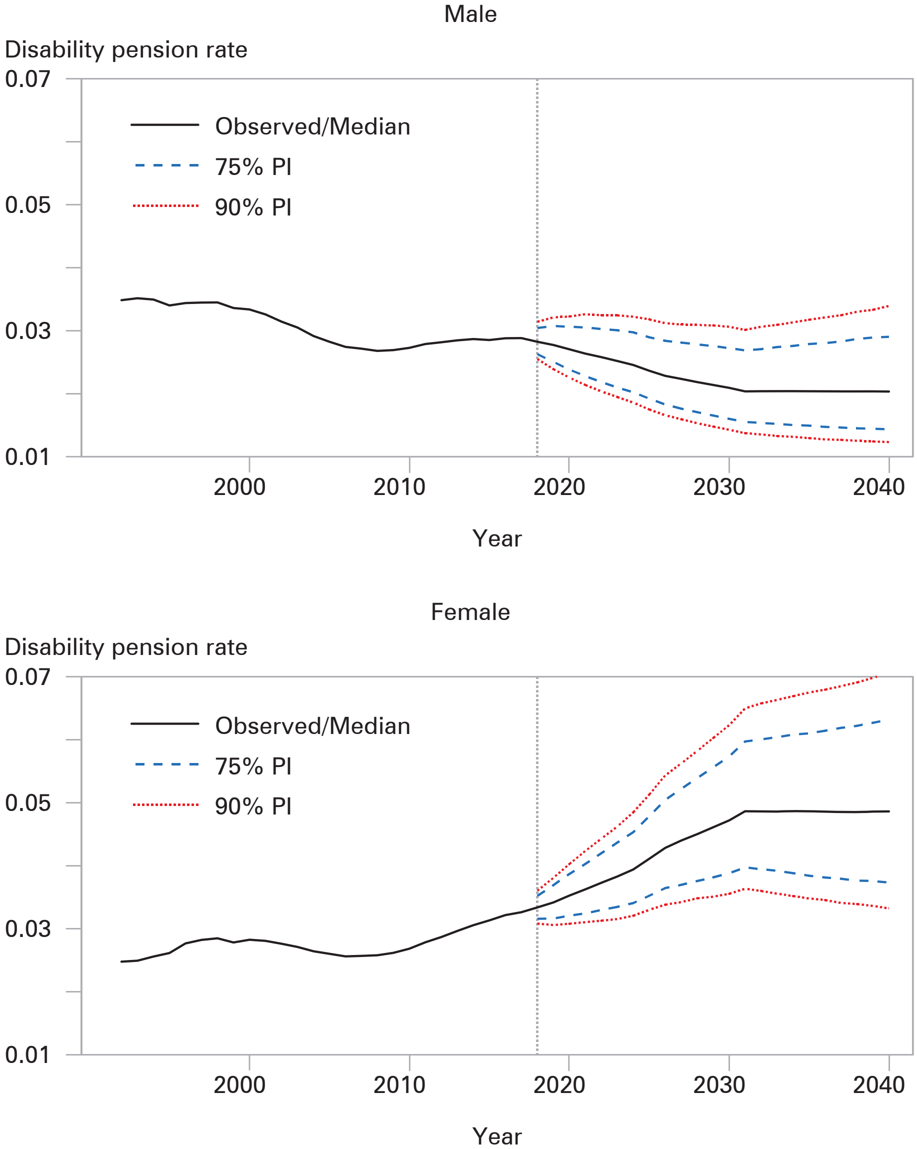
For both types of disability pension, we will observe decreasing overall rates for males and increases for females. This can be explained by a reduction in age-specific disability risks for males due to healthier life circumstances and a fall in the proportion of people working in physically exhausting fields of work, which more often precede disabilities (*Rodriguez Gonzalez et al.* 2015). The trends for females are much different. First, the susceptibility to serious disabilities in the high age groups is much greater among females than among males (*Vanella*/*Heß*/*Wilke* 2020). Second, due to females' increasing labour force participation rates, they are more eligible for disability pensions in comparison with preceding generations.

Multiplying the ASSPRs derived in this study by the age- and sex-specific population estimated by *Vanella* and *Deschermeier* (2020) results in forecasts of future pension numbers. The pension rates of males converge to zero, leading to narrower PIs. Figure 7 illustrates the resulting forecast of the total numbers of old-age pensioners by sex.

In the mean, we observe a monotonic increase in the number of old-age pensions for both sexes up to the mid-2030s. The increase is especially large up to the late 2020s, the period in which the strongest birth cohorts reach their respective retirement ages. After this point, there is a high probability that the total number of pensioners will increase further, but at weaker rates. This trend is caused by slightly decreasing birth cohorts entering their retirement ages, combined with the effects of the pension reforms since 1992, which imply lower age-specific old-age pension rates. The decreasing trend after the mid-2030s reflects the weaker birth cohorts since the 1970s, which can also be observed in Table 1. Overall, we see that the median number of old-age pensions will increase from 8.1 million to 9.9 million for males and from 10.1 to 12.8 million for females between 2017 and 2036, the year in which the number of old-age pensions for both genders is predicted to be at its highest. These results include demographic trends and the effect of labour market participation. These results show the massive increase in retirees occurring over the forecast horizon. There is less uncertainty in the forecast for females as the development of the female population is more certain than it is for males. The increase in legal retirement ages by two years is obviously not sufficient to address demographic development from the perspective of the DRV.

Figures 8 and 9 show the forecasts of the numbers of disability pensions for fully and partially disabled persons by sex, respectively. The long-term trend for males

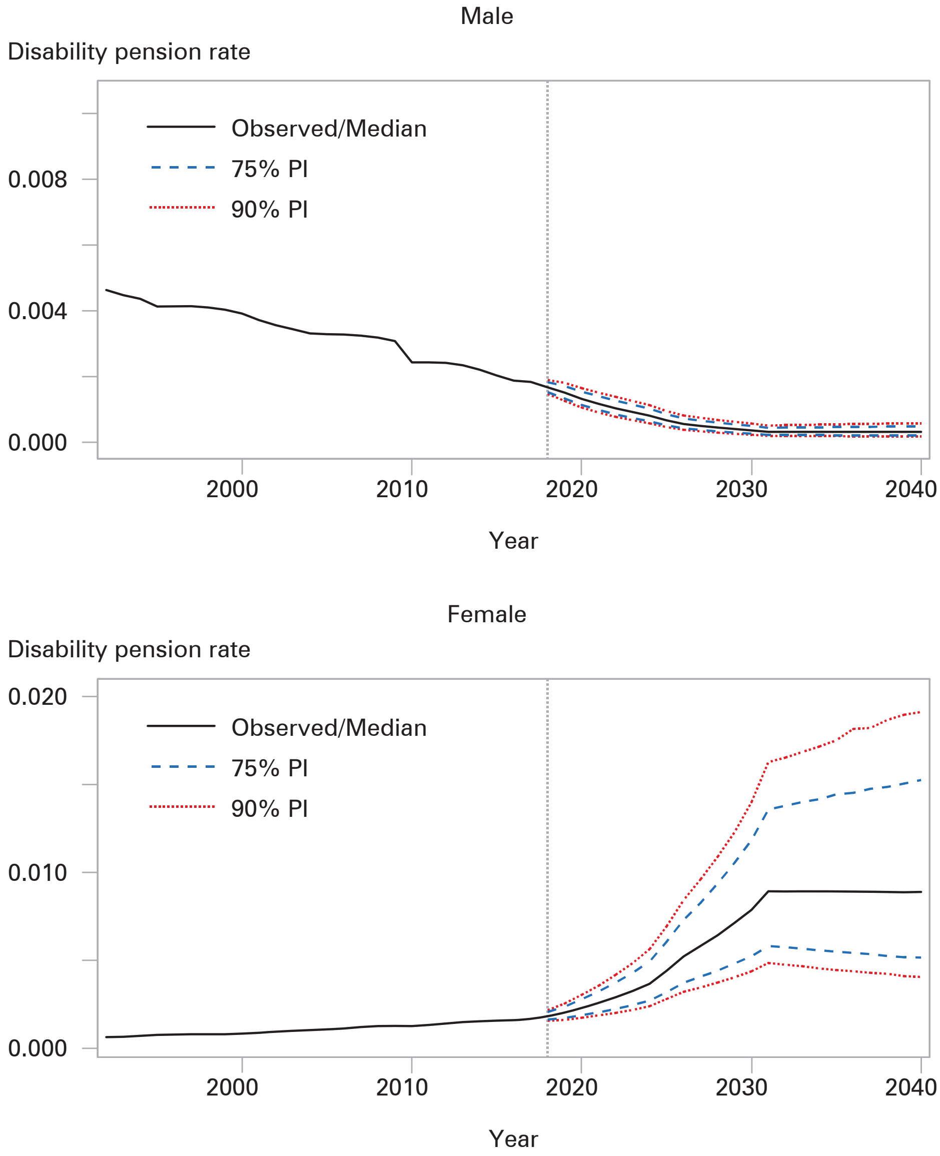
Fig. 5: Forecast of full disability pension rate by sex



Source: *Deutsche Rentenversicherung Bund* 2018; *Forschungsportal der Deutschen Rentenversicherung* 2018; *Statistikportal der Rentenversicherung* 2020b; *Human Mortality Database* 2019; Own calculation and design

was negative because the relative prevalence of disability decreased, as illustrated in Figure 8. On the other hand, the increase in the legal retirement age means, *ceteris paribus*, an increase in the risk of disability pension claims. These trends are superimposed on the demographic trends for females; therefore, increasing

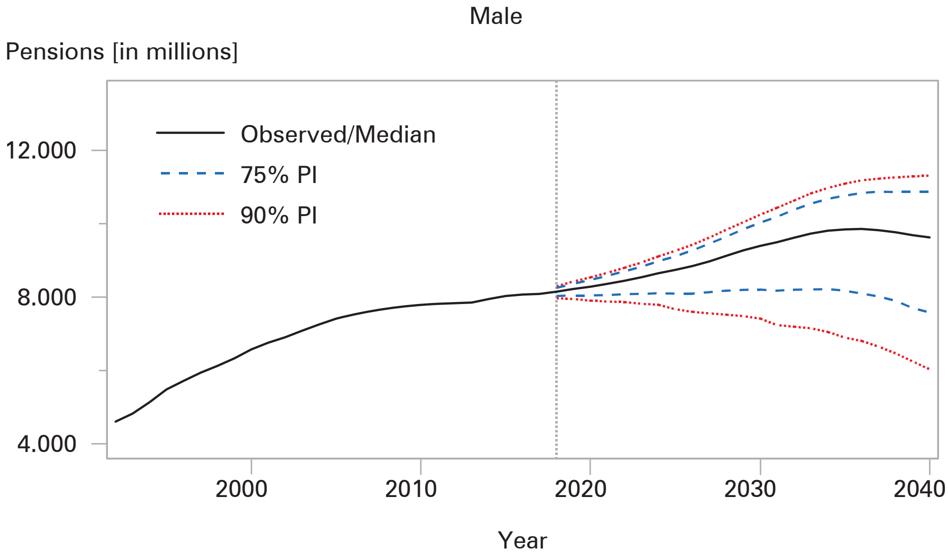
Fig. 6: Forecast of partial disability pension rate by sex

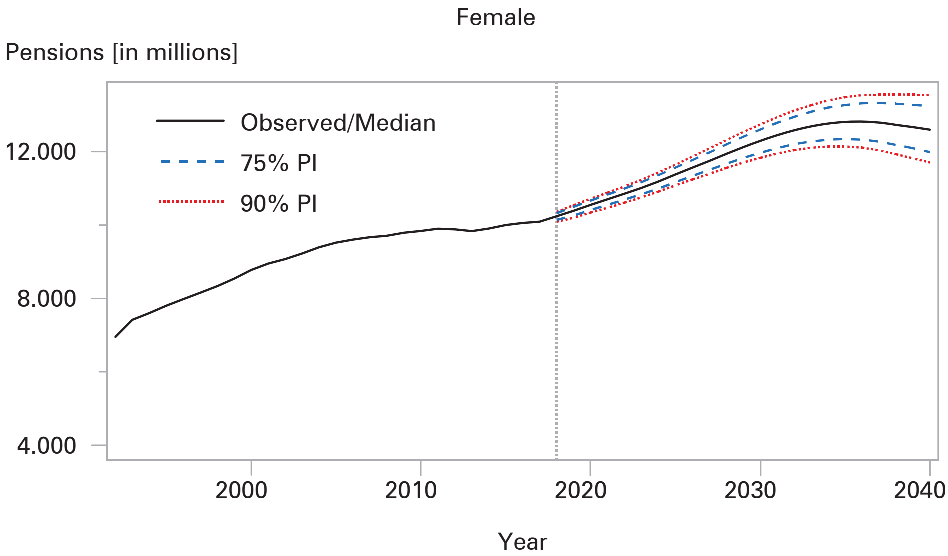


Source: *Deutsche Rentenversicherung Bund* 2018; *Forschungsportal der Deutschen Rentenversicherung* 2018; *Statistikportal der Rentenversicherung* 2020b; *Human Mortality Database* 2019; Own calculation and design

numbers of pensions can be expected up to the early 2030s. After that point, the strong birth cohorts enter the legal retirement age, so the disability pension numbers will probably decrease again slightly because of the decrease in the population numbers in the respective age group.

Fig. 7: Forecast of old-age pensions by sex up to 2040

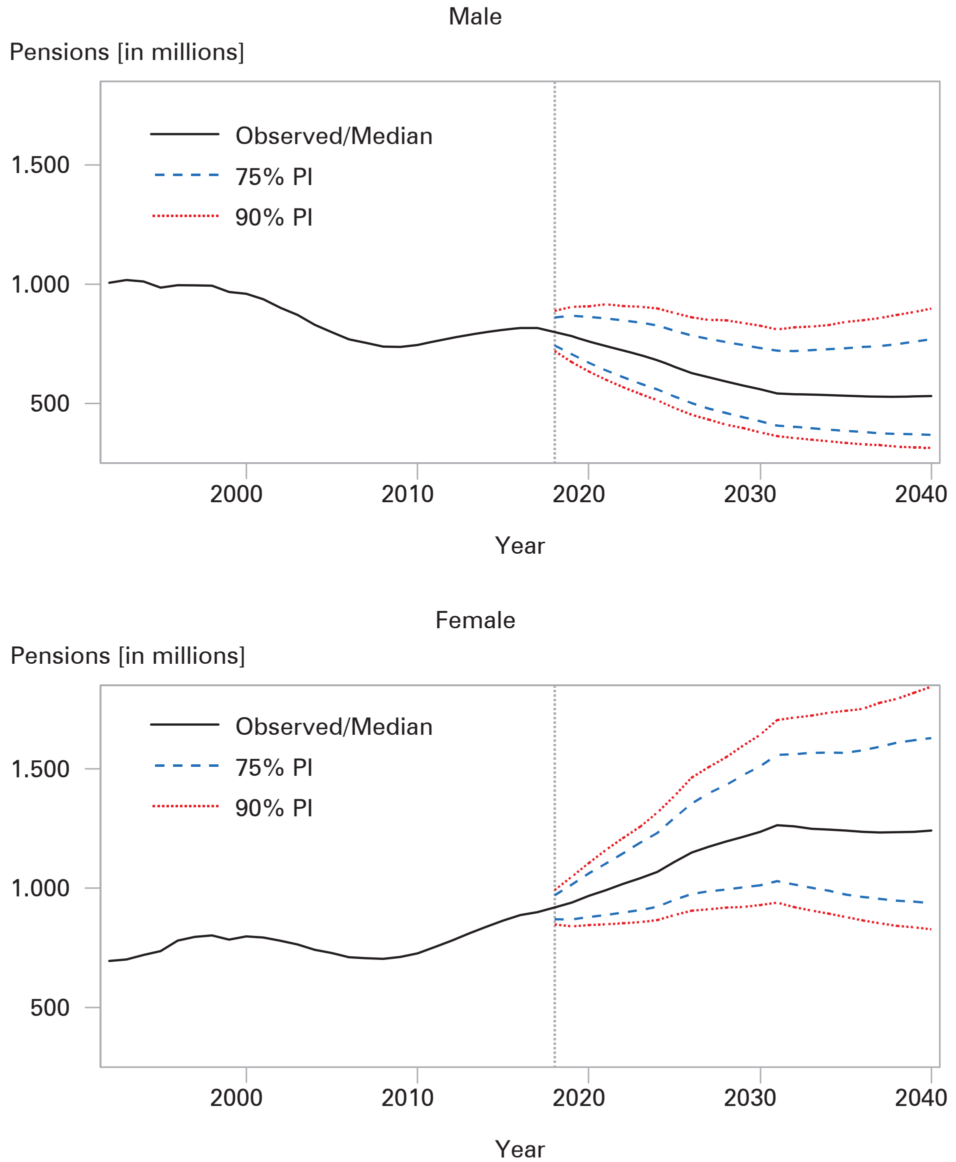




Source: *Destatis* 2018; *Statistikportal der Rentenversicherung* 2020a; *Vanella/ Deschermeier* 2020; Own calculation and design

It can be concluded that the pension reforms raising the legal retirement age will not only mitigate the increase in old-age pension numbers but also increase the number of disability pensions through to the early 2030s. For females in particular, the increase in the legal retirement age might lead to a sharp rise in the number of cases in which a disability pension will be claimed. This is an effect of

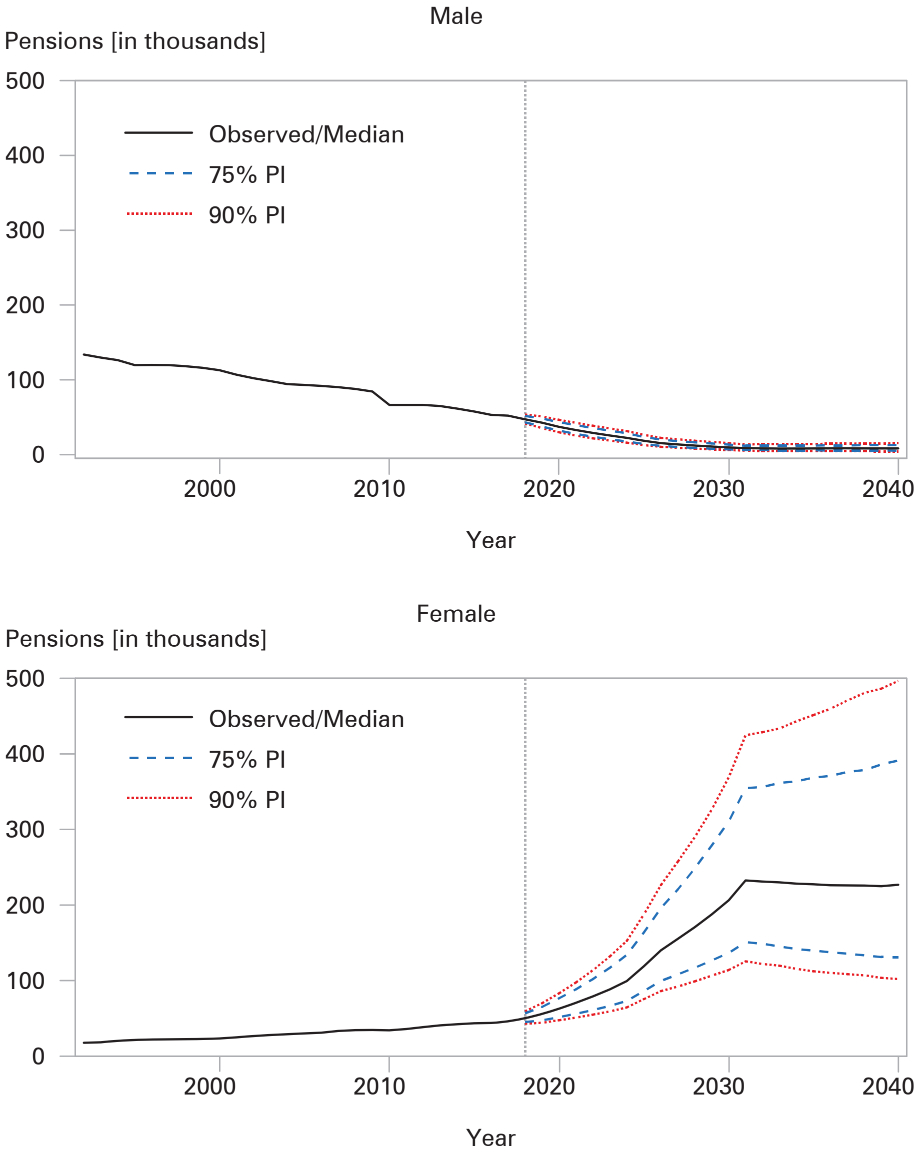
Fig. 8: Forecast of full disability pensions



Source: *Deutsche Rentenversicherung Bund* 2018; *Forschungsportal der Deutschen Rentenversicherung* 2018; *Statistikportal der Rentenversicherung* 2020b; *Vanella/Deschermeier* 2020; Own calculation and design

increasing female labour force participation rates in combination with the increase in the legal retirement age; more women will be active in the labour market and will therefore be "eligible" for disability pensions; in the past, these women might have retired earlier. From the perspective of this population, this therefore represents

Fig. 9: Forecast of partial disability pensions



Source: *Deutsche Rentenversicherung Bund* 2018; *Forschungsportal der Deutschen Rentenversicherung* 2018; *Statistikportal der Rentenversicherung* 2020b; *Vanella/Deschermeier* 2020; Own calculation and design

an improvement as increasing female labour force participation allows for better financial compensation in the event of a disability resulting in a reduced ability or inability to work, giving them greater financial independence.

To conclude, we see that a thorough forecast of the demand for statutory pension payments cannot be made from a trivial analysis based on simple statistics such as the old-age dependency ratio. An age-specific and joint forecast of old-age and disability pensions is needed in order to gain a full understanding of the real sensitivity of the pension system to reforms and demographic developments. Moreover, the stochastic approach accounts for the high uncertainty of the complex system of interacting population trends, labour market effects, and the regulations of the pension system.

5 Discussion

Our model predicted the future demand for old-age and disability pensions in Germany by gender, age, and type of pension, quantifying not only the most likely future course but also estimating prediction intervals for all variables. Our model includes cross-correlation between the pension variables via PCA and autocorrelation of the pension variables by ARIMA models. We checked the appropriateness of PCA to our data, following *Kaiser* (1970). We found Kaiser-Meyer-Olkin values between 0.32 and 0.91 for the separate time series and 0.72 for the set of all time series. Considering that *Kaiser* and *Rice* (1974) defined values above 0.5 as suitable for factor analysis or PCA, we concluded that our approach was valid. Monte Carlo simulation quantified uncertainty in our forecast. Although our forecast is contingent on future retirement ages as explanatory variables, it is stochastic, as it simulates all realistic future scenarios under the assumed retirement ages. These are, however, legally fixed for the long term and can be assumed to apply to the forecast horizon, since no new regulations in this regard are likely in the near future.

Even though our main result concerning an increase in the number of future pensions appears quite robust, our approach nevertheless has some limitations. For example, the model does not consider age-specific disability pension rates. This approach was tested as well but did not give plausible loadings for all variables. Consequently, disability pensions are differentiated only by sex and type of pension. Moreover, the model does not include widow and orphan pensions. There are three reasons for this: first, the inclusion in the model of disabled persons under 60 could give false indications of sensitivity to retirement ages;[15] second, the data for this type of pension are not available in the form needed to fit our model; third, we would need data or strong assumptions on nuptial behaviour, eradicating the advantages of the chosen probabilistic approach to some degree. Another conceivable limitation is the deterministic part of the model, which relies on future retirement ages as explanatory variables but which are legally fixed over the forecast horizon. The stepwise procedure to choose the final model might be subject to discussion (*Smith* 2018). However, we chose our model based on information criteria, which

[15] Of course, those effects do not exist because persons do not "decide to die" based on the pension policy regime.

weigh the model's goodness-of-fit against its complexity, thereby accounting for multicollinearity. As the connection between the explanatory variables and the target variable appears plausible in qualitative terms, we believe our results are plausible.

Further studies might include widow and orphan pensions in their analyses. To provide a full picture of not only the numbers of pensions but also their volumes, an enhanced pension model should include all kinds of pensions covered by the DRV as well as the development of the labour market. A joint model for the labour market and pensions would present a meaningful extension, as the labour market and the pension system are basically two sides of the same coin and heavily influence one another. Moreover, this paper has been restricted to persons instead of economic entities such as monetary units. Such deeper analyses require forecasts of economic development as well. Because our pension model is fully probabilistic, the associated economic model should also be probabilistic. The available labour market data, however, do not yet allow long-term trends to be derived as the time series are still too short, due to structural breaks in the data. Drawing stochasticity from one source only, as done in previous studies, would create a biased picture of reality by creating some kind of pseudostochasticity. This is especially important, as the proportions of the population who enter higher education after graduating from school in Germany have significantly increased since 2006 (*GENESIS-Online* 2021). This trend means that payments into the DRV begin later on average and periods of payments are shorter if the retirement age is not adjusted accordingly. This trend is both a result of personal preferences to work in less physically demanding fields (*Schirner et al.* 2021) and the higher educational requirements on the labour market due to digitisation (*Steffes et al.* 2016). These developments on the reverse side are observed, *ceteris paribus*, in decreasing disability risks, which are covered indirectly in our time series data of disability pensions. Moreover, we found the development of a stochastic joint labour-pension model to exceed the scope of a single paper. Further research might add forecasts addressing the financial effects that result from using a probabilistic economic model, and might also elaborate on previous approaches.

6 Conclusions

The present study showed the effect of future demographic development in Germany on the numbers of old-age and disability pensions under the public pension system. Due to the ageing of the baby boom generation, we expect the numbers of old-age pensions to increase by almost 5 million, from 18 million in 2017 to 23 million in 2036. This increase will continue to be the case even if legal retirement ages are raised, as per the 2007 pension reform. Stochastic modelling for trajectories with high mortality rates equally shows increasing pension numbers. Pension reforms targeting obvious demographic trends do help mitigate the effects of the ageing process to some extent but are far from sufficient.

Further reforms concerning the three basic parameters of the DRV in Germany – namely the pension contribution rate, the pension level, and the legal retirement age – are thus inevitable. Furthermore, proposals regarding the financing option, such as a (partial) shift to a tax-funded system[16] (*D'Addio* 2013) or the implementation of financial market-linked pensions, following the Swedish example (*Groll* 2021), are likewise being discussed. Furthermore, demography and labour market policy could offer another option for the long-term stabilisation of the pension system. A larger number of pensioners means that there is a need for a proportional increase in the labour force, assuming that the labour market offers enough jobs to support this increase. Because the influence of fertility on the labour market is only felt after approximately 20 years (*Zuchandke et al.* 2014), a short-term or mid-term effect can only be achieved by either decreasing emigration of the labour force or increasing the immigration of skilled workers, who can be integrated into the labour market quickly (*Fuchs et al.* 2021).[17] However, we need to keep in mind that increases in the labour force as a result ofhigher fertility or international migration will mean higher pension payments, for which they will gather entitlements, in the long run. Complimentary increases in labour force participation rates may alleviate unfavourable trends in old-age dependency ratios (*Scherbov et al.* 2014). This addresses not only the trends in higher labour force participation by persons aged 65 and over, which is the aim of the pension reforms that have been implemented, but also the higher rate of female labour force participation, especially among the migrant population (*Fuchs et al.* 2018). In general, integrating migrants, especially refugees, into the labour market more quickly could have positive impacts on the financial sustainability of the DRV (*Fuchs et al.* 2021).

Improvements to our modelling approach, as indicated in Section 5, might be considered in further studies. The approach could be supplemented by the adoption of a more detailed economic approach, which takes account of the pension formula and predicts the future payments of the DRV.

Acknowledgments
We would like to express our thanks to Andreas Dannenberg from the DRV for his patience in not only providing much of the underlying pension data for our study but also offering valuable information on the limitations and problems associated with them. Moreover, we appreciate the critical discussion of an earlier version of the model by J.-Matthias Graf von der Schulenburg, which helped to improve the final model significantly. Finally, we would like to thank the anonymous reviewers

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16 In fact, in 2020 already, just 76 percent of the DRV's pension benefits were transferred via pension insurance payments, the rest was financed from additional sources such as taxes (*Deutsche Rentenversicherung Bund* 2021).

17 *Guest* 2008, for example, also discusses a number of issues, including measures to stimulate labour force participation rates among the elderly population, the fertility rate and higher immigration, as well as other measures like superannuation or health and care policy.

for their thorough and knowledgeable comments on our paper, which contributed to further improvements.

Authors' contributions

PV developed the model, researched the literature and legal texts, obtained and analysed the data, ran the simulations, and wrote the majority of the paper. Sections of the paper were written by MRG and CBW, both of whom also provided support in the research of the literature. CBW contributed her expertise on the German pension system and its past reforms. The text was edited by all of the authors and revised by PV and CBW.

The datasets used and analysed during this study are available from the corresponding author upon reasonable request.

References

Baldacci, Emanuele; Tuzi, Donatella 2003: Demographic Trends and Pension System in Italy. an Assessment of 1990s Reforms. In: LABOUR. Review of Labour Economic and Industrial Relations 17,s1: 209-240. https://doi.org/10.1111/1467-9914.17.specialissue.8

Börsch-Supan, Axel H. 1992: Population Aging, Social Security Design, and Early Retirement. In: Journal of Institutional and Theoretical Economics 148,4: 533-557.

Börsch-Supan, Axel H. 2000: Incentive effects of social security on labor force participation. Evidence in Germany and across Europe. In: Journal of Public Economics 78,1-2: 25-49. https://doi.org/10.1016/S0047-2727(99)00110-3

Box, George E.P. et al. 2016: Time Series Analysis. Forecasting and Control. Wiley Series in Probability and Statistics. 5th edition. Hoboken: John Wiley & Sons.

Brussig, Martin 2012: Weiter steigendes Renteneintrittsalter, mehr Renteneintritte aus stabiler Beschäftigung, aber zunehmend geringere Altersrenten bei Langzeitarbeitslosen. Aktuelle Entwicklungen beim Rentenzugang. Altersübergangs-Report 2012-02 [https://duepublico2.uni-due.de/receive/duepublico_mods_00045436, 05.11.2021].

Buchholz, Sandra; Rinklake, Annika; Blossfeld, Hans-Peter 2013: Reversing Early Retirement in Germany. A Longitudinal Analysis of the Effects of Recent Pension Reforms on the Timing of the Transition to Retirement and on Pension Incomes. In: Comparative Population Studies 38,4: 881-906. [https://doi.org/10.12765/CPoS-2013-23]

Bundesregierung 2013: Deutschlands Zukunft gestalten: Koalitionsvertrag zwischen CDU, CSU und SPD: 18. Legislaturperiode [https://www.bundesregierung.de/Content/DE/_Anlagen/2013/2013-12-17-koalitionsvertrag.pdf?blob=publicationFile, 12.12.2017].

Chatfield, Christopher; Collins, Alexander J. 1980: Introduction to Multivariate Analysis. Texts in Statistical Science. Boca Raton/London/New York/Washington: Chapman & Hall.

Coppola, Michela; Wilke, Christina B. 2014: At What Age Do You Expect to Retire? Retirement Expectations and Increases in the Statutory Retirement Age. In: Fiscal Studies. The Journal of Applied Public Economics 35,2: 165-188. [https://doi.org/10.1111/j.1475-5890.2014.12027.x]

D'Addio, Anna C. 2013: Pension Entitlements of Women with Children: The Role of Credits within Pension Systems on OECD and EU Countries. In: *Holzmann, Robert; Palmer, Edward; Robalino, David* (Eds.): Nonfinancial Defined Contribution Pension Schemes in a Changing Pension World. Volume 2: Gender, Politics, and Financial Stability. Washington, D.C.: The World Bank: 75-110.

Destatis 2018: Statistik des Rentenbestands, Deutsche Rentenversicherung Bund [http://www.gbe-bund.de, 29.05.2018].

Deutsche Rentenversicherung Bund 2017: Statistik der Deutschen Rentenversicherung Band 209: Rente 2016. Berlin: Deutsche Rentenversicherung Bund.

Deutsche Rentenversicherung Bund 2018: Rentenbestand am 31.12.1992-1999, Renten nach SGB VI wegen verminderter Erwerbsfähigkeit. Data provided on 07.06.2018.

Deutsche Rentenversicherung Bund 2021: Rentenversicherung in Zahlen 2021. Berlin: Deutsche Rentenversicherung Bund.

Federal Ministry of Labour and Social Affairs 2019: Bericht der Bundesregierung über die gesetzliche Rentenversicherung, insbesondere über die Entwicklung der Einnahmen und Ausgaben, der Nachhaltigkeitsrücklage sowie des jeweils erforderlichen Beitragssatzes in den künftigen 15 Kalenderjahren gemäß § 154 Abs. 1 und 3 SGB VI (Rentenversicherungsbericht 2019). Berlin: Federal Ministry of Labour and Social Affairs.

Fehr, Hans; Habermann, Christian 2006: Pension reform and demographic uncertainty. The case of Germany. In: Journal of Pension Economics & Finance 5,1: 69-90. https://doi.org/10.1017/S1474747205002209

Forschungsportal der Deutschen Rentenversicherung 2018: Rentenbestand am 31.12.2000-31.12.2009, Renten nach SGB VI wegen verminderter Erwerbsfähigkeit [http://forschung.deutsche-rentenversicherung.de/ForschPortalWeb/, 05.06.2018].

Fuchs, Johann; Söhnlein, Doris; Vanella, Patrizio 2021: Migration Forecasting – Significance and Approaches. In: Encyclopedia 1,3: 689-709. https://doi.org/10.3390/encyclopedia1030054

Fuchs, Johann et al. 2018: Stochastic Forecasting of Labor Supply and Population. An Integrated Model. In: Population Research and Policy Review 37,1: 33-58. https://doi.org/10.1007/s11113-017-9451-3

GENESIS-Online 2021: Studienanfängerquote (Hochschulzugangsberechtigung): Deutschland, Jahre, Geschlecht [https://www-genesis.destatis.de/, 09.11.2021].

Goffart, Daniel 2018: Zeitbombe Altersversorgung. In: Focus 36: 52-60.

Graf von der Schulenburg, Johann-Matthias; Lohse, Ute 2014: Versicherungsökonomik. Ein Leitfaden für Studium und Praxis. Karlsruhe: Verlag Versicherungswirtschaft.

Groll, Tina 2021: Die Börse soll das Rentenproblem lösen [https://www.zeit.de/wirtschaft/geldanlage/2021-08/gesetzliche-aktienrente-rentenreform-fdp-altersvorsorge-vorbild-schweden, 09.11.2021].

Gruber, Jonathan; Wise, David A. 2000: Social Security Programs and Retirement around the World. In: Research in Labor Economics 18: 1-40.

Guest, Ross 2008: Evaluating Public Policy Responses to the Economic Burden of Population Ageing with Application to Australia. In: Journal of Population Research 25,2: 99-118. https://doi.org/10.1007/BF03031944

Handl, Andreas 2010: Multivariate Analysemethoden. Theorie und Praxis multivariater Verfahren unter Berücksichtigung von S-Plus. Statistik und ihre Anwendungen. 2nd edition. Heidelberg/Dordrecht/London/New York: Springer-Verlag.

Hertrampf, Susanne 2008: Ein Tomatenwurf und seine Folgen. Eine neue Welle des Frauenprotestes in der BRD [http://www.bpb.de/gesellschaft/gender/frauenbewegung/35287/neue-welle-im-westen, 15.02.2018].

Human Mortality Database 2019: Germany, Population Size (abridged). University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany) [URL: www.mortality.org or www.humanmortality.de, 07.07.2019].

Kaiser, Henry F. 1970: A second generation little jiffy. In: Psychometrika 35,4: 401-415. https://doi.org/10.1007/BF02291817

Kaiser, Henry F.; Rice, John 1974: Little Jiffy, Mark IV. In: Educational and Psychological Measurement 34,1: 111-117. https://doi.org/10.1177/001316447403400115

Keilman, Nico; Pham, Dinh Quang; Hetland, Arve 2002: Why population forecasts should be probabilistic – illustrated by the case of Norway. In: Demographic Research 6,15: 409-454. https://doi.org/10.4054/DemRes.2002.6.15

Koissi, Marie-Claire 2006: Longevity and adjustment in pension annuities, with application to Finland. In: Scandinavian Actuarial Journal 2006,4: 226-242. https://doi.org/10.1080/03461230600803935

OECD 2018: OECD Pensions Outlook 2018. Paris: OECD Publishing. https://doi.org/10.1787/pens_outlook-2018-en

OECD 2021: Pensions at a Glance 2021: OECD and G20 Indicators. Paris: OECD Publishing [https://www.oecd-ilibrary.org/finance-and-investment/pensions-at-a-glance-2021_9a567f6c-en, 18.01.2022].

Ogawa, Naohiro 2005: Population aging and policy options for a sustainable future: the case of Japan. In: Genus. Journal of Population Sciences 61,3-4: 369-410.

Rodriguez Gonzalez, Miguel A. et al. 2015: Sozioökonomische Analyse des Erwerbsminderungsrisikos – Eine Untersuchung anhand von BASiD-Daten. In: Zeitschrift für die gesamte Versicherungswissenschaft 104,2: 151-178. https://doi.org/10.1007/s12297-015-0300-3

RRG 1992: Gesetz zur Reform der gesetzlichen Rentenversicherung. In: Bundesgesetzblatt Teil I, Nr. 1989/60: 2261-2395.

RRG 1999: Gesetz zur Reform der gesetzlichen Rentenversicherung. In: Bundesgesetzblatt Teil I, Nr. 1997/85: 2998-3038.

RÜG 1991: Gesetz zur Herstellung der Rechtseinheit in der gesetzlichen Renten- und Unfallversicherung. In: Bundesgesetzblatt Teil I, Nr. 1991/46: 1606-1708.

RV-AltAnpG 2007: Gesetz zur Anpassung der Regelaltersgrenze an die demografische Entwicklung und zur Stärkung der Finanzierungsgrundlagen der gesetzlichen Rentenversicherung. In: Bundesgesetzblatt Teil I, Nr. 2007/16: 554-575.

RVLeistVerbG 2014: Gesetz über Leistungsverbesserungen in der gesetzlichen Rentenversicherung. In: Bundesgesetzblatt Teil I, Nr. 2014/27: 787-790.

Scherbov, Sergei; Sanderson, Warren C.; Mamolo, Marija 2014: Quantifying policy tradeoffs to support aging populations. In: Demographic Research 30,20: 579-608. https://doi.org/10.4054/DemRes.2014.30.20

Schirner, Sebastian et al. 2021: KOFA-Studie 1/2021. Fachkräfteengpässe in Unternehmen. Fachkräftemangel und Nachwuchsqualifizierung im Handwerk [https://www.iwkoeln.de/studien/helen-hickmann-lydia-malin-dirk-werner-fachkraefteengpaesse-in-unternehmen-fachkraeftemangel-und-nachwuchsqualifizierung-im-handwerk.html, 09.11.2021].

Shumway, Robert H.; Stoffer, David S. 2016: Time Series Analysis and Its Applications. With R Examples. 4th edition. New York/Dordrecht/Heidelberg/London: Springer Science+Business Media.

Smith, Gary 2018: Step away from stepwise. In: Journal of Big Data 5: 32. https://doi.org/10.1186/s40537-018-0143-6

Spijker, Jeroen; García González, Juan M.; Puga, Dolores 2020: Spain. In: *Léime,* Áine *Ní et al.* (Eds.): Extended Working Life Policies. International Gender and Health Perspectives. Cham: Springer: 427-437.

Statistikportal der Rentenversicherung 2020a: Rentenbestand: Renten wegen Alters nach SGB VI [https://statistik-rente.de/drv/, 20.01.2020].

Statistikportal der Rentenversicherung 2020b: Rentenbestand: Renten wegen verminderter Erwerbsfähigkeit nach SGB VI [https://statistik-rente.de/drv/, 20.01.2020].

Steffes, Susanne; Arnold, Daniel; Bellmann, Lutz; Wolter, Stefanie 2016: Digitalisierung am Arbeitsplatz. Technologischer Wandel birgt für die Beschäftigten Chancen und Risiken. In: IAB-Forum 01/2016: 98-105 [https://www.wbv.de/shop/themenbereiche/bildungs-und-sozialforschung/shop/detail/name/_/0/1/IFO1601W/facet/IFO1601W//////nb/0/category/213.html, 17.11.2021].

Tomaš, Ivan 2020: A stochastic forecast for the Croatian pension system. In: Public Sector Economics 44,1: 41-98. https://doi.org/10.3326/pse.44.1.2

Vanella, Patrizio 2017: A principal component model for forecasting age- and sex-specific survival probabilities in Western Europe. In: Zeitschrift für die gesamte Versicherungswissenschaft 106,5: 539-554. https://doi.org/10.1007/s12297-017-0393-y

Vanella, Patrizio 2018: Stochastic Forecasting of Demographic Components Based on Principal Component Analyses. In: Athens Journal of Sciences 5,3: 223-246. https://doi.org/10.30958/ajs.5-3-2

Vanella, Patrizio; Deschermeier, Philipp 2018: A stochastic Forecasting Model of international Migration in Germany. In: *Kapella, Olaf; Schneider, Norbert F.; Rost, Harald* (Eds.): Familie – Bildung – Migration. Familienforschung im Spannungsfeld zwischen Wissenschaft, Politik und Praxis. Tagungsband zum 5. Europäischen Fachkongress Familienforschung. Opladen/Berlin/Toronto: Verlag Barbara Budrich: 261-280.

Vanella, Patrizio; Deschermeier, Philipp 2019: A Principal Component Simulation of Age-Specific Fertility – Impacts of Family Policy on Reproductive Behavior in Germany. In: Population Review 58,1: 78-109. https://doi.org/10.1353/prv.2019.0002

Vanella, Patrizio; Deschermeier, Philipp 2020: A Probabilistic Cohort-Component Model for Population Forecasting – The Case of Germany. In: Journal of Population Ageing 13,4: 513-545. https://doi.org/10.1007/s12062-019-09258-2

Vanella, Patrizio; Deschermeier, Philipp; Wilke, Christina B. 2020: An Overview of Population Projections – Methodological Concepts, International Data Availability, and Use Cases. In: Forecasting 2,3: 346-363. https://doi.org/10.3390/forecast2030019

Vanella, Patrizio; Heß, Moritz; Wilke, Christina B. 2020: A probabilistic projection of beneficiaries of long-term care insurance in Germany by severity of disability. In: Quality & Quantity 54,3: 943-974. https://doi.org/10.1007/s11135-020-00968-w

Vogt, Valentin 2017: Die Projektion der langfristigen Entwicklung der gesetzlichen Rentenversicherung. Methodische Vorgehensweise und empirische Ergebnisse. In: *Altmeppen, Klaus-Dieter et al.* (Eds.): Nachhaltigkeit in Umwelt, Wirtschaft und Gesellschaft. Interdisziplinäre Perspektiven. Wiesbaden: Springer VS: 149-170.

Wang, Huan; Huang, Jianyuan; Yang, Qi 2019: Assessing the Financial Sustainability of the Pension Plan in China: The Role of Fertility Policy Adjustment and Retirement Delay. In: Sustainability 11,3: 883. https://doi.org/10.3390/su11030883

WFG 1996: Gesetz zur Umsetzung des Programms für mehr Wachstum und Beschäftigung in den Bereichen der Rentenversicherung und Arbeitsförderung. In: Bundesgesetzblatt Teil I, Nr. 1996/48: 1461-1475.

Wilke, Christina B. 2009: German Pension Reform. On Road Towards a Sustainable Multi-Pillar System. Sozialökonomische Schriften 34. Frankfurt (a.M.): Peter Lang Internationaler Verlag der Wissenschaften.

Zuchandke, Andy; Lohse, Ute; Graf von der Schulenburg, Johann-Matthias 2014: Financial sustainability of the German statutory pension scheme through 2060 – Can higher fertility rates and immigration mitigate the financial pressure? In: Zeitschrift für die gesamte Versicherungswissenschaft 103,3: 283-299. https://doi.org/10.1007/s12297-014-0271-9

List of abbreviations

ACF	autocorrelation function
AIC	Akaike's Information Criterion
ARIMA	autoregressive integrated moving average
ASSPR	age- and sex-specific pension rate
BIC	Bayesian Information Criterion
DDR	German Democratic Republic
DRV	Deutsche Rentenversicherung
PACF	partial autocorrelation function
PCA	principal component analysis
PI	prediction interval
RKI	Robert Koch Institute
RRG	Rentenreformgesetz
RÜG	Renten-Überleitungsgesetz
RV-AltAnpG	Rentenversicherungs-Altersgrenzenanpassungsgesetz
RVLeistVerbG	Rentenversicherungs-Leistungsverbesserungsgesetz
WFG	Wachstums- und Beschäftigungsförderungsgesetz

Date of submission: 07.07.2021 *Date of acceptance: 13.01.2022*

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Appendix A: Mean retirement ages

Tab. A1: Past, current, and future mean annual legal retirement ages

Year	Standard	Insured for 35 years	Insured for 45 years	Severely disabled	Unemployed	Women	Mine-workers
1992	65.000	63.000	63.000	60.000	60.000	60.000	60.000
1993	65.000	63.000	63.000	60.000	60.000	60.000	60.000
1994	65.000	63.000	63.000	60.000	60.000	60.000	60.000
1995	65.000	63.000	63.000	60.000	60.000	60.000	60.000
1996	65.000	63.000	63.000	60.000	60.000	60.000	60.000
1997	65.000	63.000	63.000	60.000	60.292	60.000	60.000
1998	65.000	63.000	63.000	60.000	60.792	60.000	60.000
1999	65.000	63.000	63.000	60.000	61.292	60.000	60.000
2000	65.000	63.292	63.292	60.292	61.792	60.292	60.000
2001	65.000	63.792	63.792	60.792	62.292	60.792	60.000
2002	65.000	64.292	64.292	61.292	62.792	61.292	60.000
2003	65.000	64.792	64.792	61.792	63.292	61.792	60.000
2004	65.000	65.000	65.000	62.292	63.792	62.292	60.000
2005	65.000	65.000	65.000	62.792	64.292	62.792	60.000
2006	65.000	65.000	65.000	63.000	64.792	63.292	60.000
2007	65.000	65.000	65.000	63.000	65.000	63.792	60.000
2008	65.000	65.000	65.000	63.000	65.000	64.292	60.000
2009	65.000	65.000	65.000	63.000	65.000	64.792	60.000
2010	65.000	65.000	65.000	63.000	65.000	65.000	60.000
2011	65.000	65.000	65.000	63.000	65.000	65.000	60.000
2012	65.083	65.083	65.083	63.000	65.083	65.083	60.292
2013	65.159	65.159	65.159	63.000	65.159	65.159	60.538
2014	65.235	65.235	63.000	63.000	65.235	65.235	60.614
2015	65.311	65.311	63.000	63.292	65.311	65.311	60.689
2016	65.386	65.386	63.167	63.538	65.386	65.386	60.765
2017	65.462	65.462	63.333	63.614	65.462	65.462	60.841
2018	65.538	65.538	63.500	63.689	65.538	65.538	60.917
2019	65.614	65.614	63.667	63.765	65.614	65.614	61.000
2020	65.689	65.689	63.833	63.841	65.689	65.689	61.167
2021	65.765	65.765	64.000	63.917	65.765	65.765	61.300
2022	65.841	65.841	64.167	64.000	65.841	65.841	61.433
2023	65.917	65.917	64.333	64.167	65.917	65.917	61.567
2024	66.000	66.000	64.500	64.300	66.000	66.000	61.700
2025	66.167	66.167	64.667	64.433	66.167	66.167	61.833
2026	66.300	66.300	64.833	64.567	66.300	66.300	62.000
2027	66.433	66.433	65.000	64.700	66.433	66.433	62.000
2028	66.567	66.567	65.000	64.833	66.567	66.567	62.000
2029	66.700	66.700	65.000	65.000	66.700	66.700	62.000

Tab. A1: Continuation

Year	Standard	Insured for 35 years	Insured for 45 years	Severely disabled	Unemployed	Women	Mine-workers
2030	66.833	66.833	65.000	65.000	66.833	66.833	62.000
2031	67.000	67.000	65.000	65.000	67.000	67.000	62.000
2032	67.000	67.000	65.000	65.000	67.000	67.000	62.000
2033	67.000	67.000	65.000	65.000	67.000	67.000	62.000
2034	67.000	67.000	65.000	65.000	67.000	67.000	62.000
2035	67.000	67.000	65.000	65.000	67.000	67.000	62.000
2036	67.000	67.000	65.000	65.000	67.000	67.000	62.000
2037	67.000	67.000	65.000	65.000	67.000	67.000	62.000
2038	67.000	67.000	65.000	65.000	67.000	67.000	62.000
2039	67.000	67.000	65.000	65.000	67.000	67.000	62.000
2040	67.000	67.000	65.000	65.000	67.000	67.000	62.000

Source: *RRG* 1992; *WFG* 1996; *RRG* 1999; *RV-AltAnpG* 2007; *Bundesregierung* 2013: 72; *RVLeistVerbG* 2014; Own calculation and design

Appendix B: Correlation matrix of mean retirement ages

Tab. A2: Correlation matrix of different legal retirement ages over the period from 1992 to 2016

	Standard	Insured for 35 years	Insured for 45 years	Severely disabled	Unem-ployed	Women	Mine-workers
Standard	1	0.87	0.52	0.82	0.75	0.78	0.96
Insured for 35 years	0.87	1	0.72	0.99	0.97	0.96	0.89
Insured for 45 years	0.52	0.72	1	0.70	0.72	0.64	0.47
Severely disabled	0.82	0.99	0.70	1	0.99	0.98	0.86
Unemployed	0.75	0.97	0.72	0.99	1	0.98	0.79
Women	0.78	0.96	0.64	0.98	0.98	1	0.84
Mine-workers	0.96	0.89	0.47	0.86	0.79	0.84	1

Source: Own calculation and design

Comparative Population Studies

www.comparativepopulationstudies.de

ISSN: 1869-8980 (Print) – 1869-8999 (Internet)

Published by
Federal Institute for Population Research (BiB)
D-65180 Wiesbaden / Germany

Managing Publisher
Dr. Nikola Sander