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

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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
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), 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

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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 (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 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. 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).

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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:

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

(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

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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.
in the following years, the effects of RRG 1992 and \textit{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 (\textit{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
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.
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

$$p_1(y) = -4.551.43 + 731.96\ln(s_y) + 0.41u_y + 0.32f_y + 0.58\ln(b_y) + 355.66\ln(b_y) + r_y + \varepsilon_y$$

### Tab. 1: Model estimates for Principal Component 1

| Retirement Age | Model 1.1 | Model 1.2 | Model 1.3 | Model 1.4 |
|----------------|-----------|-----------|-----------|-----------|
| Intercept      | -4,426*** | -4,326*** | -4,551*** | -3,907*** |
| ln(Standard)   | (709)     | (625)     | (555)     | (474)     |
| Insured for 35 years | 0.52     | 0.37     | -         | -         |
| Insured for 45 years | 0.31     | 0.3     | 0.41*    | -         |
| Severely disabled | -0.21    | -0.53 | -         | -         |
| Unemployed     | -0.43*    | -0.44*   | -0.32*   | -0.14     |
| Women          | 0.64***   | 0.58***  | 0.58***  | 0.58***   |
| ln(Mineworkers) | 344***   | 363***   | 356***   | 358***   |

a One asterisk means statistical significance on a 10 percent level against $H_0: \beta_x = 0$, with $\beta_x$ 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.
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

Principal Component 1

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 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

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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):

$$\Phi_\tau = \Pi_\tau \Lambda^{-1},$$

where

- $\Pi_\tau$ is a 10,000x16 matrix of 10,000 trajectories for each PC in year $\tau$,
- $\Lambda^{-1}$ is the inverse of the loading matrix,
- $\Phi_\tau$ is a 10,000x16 matrix of 10,000 trajectories for all logit-ASSPRs in year $\tau$.

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       |                            |                          |                   |                            |                            |            |                        |                        |
| 2021 | 15.573       | 15.354                    | 15.799                   | 51.804            | 51.178                     | 52.012                     | 15.364     | 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                     | 20.369     | 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
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.

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
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

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
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.

Source: Deutsche Rentenversicherung Bund 2018; Forschungsportal der Deutschen Rentenversicherung 2018; Statistikportal der Rentenversicherung 2020b; Human Mortality Database 2019; 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
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...

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; 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

16 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\(^\text{16}\) (\textit{D’Addio} 2013) or the implementation of financial market-linked pensions, following the Swedish example (\textit{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 (\textit{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 (\textit{Fuchs et al.} 2021).\(^\text{17}\) However, we need to keep in mind that increases in the labour force as a result of higher 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 (\textit{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 (\textit{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 (\textit{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.

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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 (\textit{Deutsche Rentenversicherung Bund} 2021).

\(^{17}\) \textit{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.
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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
revised by PV and CBW.

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

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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
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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       |
| 1993 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 1994 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 1995 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 1996 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 1997 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 1998 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 1999 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2000 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2001 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2002 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2003 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2004 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2005 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2006 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2007 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2008 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2009 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2010 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2011 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2012 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2013 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2014 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2015 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2016 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2017 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2018 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2019 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2020 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2021 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2022 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2023 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2024 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2025 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2026 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2027 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2028 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |
| 2029 | 65.000                        | 63.000               | 63.000            | 60.000     | 60.000 | 60.000       |

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### Tab. A1: Continuation

| Year | Standard for 35 years | 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 | Unemployed | 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
