MILLIMAN ARTICLE

Impact of COVID-19 on Dutch mortality tables

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The COVID-19 pandemic has affected mortality in different ways. As a consequence of the physical damage caused by COVID-19, many people died in the first half of 2020. On the other hand, we see that the number of deaths that are due for example to car accidents has decreased as a result of the lockdown situation. This means that COVID-19 had and still has both positive and negative impacts on the number of deaths.

In addition, there is a lot of uncertainty about the duration of the pandemic. The duration will depend on how the virus itself evolves, whether a working vaccine will be invented and, if so, whether the vaccine will work in the long term as well. Due to these uncertainties, questions arise about how future mortality projections, and thus future cash flow projections, will emerge. In this article, multiple scenarios of the possible effects of COVID-19 on future mortality tables are analysed. As the country of interest is the Netherlands, the starting point for our analyses is the methodology for constructing the mortality tables of the Royal Dutch Actuarial Association, as described in its “Projection table AG2018” publication (Royal Dutch Actuarial Association, 2018).

The model

The approach of the Royal Dutch Actuarial Association for constructing mortality tables is to use the Li-Lee model (Li and Lee, 2005) on European death and exposure data to estimate the European trend and then subsequently use the Li-Lee model on Dutch data to determine how the country of interest deviates from this trend. This is done for both male and female data.

In line with the Royal Dutch Actuarial Association, in this article, Exposure $(E_{x,t})$ means the population of age x in year t. Deaths $(D_{x,t})$ is defined as the observed instances of death of age x in year t. From these, the force of mortality is $\mu_{x,t} = D_{x,t}/E_{x,t}$ and the one-year mortality probability is then $q_{x,t} = 1 - e^{\mu_{x,t}}$. The Li-Lee model uses the group (EU) and individual (NL) data for each gender g to obtain the European force of mortality in future years $\mu_{x,t}^{g,EU}$ and the Dutch deviation from this $\mu_{x,t}^{g,NL}$. The force of mortality for the Dutch population $\mu_{x,t}^{g}$ is then $\mu_{x,t}^{g,EU} * \mu_{x,t}^{g,NL}$. Background information regarding these quantities can be found in the “Projection table AG2018” publication (Royal Dutch Actuarial Association, 2018).

Data

The death and exposure data used by the Royal Dutch Actuarial Association, and in this analysis, come from the Human Mortality Database (HMD). The European data only contains data from the European countries that, as in the Netherlands, have a gross domestic product (GDP) above the European average: Austria, Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Norway, Sweden, Switzerland and the United Kingdom. These countries are chosen as a positive correlation exists between a country’s prosperity, here measured by GDP, and the ageing of its inhabitants. For some years, data from certain countries is missing in the HMD. In these cases, the HMD data is supplemented with data from the Eurostat database and the Dutch local Statline database.

Approach

The goal of this analysis is to determine possible impacts of COVID-19 on mortality tables. For this, four different COVID-19-impacted mortality tables containing $q_{x,t}$ for t = 2020 and later are constructed.

The first step in our analysis is to create a mortality table based on the latest available data in the data sets. This means that, for Europe and the Netherlands, data from 1970 up to and including 2018 and 2019, respectively, is used. For this mortality table the trend is projected from 2020 onwards, and it will be referred to as *Base-trend 2020*. Note that this mortality table will not show the impact of COVID-19 deaths, as the data is from before 2020.

Next to this, a *Base-trend 2023* mortality table is constructed by refitting the mortality model using the data set containing observed data until 2019, extended with estimated data for 2020 to 2022. The data is estimated as if COVID-19 did not exist, meaning that the $q_{x,t}^{trend}$ for t = 2020-2022 from *Base-trend 2020* are assumed to actually reflect the observed deaths in the 2020-2022 period. For 2020 to 2022, the $q_{x,t}^{observed}$ in *Base-trend 2023* are thus equal to $q_{x,t}^{trend}$ in *Base-trend 2020.* The difference between the *Base-trend 2020* and *Base-trend 2023* mortality tables is in the years 2023 and later. In *Base-trend 2023*, the $q_{x,t}^{trend}$ from 2023 are based on the observed data from 1970 to 2019 and the estimated data for the 2020-2022 period. In the *Base-trend 2020* mortality table, all $q_{x,t}^{trend}$ are based solely on the observed data from 1970 to 2019. As for constructing *Base-trend 2023*, extra data is used and the resulting $q_{x,t}^{trend}$ will be slightly different from the $q_{x,t}^{trend}$ in *Base-trend 2020* for 2023 and later.

Constructing the *Base-trend 2023* mortality table is necessary to make fair comparisons to the COVID-19-impacted mortality tables. As with *Base-trend 2020*, *Base-trend 2023* does not show any COVID-19 impact. The COVID-19-impacted mortality tables are determined by stressing the mortality of the *Base-trend 2020* mortality table in the years 2020 to 2022.

BASE SCENARIO

To construct the *Base-trend 2023*, the *Base-trend 2020* mortality table, estimated by the most recent 1970-2018 (EU) and 1970-2019 (NL) data, is used. From the forces of mortality $\mu_{x,t}^{g,EU}$ and $\mu_{x,t}^{g}$ together with the last available death and exposure data of 2018 and 2019, respectively, the estimated death and exposure data for the 2019-2022 and 2020-2022 periods, respectively, can be obtained per gender. The procedure for Europe is thus:

$$\begin{aligned} E_{x,2019} &= E_{x-1,2018} - D_{x-1,2018} \\ D_{x,2019} &= E_{x,2019} * \mu_{x,2019}^{g,EU} \\ E_{x,2020} &= E_{x-1,2019} - D_{x-1,2019} \\ D_{x,2020} &= E_{x,2020} * \mu_{x,2020}^{g,EU} \\ &\dots \\ E_{x,2022} &= E_{x-1,2021} - D_{x-1,2021} \\ D_{x,2022} &= E_{x,2022} * \mu_{x,2022}^{g,EU} \end{aligned}$$

As there is no $x-1$ Exposure data for $x=0$ when going from one year to the next, the assumption is made that each year $E_{0,t} = E_{0,t-1}$. It is also assumed that, for all ages, the exposure is not affected by migration from and to Europe. For the Netherlands, the same approach is followed.

COVID-19 SCENARIOS

The four different COVID-19-impacted mortality tables containing $q_{x,t}$'s for *t* = 2020 and later are constructed in two steps. First, four different scenarios of $q_{x,t}^{COVID,impact}$ for t = 2020-2022 are constructed. Next, using these $q_{x,t}^{COVID,impact}$, four scenarios for COVID-19-impacted death and exposure data in the 2020-2022 period are estimated. The $q_{x,t}^{COVID,trend}$ for 2023 and later in the four scenarios are then constructed by refitting the mortality model using a data set containing observed data until 2019, extended with the COVID-19-impacted data for 2020 to 2022. To come to the $q_{x,t}^{COVID,impact}$, the $q_{x,t}$'s for *t = 2020, 2021 and* 2022 from the constructed *Base-trend 2020* mortality table are shocked to obtain: $q_{x,t}^{COVID,impact} = q_{x,t}(1 + shock_{x,t})$.

The shocks are based on observed excess mortality values in the first 23 weeks of 2020 compared to the mortality in the first 23 weeks in the years 2015 to 2019. Four different shock scenarios are used to obtain the $q_{x,t}^{COVID,impact}$. The second step is to estimate from these $q_{x,t}^{COVID,impact}$ for each scenario the estimated COVID-19-impacted death and exposure data for the years 2020 to 2022. To obtain this death and exposure data, a similar approach is followed as when constructing the *Base-trend 2023* mortality table. However, instead of using the regular $\mu_{x,t}^{g,EU}$ and $\mu_{x,t}^{g}$, now COVID-19-impacted $\mu_{x,t}^{g,EU,COVID,impact}$ and $\mu_{x,t}^{g,COVID,impact}$ are used for the 2020-2022 period: $\mu_{x,t}^{COVID,impact} = -ln(1 - q_{x,t}^{COVID,impact})$. Using this estimated COVID-19-impacted 2020-2022 data together with observed death and exposure data from 1970 to 2019, the Li-Lee model parameters are estimated again to obtain $q_{x,t}^{COVID,trend}$ for 2023 and later.

EXCESS MORTALITY

To obtain the excess mortality in 2020, data on weekly death counts and death rates for the earlier mentioned European countries is retrieved from HMD. The data is available by gender and split into different age categories: 0-14, 15-64, 65-74, 75-84 and 85+. HMD computes the weekly death rates by dividing the number of deaths in a week by the weekly exposure (weekly exposure defined as the annual exposure divided by 52). To come to European and Dutch excess mortality percentages, first the European and Dutch reference mortality rate is determined for each gender and age group. The reference period is set at 2015 to 2019 and only the first 23 weeks are used because at the time of the analyses, no data later than week 23 was available for 2020. From the European countries used in this paper, Ireland is not present in the weekly death data. For the United Kingdom, only data for Wales, England and Scotland is provided.

The European reference mortality is determined in two steps. First, the European death rate for each year is determined by summing all deaths of the European countries in weeks 1 to 23 and dividing these deaths by the exposure in weeks 1 to 23. That is: $Death\ Rate_t = \frac{\sum_{country=i}^{N} Deaths_i\ week\ 1-week\ 23\ year\ t}{\sum_{country=i}^{N} Exposure_i\ week\ 1-\ week\ 23\ year\ t}$

Thereafter, the reference death rate over the period 2015 to 2019 is set equal to the arithmetic mean of the death rates in these years computed in the first step. By using this method, the rate is adjusted for the differences in population sizes of the different countries, while making sure that each year is weighted equally. For the Netherlands, a similar approach is followed.

Finally, the excess mortality per age group and gender is then obtained by $\frac{Death\ Rate_{2020}}{Reference\ Rate_{2015-2019}} - 1$. In figure 1, the observed excess mortality is shown. It can be seen that, for the Netherlands, the deviation from the reference rate is higher than for the European countries in general. Next, it is observed that, for certain age groups, under-mortality instead of excess mortality occurs in 2020 in weeks 1 to 23, possibly due to the side effects of the lockdown situation in most countries.

FIGURE 1: EXCESS MORTALITY IN 2020 OVER 2015-2019 IN WEEKS 1-23

	0-14	15-64	65-74	75-84	85+
			NLD		
M	-4.2%	2.1%	8.1%	4.6%	7.8%
F	-15.8%	-7.3%	7.0%	2.2%	4.0%
			EUR		
M	-10.3%	2.2%	5.3%	3.9%	4.7%
F	-9.8%	2.8%	3.6%	3.3%	3.3%

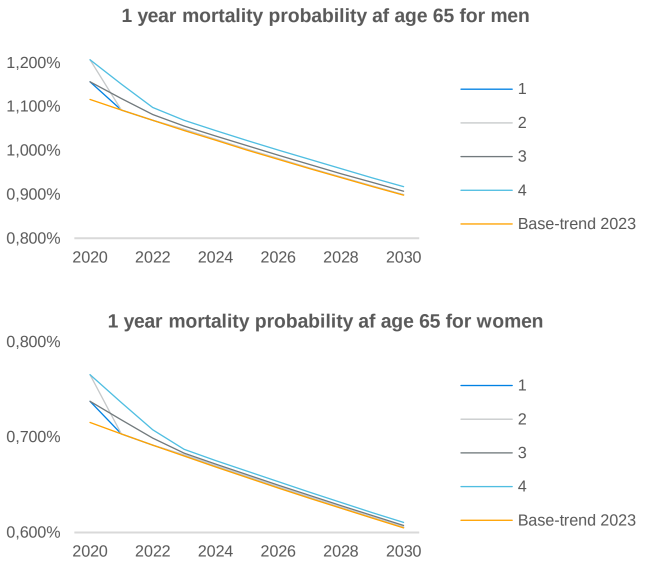
SHOCKS

From Figure 1, four different shock scenarios are defined. In Scenario 1 and Scenario 2, the $q_{x,t}$ for obtaining 2020-2022 death and exposure data are only shocked in 2020, reflecting the situation where COVID-19 disappears after this year. In Scenario 1, the mortality rate is assumed to be at its reference level in weeks 24 to 52, meaning that no second COVID-19 wave will occur. To come to the shocks in Scenario 1, the excess mortalities in figure 1 are multiplied by 23/52. In Scenario 2, a second COVID-19 wave is assumed and therefore the multiplication by 23/52 is omitted here.

In Scenarios 3 and 4, COVID-19 is assumed to be effective from 2020 to 2022, having one (Scenario 3) and two (Scenario 4) waves each year. This means that in these scenarios the $q_{x,t}$ for obtaining 2020-2022 death and exposure data are shocked in the 2020-2022 period. However, the COVID-19 effect are assumed to fade away over the years due to more and better cures becoming available. This means that, in 2020, the shocks are as shown in figure 1 (multiplied by 23/52 in Scenario 3), in 2021 the shocks are two-thirds of these percentages and in 2022 the shocks are one-third of these percentages.

Using this approach, the effect of a shock is one-off: it does not affect the trend in later years (before recalibration). The assumption is that as soon as COVID-19 is eliminated we get back to the original trend as calculated using the most recent available data until 2019. In Figure , the one-year mortality probability at age 65 for men and women is shown. The differences between the scenarios are larger for men than for women, which is in line with the excess mortality values in Figure 1. It is also clear that in all scenarios the trend is similar from 2023 on. In Scenarios 1 and 2, the trend for years 2021 and 2022 is by construction not affected at all. In addition, the effect of the shock in these scenarios for the years 2023 and later is negligible compared to Scenarios 3 and 4.

FIGURE 2: 1-YEAR MORTALITY PROBABILITIES AT AGE 65 FOR MEN AND WOMEN FOR 2020-2030



Results

LIFE EXPECTANCIES

From mortality tables, the cohort life expectancy (LE) at a certain age in a specific year can be obtained by going "diagonally" across the mortality table, moving in both age and year each step: $LE^{coh}_{x,t} = \frac{1}{2} + \sum_{k=0}^{\infty} \prod_{s=0}^{k} (1 - q_{x+s,t+s})$. Cohort life expectancies for age 0 and age 65 in 2020 and 2023 can be found in Figure 3, calculated using the most recently published mortality table of the Royal Dutch Actuarial Association (AG2018), the *Base-trend 2020* and the *Base-trend 2023* mortality tables.

FIGURE 3: LIFE EXPECTANCIES FOR AGE 0 AND AGE 65 IN 2020 AND 2023

	Life Expectancy at age 0 in 2020			Life Expectancy at age 0 in 2023		
	AG 2018	B-T 2020	B-T 2023	AG 2018	B-T 2020	B-T 2023
M	90.1	90.2	90.2	90.4	90.5	90.5
F	92.6	91.5	91.5	92.9	91.7	91.7
	Life Expectancy at age 65 in 2020			**Life Expectancy at age 65 in 2023**		
	AG 2018	B-T 2020	B-T 2023	AG 2018	B-T 2020	B-T 2023
M	85.4	85.4	85.4	85.8	85.8	85.8
F	88.2	87.9	87.9	88.6	88.2	88.2

Calculated by the AG2018, Base-trend 2020 and Base-trend 2023 mortality tables.

In the tables in Figures 4 and 5, life expectancies at ages 0 and 65 can be found in both 2020 and 2023 under all scenarios. Scenarios 1 and 2 show no differences compared to the base scenarios, except for the increased LE at age 0 for women. This can be caused by the relatively large under-mortality for the ages 15 to 64 of -7.3% that is used in this scenario. In line with this, in Scenario 4 similar LEs are found for age 0 for women. Scenarios 3 and 4 show decreased LEs for men at both age 0 and age 65, probably caused by the large positive excess mortality shocks for all 15+ ages that in these scenarios hold for three years instead of one. For women at age 65, only the life expectancy in 2020 has decreased slightly in Scenario 4. In general, the changes compared to the base situation are similar for 2020 and 2023.

In Figure 6, the life expectancy in 2020 for ages 0 to 85 are compared with the base-trend 2023 for all scenarios. It can be seen that for men the LEs are more heavily impacted by the shocks used in the scenarios than for women. This is in line with figure 1 above. For women, under-mortality instead of excess mortality is more frequently observed than for men. For men, it is clear from figure 1 that, for ages over 15, Scenario 4 is most severe. For women this cannot be concluded due to the under-mortality for ages 15 to 64 in the Netherlands. Consequently, for ages 0 to 65, there is less difference in LE between the scenarios for women than for men.

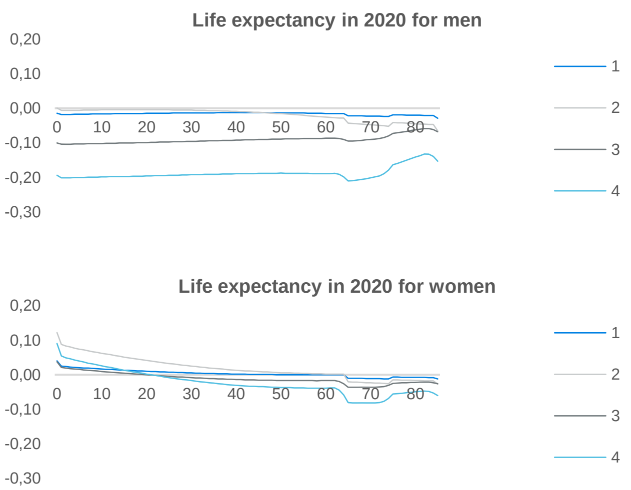
FIGURE 4: LIFE EXPECTANCIES AT AGE 0 FOR ALL SCENARIOS AND BASE-TREND 2023

	Life Expectancy at age 0 in 2020					Life Expectancy at age 0 in 2023				
	B-T 2023	S1	S2	S3	S4	B-T 2023	S1	S2	S3	S4
M	90.2	90.2	90.2	90.1	90.0	90.5	90.5	90.5	90.4	90.3
F	91.5	91.5	91.6	91.5	91.6	91.7	91.8	91.8	91.7	91.8

FIGURE 5: LIFE EXPECTANCIES AT AGE 65 FOR ALL SCENARIOS AND BASE-TREND 2023

	Life Expectancy at age 65 in 2020					Life Expectancy at age 65 in 2023				
	B-T 2023	S1	S2	S3	S4	B-T 2023	S1	S2	S3	S4
M	85.4	85.4	85.4	85.3	85.2	85.8	85.8	85.8	85.7	85.6
F	87.9	87.9	87.9	87.9	87.8	88.2	88.2	88.2	88.2	88.2

FIGURE 6: DIFFERENCE IN LIFE EXPECTANCY IN 2020 FOR AGES 0-85 FOR MEN AND WOMEN COMPARED TO BASE-TREND 2023



CASH FLOW BEST ESTIMATES

The effect of the use of the COVID-19-impacted mortality tables on cash flow projections is calculated for two different insurance products: an immediate annuity product and a funeral insurance product. These products act in opposite ways in premium collection and payout moments. For an immediate annuity, premium is collected by the insurer once at the start. The insurance starts paying out a fixed amount every year from the pension date to the moment of death. For a funeral insurance product, the premium is collected yearly from the start of the insurance. The payout moment is once at the moment of death. Due to these characteristics, an immediate annuity product entails the risk of longevity, whereas funeral insurance is more exposed to mortality risk. It is therefore expected that the COVID-19-impacted mortality tables have an opposite effect on the best estimate cash flows of these kinds of products. This hypothesis is checked by estimating discounted cash flows of two hypothetical portfolios in the different scenarios. In both portfolios there are around 50% men and 50% women. In the immediate annuity portfolio, the age at issue of the policyholders varies between 60 and 70 and the current age between 61 and 78. For the funeral insurance, this is 10 and 60, and 11 and 79, respectively. The annual annuity varies between €5,000 and €25,000. The insured sum of the funeral insurance product varies between €4,500 and €11,000 and the annual premium is €50 to €350.

In the AG2018 mortality table published by the Royal Dutch Actuarial Association, data until 2017 is used. Using the *Base-trend 2020* and *Base-trend 2023* mortality tables instead of the AG2018 table leads to a decrease of the best estimate of 0.45% for the immediate annuities portfolio. For the funeral insurance portfolio the best estimate increases with 0.74%.

The impact on the height of the discounted cash flows when using the COVID-19-impacted mortality tables, compared to when using the *Base-trend 2023* mortality table, is shown in Figure 7. It can be seen that the use of the COVID-19-impacted mortality tables has an opposite impact on the discounted cash flows compared to the base scenario for the immediate annuity and funeral insurance products. Figure 6 above shows that, overall, the life expectancies are decreasing over the scenarios. This is in line with the increasing impact on the discounted cash flows in each scenario.

FIGURE 7: IMPACT ON DISCOUNTED CASH FLOWS OF USING COVID-19-IMPACTED MORTALITY TABLES COMPARED TO THE BASE-TREND 2023 MORTALITY TABLE.

	S1	S2	S3	S4
Immediate Annuities	-0.06%	-0.13%	-0.25%	-0.56%
Funeral Insurance	0.05%	0.08%	0.34%	0.74%

Conclusion

In this article, four scenarios from the possible effects of COVID-19 on future mortality tables are analysed. These scenarios, which differ by severity and duration of the COVID-19 pandemic, are compared to a base scenario not affected by COVID-19. The four scenarios show that the impact on life expectancies is limited, where the impact is larger for men than for women. If COVID-19 is gone next year, there is basically no impact on the best estimate of the sample portfolios, if it decays over 3 years the impact is still lower than 1%.

It has to be taken into account that the calculated impact is dependent on the assumption that the mortality due to COVID-19 is temporary: the shocks in our analyses do not affect the trend in later years (before recalibration). Under this assumption, the expectation is that, before seeing a significant impact, the pandemic must hold for a longer period than analysed in this article.

Literature used

- R.D. Lee and N. Li. Coherent mortality forecasts for a group of populations: An extension of the Lee-Carter method. Demography, 42(3):575–594, 2005.
- Royal Dutch Actuarial Association. Projection Table AG2018, 2018

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