Online Supplement

Estimating the impact of tax policy interventions on the projected number and prevalence of adults with type 2 diabetes in Germany between 2020 and 2040

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To project the prevalence of type 2 diabetes in the illness-death model, we used the following partial differential equation:[1 2]

$$\left(\frac{\partial}{\partial t}+\frac{\partial}{\partial a}\right)p=(1-p)\left\{i-m\frac{p(MRR-1)}{p(MRR-1)+1}\right\} \tag{1}$$

where p is the prevalence, t and a are calendar time and age, respectively, $\left(\frac{\partial}{\partial t}+\frac{\partial}{\partial a}\right)p$ is the temporal change in prevalence (with regard to t and a), i is the incidence rate, m is the mortality rate of the general population and MRR is the mortality rate ratio of the population with type 2 diabetes compared to the population without type 2 diabetes (i.e. relative excess mortality). The prevalence and all rates in the model depend on t and a. Similar to previous work, we used equation (1) to project the number of type 2 diabetes cases in Germany between 2020 and 2040. A more detailed description can be found in Tönnies et al.[3]

As described in the main text, we combined the German Diabetes Risk Score (GDRS) with equation (1) based on the method by Hoyer et al.[4] In this approach, the incidence rate depends on the GDRS. Since equation (1) describes the illness-death model on the population level, the mean incidence rate is needed as input. The mean incidence rate in dependence of the GDRS can be calculated by $i=\int i(Z)\times f(Z)dZ$, where $i(Z)$ is the incidence rate associated with the GDRS value Z and $f(Z)$ is the probability density function of the GDRS. $f(Z)$ was estimated with data from Paprott et al.[5] This estimated $f(Z)$ was calibrated to the incidence rate given by Tamayo et al.[6] To incorporate the interventions, we changed the probability density $f(Z)$ of the GDRS. We shifted the age-specific GDRS distribution based on tax-induced changes of single GDRS items. This shifted GDRS distribution was translated into changes of the incidence rate based on incidence rate ratios of the comparison between original vs. shifted GDRS distribution.

Changes in single items of the GDRS were based on price elasticities of demand (PED) using the following equation:

$$RF_{diff}=RF\times PED\times P_{Diff}, \tag{2}$$

where RF_{diff} is the absolute difference in the age-specific mean (in case of continuous variables) or prevalence (in case of dichotomous variables) of the risk factor due to the price increase, RF is the mean/prevalence of the risk factor before the price increase and P_{Diff} is the relative increase in price. RF_{diff} multiplied with the corresponding GDRS points in equation (2) yielded the change in GDRS points. As the age-specific mean/prevalence of the risk factors was only available for age groups (18-34, 35-49, 50-54, 55-59, 60-64, 65-69, 70-74 and 74-79 years), we interpolated linearly between age groups in order to yield values for one-year age intervals. Equation (2) was applied to each age group. As an illustrative example, figure S3 shows the incidence rate for the cohort of women aged 30 years in the year 2020, hypothetically followed up until the year 2040.

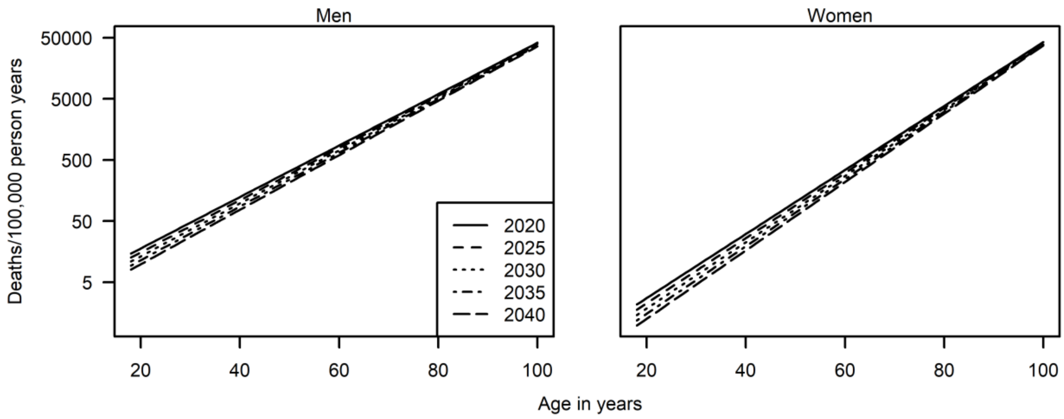

Figure S1. Age-specific mortality rate of the general population in Germany between 2020 and 2040 based on the population projection of the Federal Statistical Office.[7]

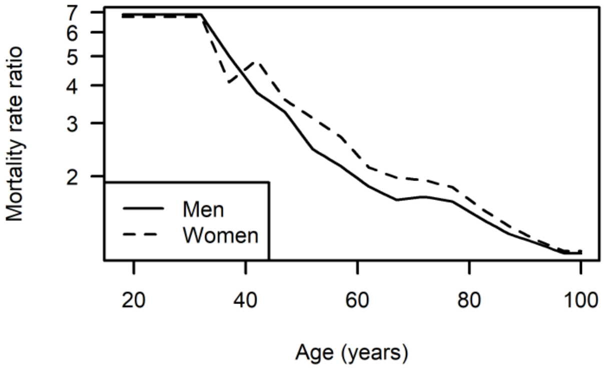

Figure S2. Age-specific mortality rate ratio of people with type 2 diabetes compared to people without type 2 diabetes. Figure based on data from the national diabetes surveillance.[8]

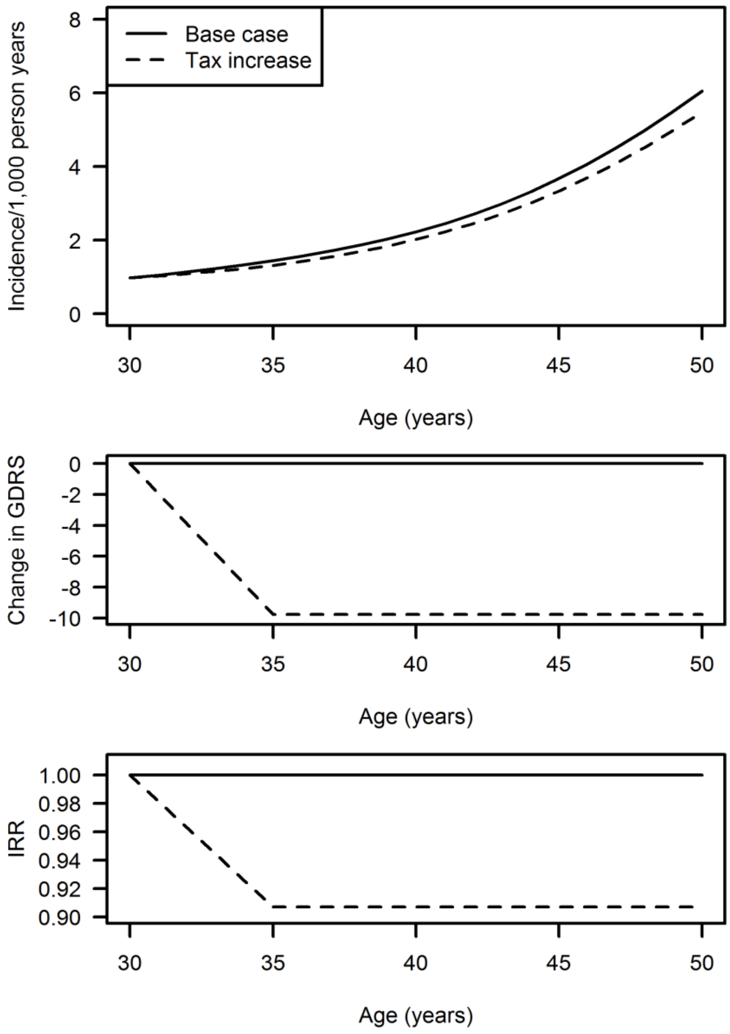

Figure S3. Example of the effect of tax policy interventions on the type 2 diabetes incidence rate.

The example shows the incidence rate between 2020 and 2040 for the cohort of women aged 30 years in 2020. In the base case scenario, no changes in the German Diabetes Risk Score (GDRS) occur, which results in no change of the age-specific incidence compared to Tamayo et al.,[6] which was used as input data for the model. No change in the incidence rate corresponds to an incidence rate ratio (IRR) of 1.0. In the intervention scenario, taxes implemented in the year 2020 (corresponding to age 30 years in the example) were assumed to result in changes of the GDRS over a 5-year period. These changes in GDRS were translated into relative changes of the incidence rate in terms of IRR, in comparison to the base case scenario. Between age 35 years and 50 years (corresponding to the years 2025 and 2040), it was assumed that the IRR remains constant. Hence, in each year between age 35 years and 50 years, the incidence rate corresponding to the attained age of the cohort was multiplied with the IRR obtained for that cohort at age 35 years.

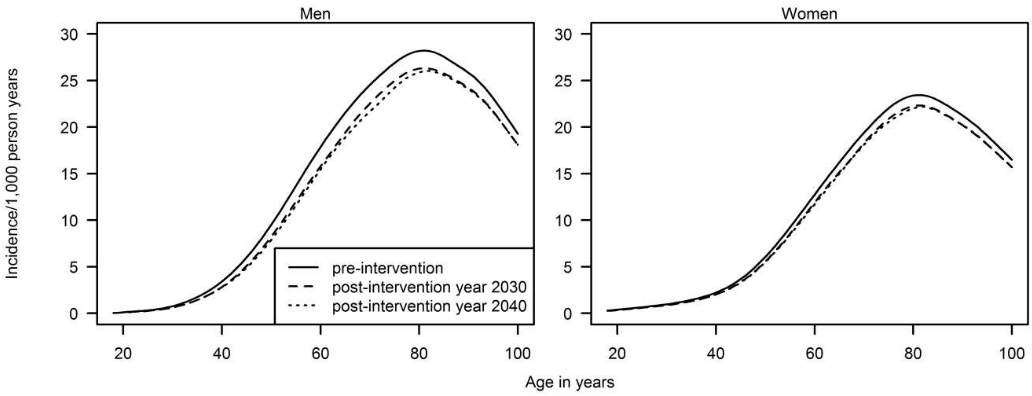

Figure S4. Age-specific incidence rate of type 2 diabetes in Germany without tax policy intervention ('pre-intervention')[6] and with tax policy intervention ('post-intervention').

We assumed that the age at intervention for a birth cohort aged *a* in the year 2020 determined the relative effect on the incidence rate for that birth cohort during their remaining life course. This assumption means that based on the age-specific risk factor values and the intervention described in the main text, an age-specific incidence rate ratio for the year 2020 was calculated. This age-specific incidence rate ratio was assumed to be constant for the birth cohort aged *a* in the year 2020 during their remaining life course. The effect of the intervention was larger in younger compared to older age groups (mainly because of higher pre-intervention risk factor values in the young). Hence, these larger effects were 'carried' into older age groups between the years 2020 and 2040 by those who were in younger age groups in 2020. This is why the post-intervention incidence rate in 2040 is slightly lower than in 2030.

Table S1. Effect of tax policy interventions on the prevalence of type 2 diabetes in 2040 – Alternative price increase by 30% instead of 50%.

Intervention	No. of cases (million)	Difference in no. of cases (million)	Prevalence (in %)	Prevalence difference (%-points)	Prevalence Ratio
Women					
Base case	5.57	reference	16.4	reference	reference
Tobacco taxes	5.56	-0.01	16.3	-0.03	1.00
Meat taxes	5.49	-0.08	16.1	-0.24	0.99
Waist circumference[#]	5.52	-0.05	16.2	-0.14	0.99
Combined	5.43	-0.14	15.9	-0.41	0.98
Men					
Base case	5.93	reference	17.9	reference	reference
Tobacco taxes	5.91	-0.02	17.9	-0.05	1.00
Meat taxes	5.80	-0.13	17.5	-0.39	0.98
Waist circumference	5.82	-0.11	17.6	-0.33	0.98
Combined	5.68	-0.25	17.2	-0.76	0.96
Overall					
Base case	11.50	reference	17.1	reference	reference
Tobacco taxes	11.47	-0.03	17.1	-0.04	1.00
Meat taxes	11.29	-0.21	16.8	-0.31	0.98
Waist circumference	11.34	-0.16	16.9	-0.23	0.99
Combined	11.11	-0.39	16.6	-0.58	0.97

Effect of a 30% price increase of tobacco products, red meat and sugar sweetened beverages between 2020 and 2025 on prevalence of type 2 diabetes and number of people with type 2 diabetes in Germany in 2040.

[#]The effect of changes in the waist circumference item were based on the indirect effect of red meat and SSB taxes on waist circumference.

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