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ORIGINAL ARTICLE

Mainstreaming of climate extreme risk into fiscal and budgetary planning: application of stochastic debt and disaster fund analysis in Austria

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Abstract

While ageing-related costs are perceived as the major drivers of fiscal pressure in the EU, concerns over climate-related public expenditures have received comparatively little attention in securing the EU's long-term fiscal sustainability. Using the Shared Socioeconomic Pathways (SSPs) scenarios as bridging concept for linking the assessment of public cost of demography- and climate-related expenditures, this study proposes a climate risk mainstreaming methodology. We apply a stochastic debt model and assess the potential flood risk in Austria to the public debt and the national disaster fund. Our results indicate that public debt under no fiscal consolidation is estimated to increase from the current level of 84.5% relative to GDP in 2015 to 92.1% in 2030, with macroeconomic variability adding further risk to the country's baseline public debt trajectory. The study finds that the estimated public contingent liability due to expected flood risk is small relative to the size of economy. The existing earmarked disaster risk reduction (DRR) funding will likely reduce the risk of frequent-and-low impact floods, yet the current budgetary arrangement may be insufficient to deal with rising risk of extreme floods in the future. This prompts the need for further discussions regarding potential reforms of the disaster fund. As many EU member states are in the early stages of designing climate change policy strategies, the proposed method can support the mainstreaming of climate-related concerns into longer-term fiscal and budgetary planning.

Keywords Stochastic debt assessment · Climate extremes · Flood risk · Public contingent liability

Introduction

Longer-term fiscal discipline is increasingly seen as an integral part of sound macroeconomic planning. According to the latest survey conducted by the International Monetary Fund, 89 countries around the globe have now adopted some forms of fiscal rules—such as debt, budget balance, expenditure and revenue rules—to ensure fiscal sustainability (IMF 2015). Within the European monetary union, the Stability and Growth Pact (SGP) serves as the cornerstone of such fiscal governance. Under this pact, member states must adhere to their deficit criterion (an annual government deficit of less than 3% of GDP) and debt criterion (a government debt-to-GDP ratio of less than 60%) (EC 2015a). Temporary deviations from these criteria are allowed in the case of extraordinary circumstances, as seen during the recent economic crisis. In the foreseeable future, however, fiscal consolidation will likely be required for many EU states, which must plan for long-term adjustment of their revenue and spending structures.

Under the existing EU fiscal governance, demographic concerns—such as population ageing, future unemployment and education and health care needs—are considered as major drivers of longer-term fiscal pressure (EC 2015a). The Medium-Term Budgetary Objective (MTO) therefore mandates that contingent liabilities resulting from the future costs

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of demography related expenses be estimated and incorporated through a process known as 'front-loading'. A forward-looking fiscal planning framework such as this ensures that revenue and expenditure forecasts are made in a transparent and harmonized manner, and open discussions on the most desirable policy actions can take place. While ageing-related costs are perceived as the major drivers of fiscal pressure in the EU (EC 2015a), concerns over climate-related public expenditures have received comparatively little attention.

This lack of a formal approach on the topic of climate contingent liability is surprising, since the EU as a whole has made a visible public commitment for climate-related public spending. The 2014–2020 EU budget, for example, stipulates that at least 20% of the European budget (1.7 billion €) be allocated for climate-related expenses (EC 2013). At the individual country level, a number of studies evaluate the current and future impacts on climate-related expenditures on public budgets, as Schinko et al. (2016) for example, find that due to flood risk alone, Austria may experience significant fiscal pressure up to 2030 and 2050.[1]

As many EU member states are in the early stages of designing climate change policy strategies, there is the need, and opportunity, to integrate climate-related concerns into longer-term fiscal and budgetary planning. Approximately 20 EU member states have officially adopted a national adaption strategy as of June 2014 and 17 of those have also defined a national action plans (European Environment Agency 2015). As these countries move toward the implementation phase of these climate policy plans, evaluation of economic feasibilities, deliberation on potential financing options and understanding of public budget implications to current and future generations become important areas for public discourse. There is a risk that these important discussions will take place in isolation from larger-scale debates on fiscal discipline and governance.

The aim of this study is, therefore, to design a mainstreaming methodology with which longer-term climate change concerns may be integrated into fiscal modelling and fiscal governance discussions. We highlight how linkages created through the use of Shared Socioeconomic Pathways (SSPs) allow major public finance concerns such as ageing and climate change, which have hitherto been discussed and modelled separately, to be jointly evaluated. We demonstrate that such linkages open up a space for further discourse and evaluation. This is crucial to overcoming the common barriers to fiscal sustainability of fiscal myopia and sectoral divide that repeatedly hamper effective collaboration and coordination.

[1] In addition, longer-term budget projections for Austria qualitatively highlight the potentially high impacts associated with future climate-related public expenditures (BMF 2016a), stemming from factors such as the purchasing requirements of AAUs, write-downs after a burst of the 'carbon bubble' (given public stakes in fossil-based industries), to potential losses and damages of increasing climate-related risks (such as flood and drought risks).

While there are a plethora of methods for assessing a country's fiscal sustainability (Balassone and Franco 2000, Burnside 2004, Wyplosz 2007), we build our mainstreaming methodology on the existing sustainability assessment tools adopted at the EU level and expand it to nationally salient fiscal policy issues. This will allow climate to be considered within a widely accepted method for existing public policy, as opposed to designing a new methodology that is applied to distant policy issues. It will also likely be an effective way of communicating the public-finance consequences of climate change. As considerations for the risk of climate extremes are identified as one of the primary policy drivers of adaptation within the European Union (European Environment Agency 2014), and as the public share of adaptation investment in areas such as flood protection is particularly high (Osberghaus and Reif 2010), this study focuses on the public costs of climate extreme events as a starting point of fiscal mainstreaming discussions. Following Osberghaus and Reif (2010), this study adopts the term 'fiscal consequences' of climate extremes to imply 'budgetary effect'—i.e. the projected changes in expenditure and revenues and fiscal positions in terms of their impact on variables such as primary balance and external borrowing.

This study demonstrates the applicability of the proposed approach in the assessment of fiscal impact due to contingent liability arising from future flood risk in Austria. Austria was chosen as the geographical focus of our case study since the country is in an advanced planning stage for climate adaptation policy and shares many of the common challenges of fiscal consolidation and climate change adaptation with other EU member countries. Moreover, we chose the costs of riverine flooding, since it is one of the most costly disasters in Austria and Europe, and a relatively reliable probabilistic risk estimation method is available (Jongman et al. 2014; Timonina et al. 2015). The issue of flood protection is high on Austria's domestic policy agenda, as devastating flood events of recent years have demonstrated the need for proactive management of these risks. The floods of August 2002, August 2005 and June 2013, for instance, resulted in approximately 2445 million €, 515 million € and 866 million € in economic damage respectively (Thieken et al. 2014). These events have triggered increased public and private efforts to improve flood protection measures in the country. Following the 2002 flood event, for example, federal and provincial governments introduced flood protection measures worth 2.9 billion €, targeted at protecting human lives and properties (Hahn 2009). Flood protection and proactive risk management of extreme climatic events is, therefore, an important entry point for public discussions on longer-term climate change adaptation decisions (Schinko et al. 2016).

The remainder of the article is organized as follows: "Methodology for integrating climate-related costs into mainstream fiscal planning" section outlines a mainstreaming methodology for fiscal modelling of climate change related costs, detailing scenario assumptions and data needs. We will then demonstrate the applicability of this modelling framework using the Austrian flood risk case study in the "Evaluating future cost of flood risk under climate change—stochastic assessment of debt and disaster" section. The "Results" section discusses the wider applicability of this methodology and future directions for research in this field. The "Discussions and Conclusions" section provides major lessons learned and conclusions.

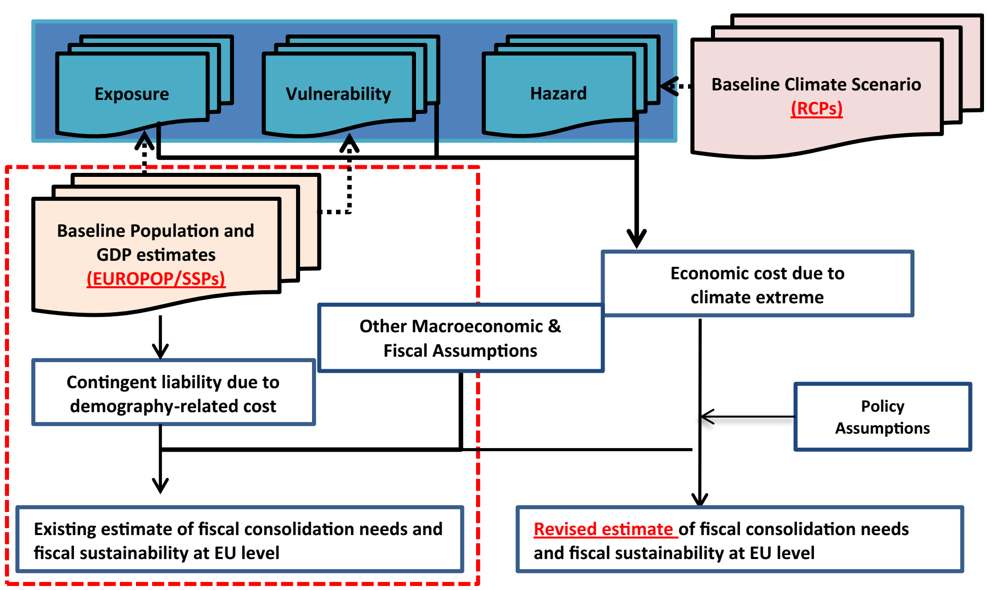
Methodology for integrating climate-related costs into mainstream fiscal planning

Fiscal sustainability assessment in the EU has been conducted triennially by the Directorate General of Economic and Financial Affairs since 2006, following the 2005 reform of the Stability and Growth Pact (EC 2006; Barta 2015). A common basis for demographic projections and age-related expenditure forms an important starting point of this EU-wide fiscal sustainability assessment. Currently, the Economic Policy Committee (EPC) is given a mandate to lead and update the harmonized, EU-wide projection exercise of age-related expenditures. Under the EPC's mandate, the ageing working group (AWG; consisting of policy-makers from relevant national ministries such as finance, economy and planning), together with the central bank and other representatives, conduct the cost-projection exercise. In the latest AWG cost projections, EURPOP 2013 was used as a basis for budgetary projections of demography-related expenses including pensions, education, long-term care, health care and unemployment benefits. While harmonized methodologies using income elasticity, unit costs and other assumptions are used for education, health and unemployment benefit calculations, individual countries simulate pension expenditures based on agreed methodologies and macroeconomic assumptions, reflecting country differences (EC 2015b). The basic steps of this calculation flow can be simplified as those within red-dotted lines in Fig. 1.

Using this framework as a basis, this study prposes a mainstreamining methodology. We incorporate a climate change related cost calculation based on the combined use of the SSPs and representative concentration pathways (RCPs), as an area outside of red-dotted lines in Fig. 1 demonstrates. SSPs are 'reference pathways describing plausible alternative trends in the evolution of society and ecosystems over a century timescale, in the absence of climate change or climate policies (O'Neill et al., 2014, p. 387)', which allow for the standardization of assumptions and storylines used in integrated assessments. There are currently five different SSPs that are used in the integrated assessment community, namely SSP1—sustainable pathway, SSP2—moderate pathway, SSP3—rocky road, SSP4—regional pathways and SSP5—taking the fast road (Moss et al., 2008). The RCPs are made up of four different radiative forcing pathways in the future (Mosse et al. 2010).

Instead of (or in combination with) conventional demographic projections (such as EUROPOP used in the EU fiscal assessment), SSP-based projections can be used as a harmonized basis for age-related expenditure in fiscal sustainability assessment. As described in Cuaresma 2017, projections of age, gender and educational level-disaggregated population up to 2100 can be used to estimate future projections of potential GDP. The use of demographic assumptions as a means to link ageing cost and climate concern has multiple benefits

Fig. 1 Conceptual flow of fiscal mainstreaming model (applied to climate risk cost calculations) using IPCC scenarios. Source: The authors



since demographic and climate projections typically share similar forecast spans that are far beyond the usual myopic public policy framing of a few years, such as those seen in public election or budgetary planning cycles. Furthermore, demographic variables, such as population ageing, are closely linked to social vulnerability to natural hazards such as heatwaves.

The working group on 'Quantitative SSP Data and IAM Scenarios' is currently developing a set of socioeconomic variables, which will further expand our analytical scope. Preliminary results are available for dimensions such as energy demand and supply, land use and greenhouse gas emissions (IIASA 2015). The use of SSPs as a base for fiscal sustainability discussions, therefore, opens up the potential for broader discussions on environmental sustainability and wellbeing in the future. The major advantage of this mainstreaming approach is that one can harmonize socioeconomic assumptions. Calculation of public cost of mitigation and adaptation can therefore be made in a consistent manner both regionally and globally. The integrated assessment modelling community is increasingly taking this kind of harmonized approach to model climate policy costs globally, and the adoption of these scenarios provides a natural entry point to integrating available analysis from biophysical and socioeconomic modelling.

At the same time, fiscal modelling of course necessitates an incorporation of national and local differences and strict use of harmonized scenarios may be overly restrictive. It is likely that effective mainstreaming of climate concerns into fiscal sustainability discussions therefore requires combined use of harmonized and individual assumptions. This will be similar to the approach adopted by the EU fiscal assessment to harmonize demography-related cost calculations. In the following section, we will demonstrate the applicability of the outlined climate risk mainstreaming methodology in the context of flood risk management in Austria. We carry out a stochastic assessment of fiscal debt and disaster fund.

Evaluating future cost of flood risk under climate change—stochastic assessment of debt and disaster fund in Austria

Fiscal sustainability and concerns regarding extreme climatic events in Austria

In 2015, public debt in Austria stood at approximately 85% relative to GDP, and it was predicted that a sizable fiscal consolidation (of approximately 26.5 billion) would have been needed to achieve a balanced budget by 2016 (Broethaler and Getzner 2015). To improve transparency in forward-looking fiscal planning, Austria has recently mandated triannual projections of the longer-term fiscal outlook up-to the next 30 years under §15 Abs. 2 of the Bundeshaushaltsgesetz 2013 (Schiman and Orischnig 2012). The first round of the projections, released in 2013, suggested that by 2050, total public expenditure on pensions, health care, education and unemployment benefits will rise from the current level of 31.2% of GDP (in 2011) to 34.5% of GDP, assuming annual real GDP growth of 1.7%. BMF (2013) Langfristige Budgetprognose Bericht gem. § 15 (2) BHG 2013 April 2013 https://www.bmf.gv.at/budget/das-budget/Langfristige_Budgetprognose_Bericht_der_Bundesreg.pdf?6alyut. Similar to the fiscal assessment conducted at the EU level, climate-change related longer-term cost is not currently incorporated into fiscal sustainability planning in Austria.

A growing body of literature indicates that the future costs of climate change will be non-negligible in Austria (APCC 2014; Steininger et al. 2015; Steininger et al. 2016). In particular, floods are one of the most costly disasters in Austria and the average annual cost of riverine flooding alone could rise from the current level of 200 million € up to 1800 million € by the mid-twenty-first century (Steininger et al. 2015). The country's flood proneness stems partly from its geography—due to its highly mountainous topography, only approximately 38% of the country's land area is suitable for permanent settlement; as such, population and economic activities are highly exposed. Continued public works to straightening and confining of flood channels have also significantly altered flows of major rivers in Austria (BMLFUW, 2015).

The estimates of climate-related cost to the public sector vary considerably. A recent study on the costs of inaction against climate change in Austria indicates an annual average decrease in available public budget due to climate change triggered increases in flooding of up to 0.24% or 500 million € by 2050 (Steininger et al. 2015).[2] Compensation for affected households in case of flood damage and indirect macroeconomic effects (e.g. reduced tax revenues due to economic contraction) are found to be the main reasons behind this decline in available fiscal resources. In addition, the Austrian government's recent purchase of some 600 million € in assigned amount units (AAUs) to achieve its Kyoto target is an early sign of the potential significance of climate mitigation costs in public balance sheets. These recent developments make proactive management of climate-change related contingency an important component of longer-term budgetary planning.

In Austria, fiscal resources for disaster prevention, response and recovery are managed through the disaster fund (in German 'Katastrophenfonds') administered by the Federal Ministry of Finance (BMF 2016b). Currently, resources are allocated for preventive measures (73.27%), remedying of damages due to catastrophic events (17.84%) and equipment for fire departments (8.89%), with an option of excess reserve

[2] Assuming government budget outlay remains constant, an increase in costs associated with climate change adaptation will reduce available budget for other items.

fund accumulation capped at 30 billion €. The majority of the funds are financed through a percentage share (currently 1.1%) of the federal income tax, wage tax, capital yield tax (on dividends) and corporate income tax revenues. Further resources for disaster funds include investments and repayments by the Austrian hail insurance. Additionally, until 2013, the fund accrued interest yields from the invested disaster fund reserves (Schinko et al. 2016).

As elaborated in recent studies such as Schinko et al. (2016), the Austrian disaster fund is already undercapitalized and thus frequently requires budget diversions to perform its safe-guarding function. This stems partly from the limited private flood insurance coverage in Austria. Private insurance is available for various hazards in an unregulated market, including floods; however, the coverage of flood risk in Austria is generally limited to approximately 3500–5000 €, thus limiting its protection against more costly damages (OECD 2007). In addition, the availability of public compensation through the disaster fund serves as a major disincentive to private risk reduction and insurance uptake. We take these factors into account when estimating stochastic debt sustainability in the next section.

Mainstreaming model of stochastic debt and disaster fund analysis

The mainstreaming methodology outlined in the "Methodology for integrating climate-related costs into mainstream fiscal planning" section is operationalized by means of a stochastic debt assessment and a national disaster fund analysis in this case study. A stochastic debt assessment is a common fiscal sustainability analysis tool used in various countries and contexts. Debt dynamics equations are built based on baseline projections of macroeconomic variables, and confidence bounds of debt trajectories are evaluated through stochastic simulations (IMF 2006; Medeiro 2012; Ellor and Urvova 2012; IMF 2012). Stochastic assessment, which draws on a wide range of possible future scenarios, gives a more complete depiction of debt sustainability risks than the traditional deterministic approach and thus is more appropriate for evaluating potential deviation of fiscal policy paths and macroeconomic developments that may trigger short-term liquidity crisis and other adverse consequences (Clasun et al. 2007). Our climate mainstreaming approach is unique in that we evaluate stochasticity arising from public contingency of climate extreme events in addition to conventional macroeconomic variables.

Following Berti (2013), stochastic debt dynamics incorporating macroeconomic variability and longer-term, demography-related public cost may be extended to take the following form. We include a new stochastic variable of reconstruction needs due to climate extremes ($\tilde{j}$). The baseline potential output ($\tilde{g}_t$) refers to the future GDP projections calculated according to five alternative demographic projections (Moss et al., 2008; Cuaresma 2017). Projected increase in the costs of demography-related public expenditure (c_t) can also be calculated based on SSP projections.[3]

$$d_t = d_{t-1}\frac{1+i_t}{1+g_t}-b_t+c_t+j_t+f_t \qquad (1)$$

d_t Debt to GDP ratio in year t

$\tilde{i}_t$ Real implicit interest rate at year t

$\tilde{g}_t$ Real GDP growth rate at year t

$\tilde{b}_t$ Primary balance over GDP in year t

c_t Change in age-related costs over GDP in year t relative to base year

$\tilde{j}_t$ Residual public contingent liability due to climate extreme events over GDP in year t

f_t Stock flow adjustment over GDP in year t

The variable $\tilde{j}_t$ represents both explicit and implicit public contingent liabilities that exceed available ex-ante fiscal resources, expressed relative to GDP. Here, explicit liability refers to 'government liabilities recognized by a law or contract' and implicit liability refers to 'a moral obligations of government' (Palockova 1999).

Since some of climate extreme costs may be covered with available ex-ante policy instruments such as national disaster fund, budgetary reserve, or private insurance, the total public contingent liability relative to GDP ($\tilde{j}$) and in absolute term, expressed as $\tilde{J}_t$ are calculated as residual of these ex-ante resource availabilities.

Disaster fund analysis

We extended our analysis to assess the Austrian national disaster fund, where a portion of public revenue is earmarked each year for risk reduction and disaster response expenditures. Expressed in absolute terms, flood damage at year t (FD_t) may be divided into public (PbD_t) and private (PrD_t) damages and assuming private insurance coverage (α) as follows:

$$FD_t = PbD_t + (1-\alpha)PrD_t + \alpha PrD_{t.}$$

where national disaster fund, budgetary reserve and additional resources may be used to finance the recovery of uninsured losses up to proportion β. Public indirect contingent

[3] Following the work of the European Commissions' ageing working group (EC 2014 and EC 2015b), this study adjusted the projections of pension, health care, longer-term care, education reflecting the differences in both GDP and dependency-rate projections, assuming unit elastic demand for age-related expenditures.

liability (IC_t) is thus given by the following:

$$IC_t = \beta \times (1-\alpha)PrD_t$$

where $\beta = 1$ refers to full compensation by government, and $\beta = 0$ refers to no government compensation.

Total public contingent liability due to climate extreme events at year t (TC_t) is therefore summed as follows:

$$TC_t = PbD_t + \beta \times (1-\alpha)PrD_t$$

Further, the government is assumed to fulfil its public contingent liability using the following lexicographic order based on the existing disaster financing arrangement in Austria (Schinko et al. 2016): fiscal resource for national disaster fund earmarked for reconstruction ($\gamma*Df_t$) is drawn first, followed by budgetary reserve (DR_t). Once both resources are exhausted, it is assumed that budget diversion must take place, which affects the baseline debt trajectory. Hence, residual public contingent liability that exceeds ex-ante fiscal sources (J_t) can be expressed as follows:

$$J_t = TC_t - (\gamma \times Df_t + DR_t)$$

where γ is an earmarked factor for disaster recovery usages, assumed to remain constant in the baseline.

The total resource availability for the national disaster fund (Df_t) increases proportional to the stochastic growth in output (G_t) using a baseline tax rate (τ).

$$Df_t = \tau \times G_t$$

If the disaster fund earmarked for reconstruction is unspent in year t, the resource is carried over as a budgetary reserve, which is capped at 30 million € ($\overline{DR}$).

$$DR_t = \min\left\{DR_{t-1} + CO_t; \overline{DR}\right\}$$

where CO_t is the amount of carry-over calculated as the difference of $\gamma*Df_t$ and TC_t if $\gamma*Df_t > TC_t$.

Finally, a proportion of the national disaster fund is earmarked for disaster risk reduction investment with an earmark factor (δ) where $\gamma + \delta = 1$. Total risk reduction benefit from DRR investment expressed as (DRR) is calculated as an annual average benefit (μ) summed over its project lifespan (sp), which is assumed to be 20 years in the baseline.

$$DRR = \sum_{Sp=t}^{t+20} \mu \times \delta \times Df_t$$

Figure 2 shows the calculation steps to estimate budgetary needs and resource availability in this framework.

Stochastic scenarios

Our model introduced two sources of stochastic shocks to our baseline SSP2 debt and national disaster fund projections, comprising macroeconomic variability and stochastic flood damages. To simulate potential macroeconomic shocks, we generated a historical variance-covariance matrix of GDP and long-run and short-run interest rates using quarterly observations between 2002 and 2015. We then sample sets of these variables using a Monte Carlo simulation assuming a joint normal distribution. Quarterly shocks were then aggregated to annual shocks in a manner similar to those explained in Berti (2013) taking into account an average maturing of debt for long-run interest rates. Stochastic output shocks are then translated as shocks to primary balance using the assumed semielasticityparameter. Further, direct economic risk due to flooding in Austria from 2015 to 2050 was estimated using a structured coupling of probability loss distributions on the basin scale (derived from LISFLOOD; see van der Knijff et al. 2010; Rojas et al. 2012) with the method discussed in Jongman et al. (2014) and more recently in Timonina et al. (2015). Dependencies between river basins were estimated based on maximum river discharges for the period 1990–2011, using copulas. The loss distributions from each basin were then coupled using the copulas and a minimax ordering approach in order to derive a loss distribution at the national level.[4]

Appendix Table 3 shows the baseline assumptions adopted for this study, and Appendix Table 4 shows the baseline statistics of historical macroeconomic and flood damage data for Austria. We built and implemented the model in Matlab R2015a.

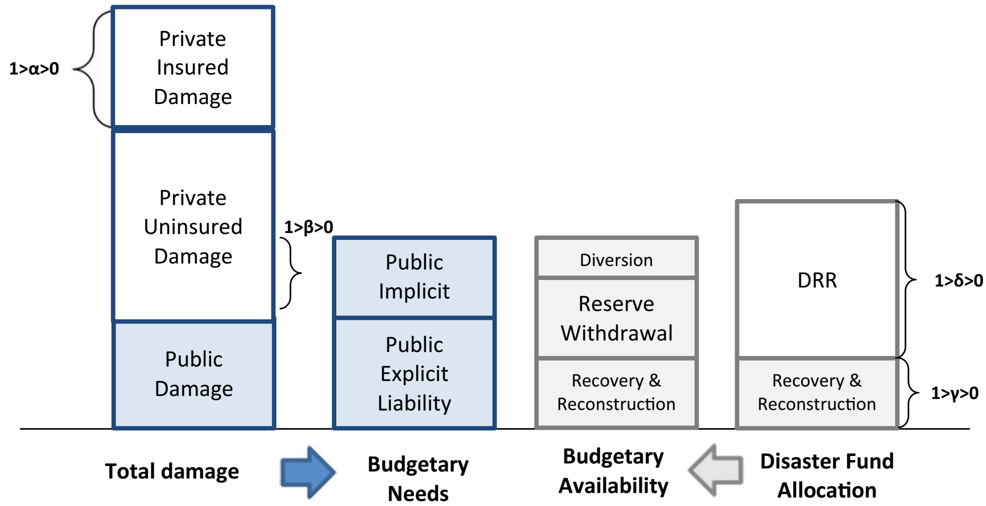
Results

Public debt, a-related costs and climate extreme liability

In the baseline scenario (SSP2), the total population of Austria is expected to increase from its current level of 8.6 million in 2015 to 9.2 million in 2050 (IIASA 2015). The population comprises a dependent proportion

[4] In this study, we first examined relationships between macroeconomic variables and past flood damage for each quarter between 2002 and 2015 which detected no statistically significant relationships, thus the model treats these two sources of variability as independent shocks.

Fig. 2 Breakdown of budgetary needs and availability examined in disaster fund analysis. Source: The authors



of 27.3%, a working age population of 53.9% and a youth population of 18.8%. Combining population growth and other demographic trends, ageing-related costs are estimated to increase by 8.2 p.p. of GDP by 2050. At the same time, flood risk in Austria is expected to increase substantially as a result of both socioeconomic development and climate change. Annual average loss (AAL) is estimated at 0.28 billion € in 2015, 0.39 billion € in 2030 and 0.55 billion € in 2050, respectively. The extreme tails of flood risk are also projected to increase, and a 100-year flood event, for example, would cause approximately 7.6 billion € (2.77% of GDP) in damages in 2015, 10.5 billion € (3.3% of GDP) in 2030 and 15.2 billion € (3.8% of GDP) in 2050. The economic cost of climate extreme events may be larger in magnitude than annual changes in age-related expenditure the former is similar in magnitude with the latter when converted on an annual average basis (Table 1). The estimated annual changes in ageing-related costs are higher in the present study due to differences in GDP growth and demographic challenges (i.e. different dependency ratio, proportion of retired population and school-age population) between EUROPOP and the SSP2 scenarios.

The baseline result indicates that public debt under a business as usual scenario (i.e. no fiscal consolidation) is estimated to increase from 84.5% relative to GDP in 2015 to 92.1% in 2030. Our result is similar to the existing estimate of the debt projection baseline (97.9% according to EC 2012 and 72.5% according to EC 2016). In addition to different base and endline years, different demographic assumptions (e.g. the population aged over 65 is estimated at 2.6 million according to EUROPOP 2013 and 3.0 million according to SSP2), potential GDP assumptions (approximately 1.3% in EC 2012 and EC 2016 and 1% in our study), non-cyclical budget balances (0.8% in EC 2012, 1% in EC, 2016 and 0.8% in our study) and implicit nominal interest rates (approximately 4.3% in EC 2012 and 1.0% in EC 2016 and 2.1% in our study) contribute to differences in estimates.

The stochastic simulation shows how the Austrian fiscal position may deviate from the baseline debt projections due both to macroeconomic variability of GDP, short and long-term interest rates and climate-related extreme events. The 95th percentile value at risk of debt-level is estimated to be as high as 249% with macroeconomic and climate extreme risks combined and 97.0% with climate extreme risks only in 2030 (Fig. 3). Note that macroeconomic variability has a much higher impact than the direct risk of climate extremes, suggesting that climate extremes per se are unlikely to put significant fiscal pressure on Austria. This result is unsurprising, given the existing flood protection efforts in Austria and the size of its economy. At the same time, the existing ex-ante arrangement of a national disaster fund seems insufficient to deal with extreme flood risks. While the annual disaster fund resources earmarked for DRR and flood protection measures will reduce the risks of relatively frequent flood events from period 2015–2030 to period 2031–2050 (hence the probability of disaster fund depletion will be reduced as a result), the magnitude of the shortfall will increase over the same period because of the expected rise in extreme flood risks (Table 2).[5]

Discussions and conclusions

The modelling insight provided in this paper informs ongoing discussions regarding national disaster fund

[5] Given the exact BC ratio of future flood risk reduction investment is unknown, we have estimated its impact between the lower bound B/C ratio of 1 and upper estimate of 4 (MMC 2005).

Table 1 Fiscal consolidation needs, ageing related costs and climate extreme costs

	EC 2012	EC 2016	Present Study
Annual changes in primary balance needed to stablize debt at 60% (p.p. of GDP)	0.4[a]	0.3[b]	0.07[c]
Average annual changes in age-related expenditure[d] (p.p. of GDP)	0.09	0.08	0.19
Annual average flood damage in 2030 (% of GDP)	n.a.	n.a.	0.12
Annual average flood damage in 2050[d] (% of GDP)	n.a.	n.a.	0.14
100 year flood damage in 2030 (% of GDP)	n.a.	n.a.	3.3
100 year flood damage in 2050 (% of GDP)	n.a.	n.a.	3.8

Source: EC (2012), EC(2016) and own estimation

[a] constant adjustment needed for period 2014-2020 to stablize debt at 2030

[b] constant adjustment needed for period 2018-2022 for stablization at 2030

[c] constant adjustment needed for period 2015-2022 for stablization at 2030

[d] excluding unemployment related costs

reform in Austria and beyond in a number of ways (Schinko et al. 2016). Generally, the magnitude of public contingent liability due to flood risk on annual average basis is found to be small relative to ageing-related public cost liability, and flood risk alone will unlikely impact Austria's budgetary stance in the future. However, further disaster fund analysis indicates that though the DRR earmarking will reduce risk of disaster fund depletion, the magnitude of shortfall will increase due to expected increase in extreme events. This may stress the country's disaster fund, prompting the need for re-evaluation of the current funding and reserve arrangements as well as for putting the disaster fund as one specific tool in a more comprehensive risk management perspective.

The Austrian disaster fund in its current form only provides financial assistance for the replacement of capital, not for additional risk reduction (or building back better) after disaster events. Neither does the fund support any ex-ante risk-reduction measures by private sector entities nor public risk reduction measures broadly beyond physical protection. These facts, combined with the lack of protection against catastrophic events, make the Austrian disaster fund less than

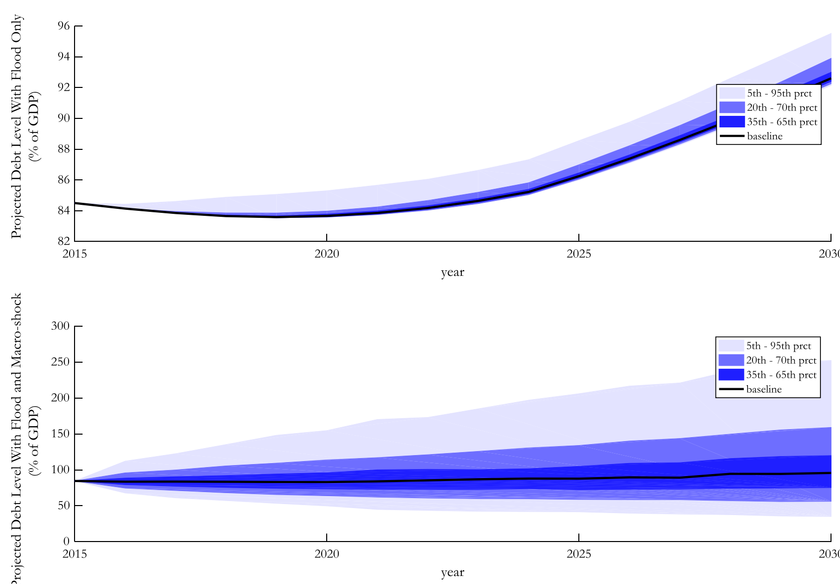


Fig. 3 Stochastic debt trajectories for Austria under SSP2 scenario up to 2030. Showing 5th to 95th percentiles. Source: The authors

Table 2 Disaster fund simulation

	2015–2030	2031–2050
Probability of disaster fund depletion	Under B/C ratio of 1: 15.0% Under B/C ratio of 4: 4.04%	Under B/C ratio of 1: 14.0% Under B/C ratio of 4: 2.88%
Magnitude of fund depletion	Under B/C ratio of 1: Median: 280 SD: 1750 Under B/C ratio of 4: Median:470 SD: 2640	Under B/C ratio of 1: median:380 SD: 2780 Under B/C ratio of 4: Median:1840 SD: 4460

comprehensive. This prompts the need for further discussions regarding potential reforms in line with the EU floods directive 2007/60/EC, which would encourage a more comprehensive approach to flood risk management (European Parliament and Council 2007). Potential risk financing mechanisms such as natural catastrophe (NatCat) insurance systems already in place in other EU member states, such as Belgium and Germany, (Prettenthaler and Albrecher 2009) and the European Solidarity Fund may be applicable instruments for managing catastrophic flood risk in Austria.

In evaluating future risk to the country's fiscal sustainability and budgetary preparedness, there are a number of important entry points for climate risk mainstreaming. These include taking proper stock of public expenditure allocation in prevention, response and recovery; clarifying the responsibility of multiple institutions (thereby avoiding institutional overlap and confusion); and identifying key decision-making mechanisms through which risk information can be incorporated into every-day planning. This study proposed a climate mainstreaming model for the assessment of fiscal and national disaster fund sustainability, with an application to flood risk in Austria. We demonstrated the potential use of the SSPs as a bridge between conventional fiscal modelling and climate risk assessment.

As EU member states strive for fiscal consolidation, sustainable growth, and climate risk management in coming years, mainstreaming of climate risk into fiscal planning, is becoming increasingly important. As many EU member states are still at the early stages of designing future policy mixes for their country's climate change adaptation strategies, there are ample opportunities to incorporate an iterative style of risk management where state-of-the art scientific information on risk (hazard, exposure and vulnerability) can be mainstreamed. Such fiscal mainstreaming not only involves probabilistic estimates of climate-related economic damages and losses, but should also create a common deliberative process through which climate-related risk may be managed in a proactive manner.

This is only a first application of the proposed mainstreaming framework, and further studies are certainly needed to test the broader applicability of this approach beyond the case of flood risk in Austria. First, given that this model builds on the existing fiscal sustainability assessment conducted at the EU level, this approach can easily be replicated in other EU member states. Second, this modelling framework can easily incorporate potential impacts of a broader range of natural hazards, such as heatwaves and drought risk that may also cause large fiscal consequences and that may benefit from proactive longer-term adjustment in policy incentives. Thirdly, it can also be expanded to include other public cost of additional climate change-related expenditure such as mitigation and adaptation costs, including potential public liability due to stranded carbon-intensive assets. Finally, economy-wide assessments of climate triggered damages and associated follow-on effects may be additionally performed such as seen in studies such as Steininger et al. (2016). These are further avenues that may be explored in future research.

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Appendix. Summary statistics of data used in this study

Table3 Data and baseline assumptions us d in this study

Items	Baseline assumptions	Sources
Potential output growth (% in annual growth between 2015 and 2050)	1	Crespo Cuaresma (2017)
Population growth (% in annual growth between 2015 and 2050)	Youth: − 0.3 Working age: − 0.3 Retired: 1.8	Samir and Lutz (2014)
Long-run interest* (convergence at year $t + 10$)	3	European Commission (2014)
GDP deflator (convergence at year $t + 5$)	2	European Commission (2014)
Average maturity of debt (years)	8	EUROSTAT
Ratio of long-run versus short-run debt (remain constant at)	Long-run debt: 0.95 Short-run debt:0.5	EUROSTAT
Budget semi-elasticity parameter (remain constant at)	0.58	Mourre et al. (2014)
Disaster risk management funding (million euro)	National Disaster Fund (base-year allocation): 292.22 Reserve Fund Ceiling: 30	Schinko et al. (2016)

*short-run interest rates are assumed to move proportional to long-run interest rates

Table 4 Summary statistics of macroeconomic variability and flood loss estimates

Variables	Statistics	Sources
Quarterly GDP growth	Min: − 9.5 Max: 6.1 Mean: 0.48 SD: 4.5	EUROSTAT
Quarterly long-run interest rate	Min: 0.45 Max: 5.3 Mean: 3.4 SD: 1.1	EUROSTAT
Quarterly short-run interest rate	Min: 0.05 Max: 5.0 Mean: 2.0 SD: 1.5	EUROSTAT
Flood risk (probable maximum losses in billion (2005 Euro)	100-year PML in 2015: 7.6 100-year PML in 2030:10.5 100-year PML in 2050:15.2 1000-year PML in 2015:17.0 1000-year PML in 2030:23.3 1000-year PML in 2050:33.2	Authors own estimation.

References

APCC (2014) Österreichischer Sachstandsbericht Klimawandel 2014 (AAR14). Austrian Panel on Climate Change (APCC), Verlag der Österreichischen Akademie der Wissenschaften, Wien, Österreich, 1096 Seiten. ISBN 978–3–7001-7699-2

Barta Z (2015) Fiscal sustainability and the welfare state in Europe. ACRN J Finance Risk Perspect: Special Issue Social and Sustain Finance 4(3):135–147 http://www.acrn-journals.eu/resources/jfrp0403h.pdf

Balassone F, Franco D (2000) Assessing fiscal sustainability: a review of methods with a view to EMU. Fiscal Sustainability Conference. Available at: https://doi.org/10.2139/ssrn.2109377

Berti K (2013) Stochastic public debt projections using the historical variance-covariance matric approach for EU countries, Economic Paper 480, European Commission. Available at: https://doi.org/10.2765/4211.

BMF (2016a) Langfristige Budgetprognose. Bericht gem. § 15 (2) BHG 2013, Federal Ministry of Finance. https://www.bmf.gv.at/budget/das-budget/Langfr_Budgetprognose_Bericht_der_Bundesreg_April_2016.pdf?5te3f8. Accessed 22 June 2017

BMF (2016b) Katastrophenfondsgesetz 1996. 11 Bericht des Bundesministeriums für Finanzen. Federal Ministry of Finance. https://www.bmf.gv.at/budget/finanzbeziehungen-zu-laendern-und-gemeinden/Katastrophenfondsbericht_2014-2015.pdf?5cpip5 . Accessed 6 Jun 2016

BMLFUW (2015) Flood control and individual precautions. Available at: https://www.bmlfuw.gv.at/english/water/Protection-against-natural-hazards/Floodcontrol.html. Accessed September 24, 2015

Broethaler J, Getzner M (2015) The tax-spend debate and budgetary policy in Austria. Int Adv Econ Res 21(3):299–315. https://doi.org/10.1007/s11294-015-9532-1

Burnside C (2004) Assessing new approaches to fiscal sustainability analysis. World Bank, mimeo. Available at: http://documents.worldbank.org/curated/en/683061468138867247/Assessing-new-approaches-to-fiscal-sustainability-analysis

Celasun O, Debrun X, Ostry JD (2007) Primary surplus behavior and risks to fiscal sustainability in emerging market countries: a "fan-chart" approach. IMF Staff Papers 53(3). ISBN 978-1-4518-63277 https://www.imf.org/External/Pubs/FT/staffp/2006/04/pdf/celasun.pdf. Accessed 7 Jun 2016

Cuaresma JC (2017) Income projections for climate change research: a framework based on human capital dynamics. Global Environ Change 42:226–236. https://doi.org/10.1016/j.gloenvcha.2015.02.012

Eller M, Urvova J (2012) How sustainable are public debt levels in emerging Europe? Evidence for selected CESEE countries from a stochastic debt sustainability, focus on European economic integration Q4/12

European Commission (2006) Long-term sustainability of public finances in the European Union. Communication from the Commission to the Council and the European Parliament http://ec.europa.eu/economy_finance/publications/publication_summary7907_en.htm

European Commission (2012) Fiscal Sustainability Report: European Economy 8/2012. Available at: https://doi.org/10.2765/19669

European Commission (2013) One-fifth of total EU budget to be spent on climate action. http://ec.europa.eu/clima/news/articles/news_2013111901_en.htm

European Commission (2014) The 2015 ageing report: underlying assumptions and projection methodologies. European Economy 8/2014. Available at: https://doi.org/10.2765/76255

European Commission (2015a) Stability and growth pact, http://ec.europa.eu/economy_finance/economic_governance/sgp/index_en.htm

European Commission (2015b) The 2015 Ageing report: economic and budgetary projections for the 28 EU member states (2013–2060). European Economy 3/2015. Available at: https://doi.org/10.2765/877631

European Commission (2016) Fiscal sustainability report 2015: European economy. Institutional Paper 018. Available at: https://doi.org/10.2765/412671

European Environment Agency (2014) National adaptation policy processes in European countries EEA report no. 4 2014. ISBN: 978-92-9213-484-6

European Environment Agency (2015) Climate change impacts and adaptation Available at: http://www.eea.europa.eu/soer-2015/europe/climate-change-impacts-and-adaptation

European Parliament and Council (2007) Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks. Official Journal of the European Union L 288/27

Hahn, C. (2009) Austria: New start-up for flood control. Flood Prevention. Available at: http://www.aquamedia.at/fileadmin/user_upload/downloads/download_4753.pdf. Accessed September 24, 2015

IIASA (2015) SSP Scenario Database Available at: http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy/SSP_Scenario_Database.html

IMF (2006) Probabilistic sustainability of public debt: a vector autoregression approach for Brazil, Mexico, and Turkey, IMF Staff Report 55(1), International Monetary Fund. Washington D.C. ISBN: 978-14-5186-5554

IMF (2012) A toolkit for assessing fiscal vulnerabilities and risks in advanced economies, working paper no. 12/11, International Monetary Fund, Washington D.C. ISBN:978-14-6393-1162

IMF (2015) Fiscal rules at a glance Available at: http://www.imf.org/external/datamapper/FiscalRules/Fiscal%20Rules%20at%20a%20Glance%20-%20Background%20Paper.pdf

Jongman B, Hochrainer-Stigler S, Feyen L, Aerts JCJH, Mechler R, BotzenWJW, Bouwer LM, Pflug GC, Rojas R, Ward PJ (2014). Increasing stress on disaster-risk finance due to large floods, nature climate change, 4:264–268. Available at: https://doi.org/10.1038/nclimate2124

Medeiro J (2012) Stochastic debt simulation using VAR models and a panel fiscal reaction function: results for a selected number of countries, Economic Papers 459, European Commission. Available at: https://doi.org/10.2765/26702

Moss RH, Edmonds JA, Hibbard KA, Manning MR, Rose SK, Van Vuuren DP et al (2010) The next generation of scenarios for climate change research and assessment. Nature 463(7282):747–756. https://doi.org/10.1038/nature08823

Moss R, Babiker M, Brinkman S, Calvo E, Carter T, Edmonds J, … , Zurek M (2008) Towards new scenarios for analysis of emissions, climate change, impacts, and response strategies. Technical Summary. Intergovernmental Panel on Climate Change, Geneva, ISBN: 978-92-9169-124-1 25 pp

MMC (2005) Natural hazard mitigation saves: an independent study to assess the future savings from mitigation activities. Vol. 1—findings, conclusions, and recommendations. Vol. 2—study

documentation. Appendices. MMC (Multihazard Mitigation Council). National Institute of Building Sciences, Washington, D.C
Mourre G, Astarita C, Prince (2014) Adjusting the budget balance for the business cycle: the EU methodology. European Economy. Economic Papers 536. Available at: http://ec.europa.eu/economy_finance/publications/economic_paper/2014/pdf/ecp536_en.pdf
OECD (2007) Climate change in the European Alps: adapting winter tourisms and natural hazards management. ISBN:978-92-6403-169-2
O'Neill BC, Kriegler E, Riahi K, Ebi KL, Hallegatte S, Carter TR et al (2014) A new scenario framework for climate change research: the concept of shared socioeconomic pathways. Climatic Change 122(3):387–400. https://doi.org/10.1007/s10584-013-0905-2
Osberghaus D, Reif C (2010) Total costs and budgetary effects of adaptation to climate change: an assessment for the European Union. Center for European Economic Research. Discussion Paper No. 10–046. Available at: http://www.cesifo-group.de/DocDL/cesifo1_wp3143.pdf
Palockova H (1999) Contingent Government liabilities: a hidden fiscal risk. Finance and Development 36(1). http://www.imf.org/external/pubs/ft/fandd/1999/03/polackov.htm
Prettenthaler F, Albrecher H-J (eds) (2009) Hochwasser und dessen Versicherung in Österreich. Studien zum Klimawandel in Österreich Bd. III. ISBN: 978-3-7001-6753-2
Rojas R, Feyen L, Bianchi A, Dosio A (2012) Assessment of future flood hazard in Europe using a large ensemble of bias-corrected regional climate simulations. Journal of Geophysical Research 117(D17). Available at: https://doi.org/10.1029/2012JD017461
Samir KC, Lutz W. (2017) The human core of the shared socioeconomic pathways: Population scenarios by age, sex and level of education for all countries to 2100. Glob Environ Chang 42:181–192
Schiman O (2012) Coping with potential impacts of ageing on public finances in Austria: the demography-based economic long-term model of Austria's public finances (DELTA-BUDGET) assumption report. Federal Ministry of Finance, Austria Available at: https://www.bmf.gv.at/services/publikationen/BMF-WP_1_2012-Coping_with_Potential_Impacts_of_Ageing_in_Pub.pdf?63xfq3
Schinko T, Mechler R, Hochrainer-Stigler S (2016) A methodological framework to operationalize climate risk management: managing sovereign climate-related extreme event risk in Austria. Mitigation and Adaptation Strategies for Global Change, 1–24. Available at: https://doi.org/10.1007/s11027-016-9713-0
Steininger et al. (2015) Economic evaluation of climate change impacts: development of a cross-sectoral framework and results for Austria, Springer. ISBN 978-3-319-12457-5
Steininger KW, Bednar-Friedl B, Formayer H, König M (2016) Consistent economic cross-sectoral climate change impact scenario analysis: method and application to Austria. Climate Services 1:39–52. https://doi.org/10.1016/j.cliser.2016.02.003
Thieken AH, Cammerre H, Dobler C, Lammel J, Schoberl F (2014) Estimating changes in flood risks and benefits of non-structural adapation strategies—a case study from Tyrol, Austria. Mitigation and Adaptation Strategies for Global Change pp. 1–34. Available at: https://doi.org/10.1007/s11027-014-9602-3
Timonina A, Hochrainer-Stigler S, Pflug G, Jongman B, Rojas R (2015) Structured coupling of probability loss distributions: assessing joint flood risk in multiple river basins: risk analysis, 35(11). Available at: https://doi.org/10.1111/risa.12382
van der Knijff J, Younis J, de Roo A (2010) LISFLOOD: Aa GIS-based distributed model for river basin scale water balance and flood simulation. Int J Geogr Inform Sci 24(2):189–212. https://doi.org/10.1080/13658810802549154
Wyplosz C (2007) Debt sustainability assessment the IMF approach and alternatives. Graduate Institute of International Studies, Geneva Available at: http://repec.graduateinstitute.ch/pdfs/Working_papers/HEIWP03-2007.pdf