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ORIGINAL PAPER

# Dealing with the COVID-19 pandemic in Slovenia: simulations with a macroeconometric model

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## Abstract

In this paper we analyse the effectiveness of fiscal policies with respect to macroeconomic stabilisation during the COVID-19 pandemic in the small open economy of Slovenia. Using SLOPOL11, an econometric model of the Slovenian economy, we simulate the development of the its economy during the 2020s under alternative assumptions about future pandemic-related shocks. We also determine optimal fiscal policies to combat the effects of the pandemic and to stabilise the economy under two scenarios for the future course of developments under COVID-19. Our simulations show that those public spending measures that entail both demand- and supply-side effects are more effective at stimulating real GDP and increasing employment than pure demand-side measures. Successful stabilisation policies should thus contain a supply-side component in addition to a demand-side component.

**Keywords** Macroeconomics · Stabilisation policy · Fiscal policy · Policy optimisation · Tax policy · Public expenditure · Demand management · Supply-side policies · Slovenia · Public debt

**JEL Classification** E62 · E17 · E37

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## 1 Motivation

Slovenia, just like almost all other industrialised and many emerging market economies, was hit hard by a sequence of adverse economic shocks in the recent past. In 2007, the financial and economic crisis, meanwhile known as the Great Recession, began to unfold. It became the most severe economic crisis since the Great Depression of the 1930s. In Slovenia, real GDP declined by as much as 7.5% in 2009. Like in other countries in the Euro Area, the only macroeconomic stabilisation policy instrument available was fiscal policy. In early 2020, the COVID-19 pandemic started to spread. When it turned out that the new Corona virus was highly infectious and could have lethal consequences, governments began to plan and implement measures to cope with the developing pandemic. These included, among others, temporary lockdowns of businesses and services, restrictions on travelling, dusk-to-dawn curfews, and financial support to firms and workers to prevent bankruptcies and layoffs. A considerable increase in different categories of government expenditures and some reductions in taxes, both by automatic stabilisers and discretionary measures, were part of the fiscal policy reactions nearly everywhere in the world.

It is, therefore, of interest to investigate the effectiveness of fiscal policy in stabilising an economy like Slovenia's. Slovenia is a particularly unusual case because it is the only small open transition economy which was already in the Euro Area before the Great Recession. Such an analysis is even more interesting since there is no consensus in academia as to the effectiveness of expansionary fiscal policy measures. In view of the architecture of the Euro Area and the fact that most of its members are small open economies, it is important and of general interest to clarify the appropriate role of fiscal policy for small open economies in a monetary union which are constrained by the problem of high public debt.

In this paper, we analyse the effects of different fiscal policy measures in Slovenia. We use the SLOPOL11 model, an econometric model of the Slovenian economy that we constructed to simulate the impact of the COVID-19 pandemic on important macroeconomic variables as well as on the level of public debt. We simulate the effects of fiscal policies announced or executed by the government to combat the pandemic and its economic consequences. These simulations extend earlier simulations reported in Blueschke et al. (2019), Weyerstrass et al. (2020), and Neck et al. (2018, 2021) by focusing on the demand- and supply-side effects of the COVID-19 pandemic and the fiscal policies designed to deal with it. Moreover, we determine optimal fiscal policies to stabilise the Slovenian economy in the context of the pandemic.

Given the fact that the COVID-19 pandemic affected Slovenia in a similar way to nearly all countries in the world, the reader may question the following analysis by asking why we simulate counterfactual scenarios in this paper which will probably not re-occur in the near future. The reason is twofold: firstly, we consider fiscal policy effects in "normal times", which may include recessions such as the Great Recession but not an unforeseen event such as COVID-19. Secondly, at the time of finishing this study (spring 2023), we hope but are not sure that the

COVID-19 crisis is over. Only tentative results can be obtained as the length and degree of the crisis and its economic impacts cannot be assessed fully. Moreover, it is not yet clear what future fiscal policies in Slovenia and – even more uncertain – in the Euro Area will look like and how they will impact on a national economy like Slovenia's. Nevertheless, we attempt to sketch possible scenarios for the macroeconomic effects of the pandemic. To do so, we construct two counterfactual scenarios based on data until 2021 that embody the effects of the COVID-19 pandemic but exclude the more recent shock from the effects of the Russian war against Ukraine. An optimistic scenario assumes that the pandemic has no more effects after 2021, while a pessimistic scenario considers further pandemic-related shocks in 2022 and 2023. Optimal fiscal policies aiming at stabilising the Slovenian economy during and after the COVID-19 crisis are calculated, based on these two scenarios.

Numerous papers have already analysed the economic effects of the pandemic, including theoretical studies and empirical assessments for different countries and regions worldwide, such as Acemoglu et al. (2021), Auerbach et al. (2020), Baqaee and Farhi (2020, 2021), Bartik et al. (2020), Bonadio et al. (2021), Caulkins et al. (2021), Chetty et al. (2020), Chudik et al. (2020), Ludvigson et al. (2020), McKibbin and Fernando (2020), Milani (2021), Weyerstrass (2021). Several methodologies were used to analyse the economic effects of the COVID-19 pandemic. For instance, macroeconomic investigations used dynamic stochastic general equilibrium models; see, e.g., Cardani et al. (2022). They have the advantage of being based on theoretically attractive assumptions but use calibration techniques which cannot capture the complexities of the empirics of a specific economy. Another class of models are input–output models, which can cover sectoral effects of such shocks, for example those affecting supply chain disturbances; e.g., Pichler and Farmer (2021). They have the disadvantage of being based on a particular class of production functions which may not always be adequate. Here we rely on a structural econometric model of the Cowles Commission type, which is strongly based on empirical data but may be criticised for neglecting differences between sectors and for their (sometimes weak) theoretical foundations.

The structure of the paper is as follows. The next section gives a short summary of the effects of COVID-19 on the Slovenian economy, followed by a brief overview of the macroeconometric model SLOPOL11 used for the empirical analysis. The following section presents two projections of the Slovenian macroeconomy for 2020 to 2030 obtained using the model and only assuming COVID-related exogenous shock in this period. This is followed by the results of optimal fiscal policies to deal with the COVID-19 crisis over the period of the simulations. The final section concludes.

## 2 COVID-19 effects in Slovenia

In Slovenia, the first person to test positive for COVID-19 was identified on 4th March 2020, with the first death attributed to the virus occurring on 14th March. The total number of infected persons increased to just over 1,000 within one month. It then took until mid-September for the total number of cases to rise to just below 4,000. After the end of summer vacations and travel-related activities, the number of new cases increased rapidly, culminating in a total of over 80,000 infections by the start of December 2020.

On 13th March, the Slovenian government reacted to the early developments by declaring an epidemic, and the Slovenian Parliament passed a number of emergency laws (approved by the European Commission where necessary), backed by measures involving the Slovenian Export and Development Bank and the Slovene Enterprise Fund. Beginning on 16th March, all educational institutions, hotels, restaurants, and nightclubs were closed while public transportation and "unnecessary" services were suspended throughout the country. On 20th March, de facto quarantine was instituted (with some exceptions) (Damijan 2020). Financial support for businesses included direct corporate financing in the form of long-term loans with subsidised interest rates, direct and indirect funding of small and medium enterprises to cover their costs during the pandemic, the financing of investments and working capital for the sustainable growth of tourism, funds for health care institutions and establishments, microloans for businesses in areas with high unemployment and near Slovenia's borders, and guarantees for bank loans.

The response of the Slovenian government to the first surge in March proved effective as the number of new infections was kept low, not only during the lockdown but also throughout the summer. During this time, Slovenia had one of the lowest infection rates per 100,000 people in Europe. At that time, economic forecasts (Damijan 2020; Bank of Slovenia 2020; IMAD 2020) were quite optimistic, predicting a decline in real GDP of 6–7% in 2020 and a recovery of approximately the same magnitude the following year.

In the second phase of the pandemic, the situation changed drastically. As was the case in many other European countries, the spring wave was followed by an autumn wave that was significantly stronger. The number of deaths per 100,000 inhabitants in Slovenia in December 2020 ranked among the ten highest worldwide (COVID-19 sledilnik 2021), despite the fact that nearly all European countries were affected by this outbreak. The Slovenian government responded in a similar way to the initial surge. Again, many economic activities (tourism, restaurants, public transport) were put on hold, resulting in temporary layoffs, while working from home was advised for those who could afford it and depending on the nature of the work (see Štebe and Vovk 2021; ILO 2021). Nonetheless, in December 2020, the number of newly infected individuals per day in Slovenia was still in the range of 1000–3000.

The second and third waves lasted until late April 2021, the latter being very short. New waves of the delta and omicron variants then occurred in the autumn and winter of 2021–2022, with the number of infections significantly exceeding that of the previous waves. However, in the spring of 2021, vaccination started to have a substantial impact on the dynamic of the pandemic in Slovenia. This resulted in the "decoupling" of the curves for infections, hospitalised cases, and deaths; the number of deaths in particular declined in more recent waves, but the number of infected cases and, in the fourth wave, also the number of hospitalised cases grew significantly, similarly to the majority of European countries (see Mathieu and Roser 2021).

In order to stabilise private household income, the authorities devised a multi-pronged policy response in 2020, totalling approximately 6.5% of GDP and focusing on wage subsidies and basic income for the vulnerable. Given the epidemiological situation, the majority of fiscal measures regarding COVID-19 continued in 2021 and into 2022. The fiscal impact of the main measures, which included extended furlough and income support, is estimated to be around 3% of GDP. Consequently, fiscal policy remained expansionary (as compared to its trend) throughout this period (EBRD 2021). According to the current draft of the National Recovery and Resilience Plan (NRRP), Slovenia received EUR 1.8 billion in grants from the EU Recovery Facility, which is less than the EU average as a share of GDP and would absorb EUR 666 million in loans. As a result of the lockdowns, consumption plummeted, while income hardly changed. Hence, as in most other industrialised countries, households built up excess savings, visible in an unusual rise in the savings rate. A more detailed account of fiscal policy measures is presented in the appendix of this paper.

After deteriorating during the first phase of the pandemic, the labour market situation improved in 2021 and continues to improve, albeit with labour shortages gradually developing for demographic reasons. The first wave of the pandemic disrupted many years of favourable labour market trends; employment fell and unemployment rose significantly, but the situation improved rapidly after intervention measures were implemented to preserve jobs. Thus, the impact of the COVID-19 crisis on the labour market was mitigated effectively by government actions.

## 3 The macroeconometric model SLOPOL11

For this study we used an updated version of SLOPOL, a medium-sized macroeconometric model of the small open economy of Slovenia. Detailed descriptions of earlier model versions and their properties may be found in Weyerstrass (2011) and in Weyerstrass et al. (2018). In the most recent version, SLOPOL11 consists of 73 equations, 21 of which are behavioural equations and 52 identities. In addition to the 73 endogenous variables, the model contains 37 exogenous variables. The behavioural equations were estimated by ordinary least squares (OLS), except for the labour demand and supply equations, which were estimated as censored Tobit models. Stationarity tests indicate that almost all the variables are either stationary or cointegrated. Some variables are stationary by construction or by definition. These are the output gap, the capacity utilisation rate, and changes in inventories. We conducted three unit root tests, namely the Augmented Dickey Fuller (ADF) test, the Phillips Perron (PP) test, and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, which indicated that the results of the unit root tests can be regarded as satisfactorily robust. Therefore, as argued in Weyerstrass (2011), we opted for OLS estimations of error correction equations except for the labour supply and demand equations.

The behavioural equations were estimated using quarterly data for the period 1995q1 to 2019q4. Although at the time of estimating the most recent model version, data were available until the end of 2022, they were not used for the estimation as they were affected not only by the recurring lockdowns and international travel restrictions due to COVID-19 from the first quarter of 2020 onwards but also by the effects of Russia's war against Ukraine in the first half of 2022, both of which caused unusually large downturns and upturns in individual countries, and, hence, substantial deviations from usual trends. Data for Slovenia and for Euro Area aggregates as well as the oil price were taken from the Eurostat database and world trade data came from the CPB Netherlands Bureau for Economic Policy Analyses.

The model contains behavioural equations and identities for the goods market, the labour market, the real effective exchange rate, the money market (albeit only rudimentarily), and the government sector. It combines Keynesian and neoclassical elements. In the short run, the model is demand driven, while in the long run the growth path is determined from the supply side via potential output. Potential GDP is determined via a Cobb–Douglas production function with the potential labour force, the capital stock, and the trend of total factor productivity (TFP) as factors of production. Trend TFP is determined in a behavioural equation, depending on public expenditures on research and development, the share of people with tertiary education, and the investment-GDP ratio. With public R&D expenditures and educational attainment (although the government can only influence them indirectly), two supply-side policy instruments targeted primarily at potential GDP can be considered in the simulations. The model equations are described in the supplementary material of this paper. Most equations have the same specification as the earlier version SLOPOL10 (Weyerstrass et al. 2018), with one major difference concerning the labour market.

In this version, labour demand and labour supply are divided into the main age group (15 to 64 years) and older people (65 years and above). The labour demand of companies, i.e. actual employment, is modelled via the employment rates of the two age groups, i.e. employment as a share of the relevant age group in the total population. For the main age group, a behavioural equation was estimated, while employment of the over 65 s was set exogenously. The equation for the main age group was estimated as a Tobit model, employment rates being restricted to lie between 0 and 0.98. The employment rate is influenced positively by real GDP and negatively by the real net wage and, additionally, by the wedge between the gross and the net wage. Labour supply is modelled via the share of the labour force of the two age groups in the total population. Again, a behavioural equation was only estimated for the main age group while the labour supply of the older group was set exogenously. The equation, too, was estimated as a Tobit model with the restriction of being positive but below 0.99. Labour supply depends positively on the real net wage and negatively on the wedge between the gross and the net wage.

Although the SLOPOL11 model is used for forecasting and policy simulations, it should be noted that the model – like every structural econometric model – may be subject to the famous Lucas critique. Lucas (1976) argued that the relations between macroeconomic aggregates in an econometric model should differ according to the macroeconomic policy regime in place. In this case, the effects of a new policy regime cannot be predicted using an empirical model based on data from previous periods when that policy regime was not in place. An approach taking the Lucas critique into account in structural models like SLOPOL11 emerged in the London School of Economics tradition initiated by Sargan (1964). According to this approach, economic theory guides the determination of the underlying long-run specification while the dynamic adjustment process is derived from an analysis of the time series properties of the data series. Error correction models involving cointegrated variables combine the long-run equilibrium and the short-run adjustment mechanism. A further argument for the robustness of our estimations can be seen in the fact that we updated the model several times while preparing this paper and found that it does well when making out-of-estimation-period forecasts without changing the estimated equations. In addition, the calculations of the multipliers presented in Weyerstrass et al. (2020) give virtually the same results as the calculations for the years immediately after the estimation period. Hence, the model can be regarded as a reliable tool for forecasting the development of the Slovenian economy in the short and medium run.

## 4 Projections of Slovenian economic development after the COVID-19 shock

We used the SLOPOL11 model to simulate two paths using different assumptions about the development of the COVID-19 pandemic from 2022 until 2030. Although we already have the data for 2022 and some for 2023, we only took the years until 2021 as known and simulated the development from 2022 to 2030 using data from the IMAD autumn 2021 forecast. This procedure serves to isolate the effects of the COVID-19 pandemic and to exclude effects due to the shock from the Russian war against Ukraine, which started on 24th February 2022. We constructed two scenarios for 2022 onwards. In the optimistic scenario, we assumed that no COVID-19 related restrictions would be necessary (which so far was actually the case). In the pessimistic scenario, we introduced negative shocks, technically in the form of negative add factors to real private consumption and exports in 2022 and 2023, approximating possible new lockdowns. We assumed new COVID-19 related restrictions to contact-intensive services including tourism. Because industry and, thus, international trade in goods would not be directly affected by a new lockdown, we did not assume shocks to world trade in goods in this scenario (which, in fact, occurred in the wake of the Russian war against Ukraine). Except for the negative shocks to private consumption and exports, the two scenarios did not differ in the paths of the exogenous variables including the policy instruments. Both scenarios are counterfactual, deliberately ignoring the war shock, but the optimistic scenario is clearly more in line with actual developments than the pessimistic one.

For both scenarios, we assumed that most spending-related fiscal policy variables, i.e., public investment, transfers to private households as well as public spending on research and development, would increase by 3% p.a. over the simulation period. For public consumption, a growth rate of 3% in 2023 was assumed, followed by annual growth of 4% from 2024 onwards. The tax rates and the rates for social security contributions were held constant at their 2021 values over the entire time horizon of these simulations as they cannot easily be changed by discretionary policy actions in normal times. For the optimisation exercise, however, we assume them to be policy instruments, which could be the case in an emergency situation like

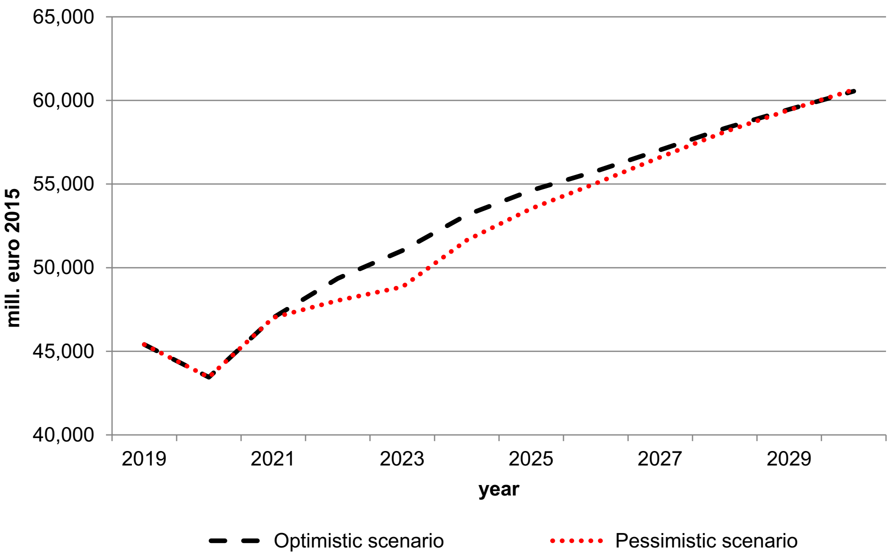



**Fig. 1** Level of real GDP. *Source*: authors' calculations and illustrations

the COVID-19 pandemic, because then the government will presumably have more power to act.

For world trade in goods, a growth rate of 3.7% p.a. was assumed in 2022 with an annual growth rate of 3% from 2023 onwards. According to the results of the EUROPOP2019 population projections produced by Eurostat for all EU Member States as well as Iceland, Liechtenstein, Norway, and Switzerland, the Slovenian population of working age would decrease by 0.4 to 0.6% p.a. from 2022 onwards.[1] Regarding the labour force of people aged 65+, we assumed that it would remain constant in the projection period. Regarding monetary policy, we assumed that the ECB would enter a process of mild monetary tightening until 2024. The SLOPOL model does not contain any monetary policy rates; it contains only the three-month money market rate and the 10-year government bond yield. For the short-term interest rate, we assumed that it would rise to 2.5% in 2023 and stay at this level until the end of the projection period in 2030. According to the term structure of interest rates, the long-term government bond yield should follow this path, implying that the 10-year bond yield would rise to 3% in 2023 and then remain at this level.

The paths of the key macro variables are illustrated in Figs. 1, 2, 3, 4, 5, 6, 7 and 8. They show the time paths of the variables in the two simulations: the optimistic scenario (dashed lines) and the pessimistic scenario (dotted lines). Here we briefly characterise the main results of the simulations without optimisation. For 2020 to 2021, both scenarios give the same results for all variables by construction as these years were calibrated with the actual data.

[1] See https://www.stat.si/StatWeb/en/News/Index/8917 for the EUROPOP2019 projections for Slovenia.

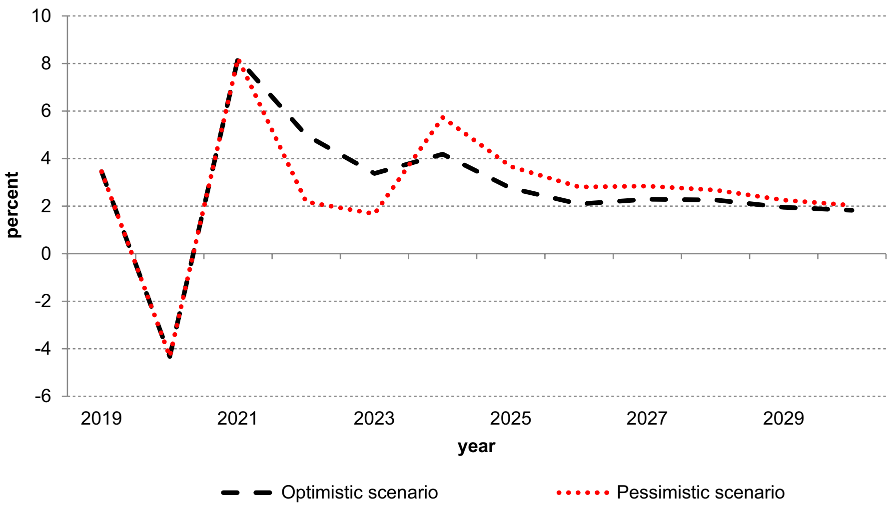



**Fig. 2** Growth rate of real GDP. *Source*: authors' calculations and illustrations

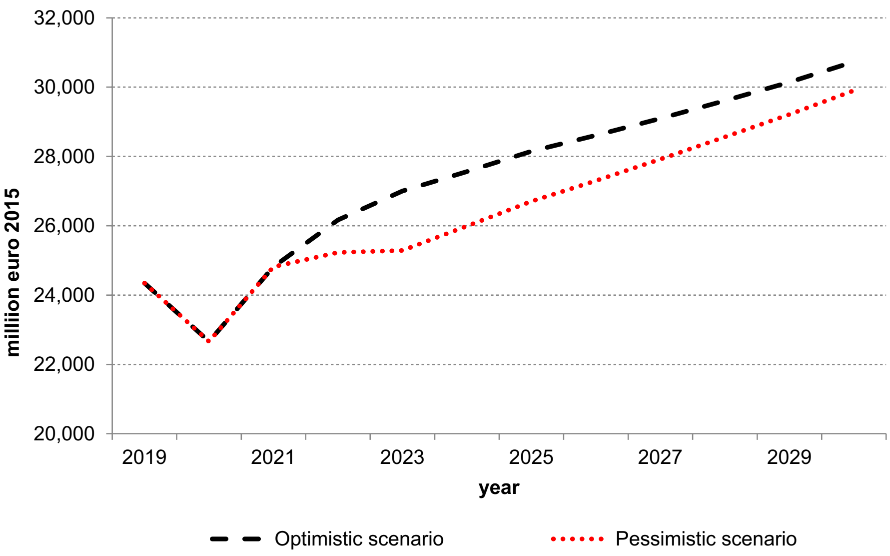



**Fig. 3** Real private consumption. *Source*: authors' calculations and illustrations

Following recovery-driven high growth of 8.2% in 2021, in the optimistic scenario real GDP grows, albeit with decreasing growth rates until 2030. The pessimistic scenario predicts low but positive growth due to additional shocks in 2022 and 2023, a recovery in 2024, and then decreasing growth rates like in the optimistic scenario, both ending up in slow growth rates of approx. 2% in 2030. Due to the negative shock to private consumption assumed, this demand component

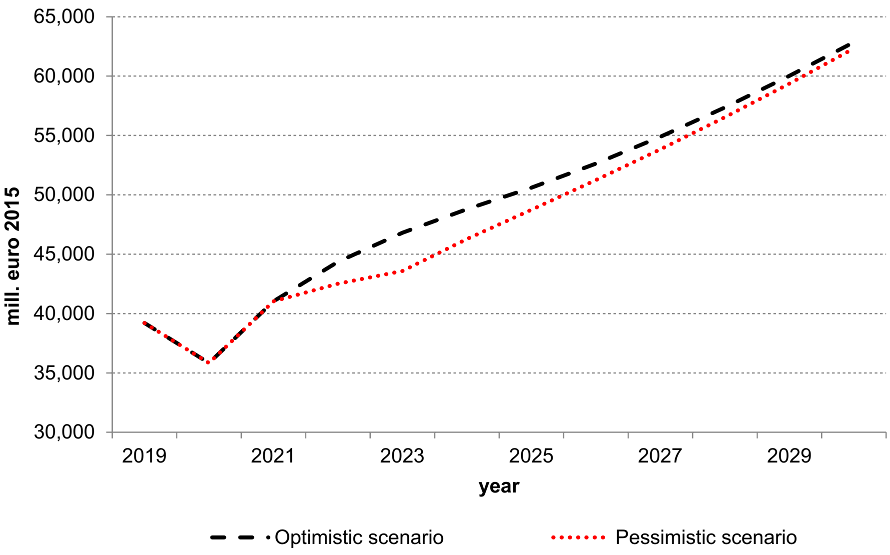



**Fig. 4** Exports of goods and services. *Source*: authors' calculations and illustrations

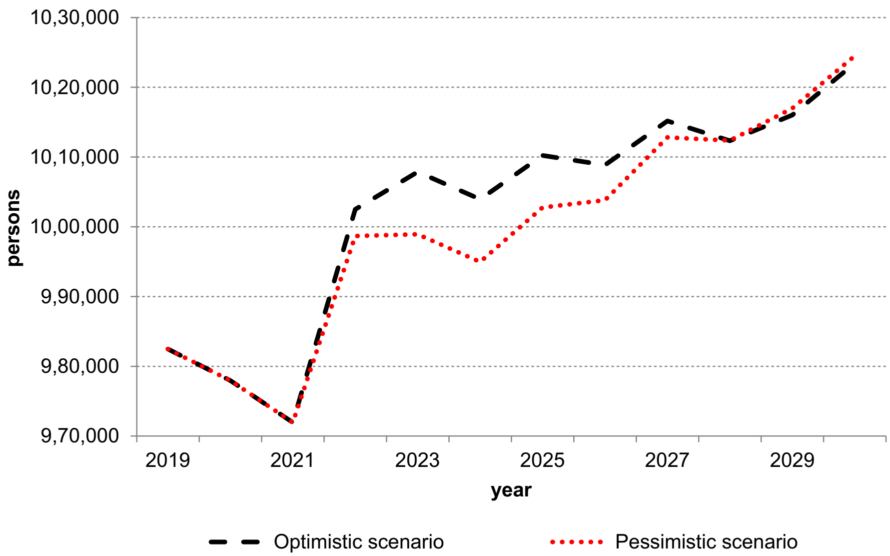



**Fig. 5** Employment. *Source*: authors' calculations and illustrations

is also lower in the pessimistic scenario over the entire period 2022 to 2030. Furthermore, multiplier effects amplify this negative deviation and these multiplier effects are also the reason for investment to deviate negatively from the optimistic scenario, although only until 2026. Due to strong economic growth, employment

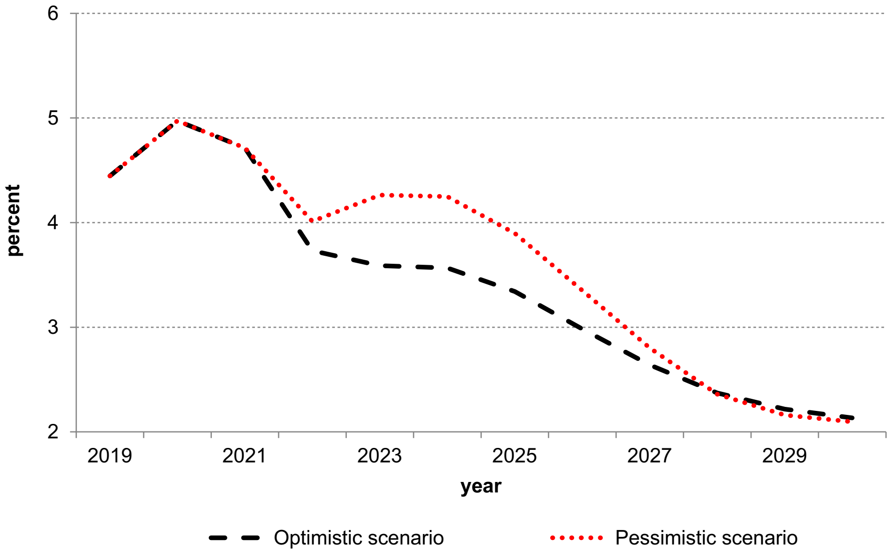



**Fig. 6** Unemployment rate. *Source*: authors' calculations and illustrations

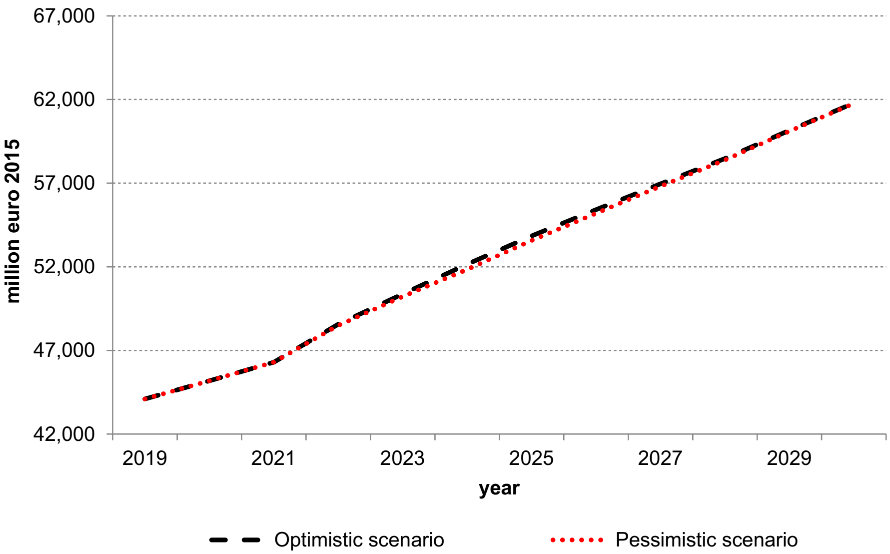



**Fig. 7** Level of potential output. *Source*: authors' calculations and illustrations

exceeds its 2019 value in a quick recovery by 2022. From then, it increases slowly in the optimistic scenario and less so in the pessimistic one, with the two scenarios converging in 2028. The rate of unemployment decreases over the entire time

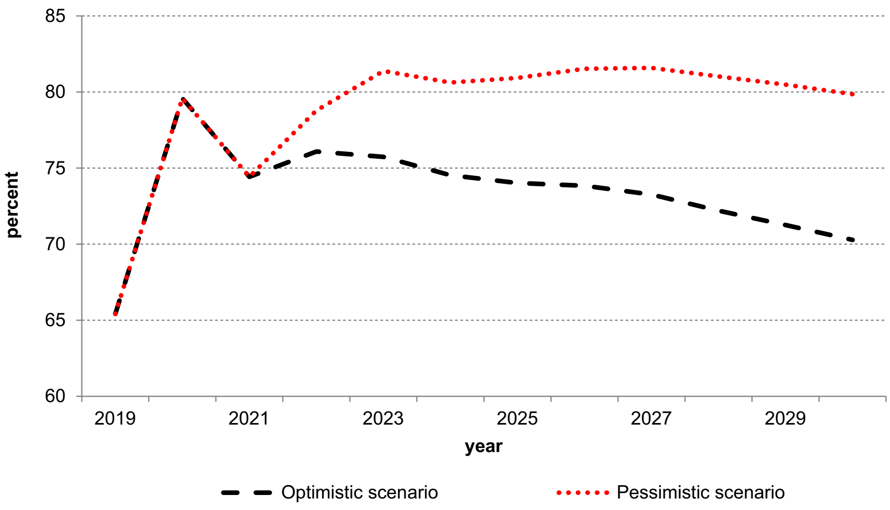



**Fig. 8** Public debt-to-GDP ratio. *Source*: authors' calculations and illustrations

horizon to 2% in 2030 in the optimistic scenario, and does so in the pessimistic one but with higher values in 2023 to 2027.

We neglect further supply-side shocks (such as the disturbances to supply chains and price increases for energy and food due to the war in Ukraine) and assume that further COVID-19 shocks in 2022 and 2023 in the pessimistic scenario are mainly demand driven. Therefore, the potential output in both scenarios exhibits nearly the same smooth growth path until 2023. In the optimistic scenario, public finances gradually improve, although with a budget deficit until 2030. The debt-to-GDP ratio decreases nevertheless after the initial high of nearly 80% in 2020, reaching 70% in the optimistic scenario but staying around 80% in the pessimistic one. Even in the optimistic scenario, it is thus considerably higher than the 60% Maastricht reference level.

Of course, it must be stressed that the two scenarios were constructed under a very high degree of uncertainty, both with respect to future epidemiological developments as well as international and national policy reactions, especially in the EU in general and in the Euro Area in particular. Even the pessimistic scenario, although it is far from what seems plausible to Slovenian authorities and observers now, may be too optimistic if unpredictable events such as increased political tensions, wars, or financial turmoil occur, or if predictable negative supply shocks such as those resulting from climate change cause further changes for the worse. The negative impacts of the Russian invasion of Ukraine is a prominent current example of such unforeseeable events.

## 5 Optimal fiscal policies under the COVID-19 shock

Next, we ask what optimal fiscal policies would look like under the different scenarios. The purpose of such an exercise cannot be to judge the performance of actual policy makers in Slovenia, for at least two reasons. Firstly, we consider information available about the COVID-19 pandemic to date that was not available to even the best-informed policy maker at any point in the last few years. This means that all the uncertainty (stochastic or otherwise) about this new phenomenon is absent from a comparison between ex-post results and the real situation of a policy maker confronted with an entirely or at least partly unknown situation. Although in principle it would be possible to consider additive and multiplicative (parameter) stochastics by using the OPTCON algorithm (Blueschke et al. 2021), we use the deterministic version of this algorithm because the additional computational power required for executing stochastic simulations of a model the size of SLOPOL11 by far exceeds the additional insights to be expected: the real challenge for a policy maker is not the stochastics of a particular econometric model but the black swan of a hitherto unknown pandemic.

Secondly, it must be warned that such an exercise depends crucially upon the objective function assumed for a (hypothetical or actual) policy maker. It would be misleading to interpret the results in a strictly normative sense as implying prescriptions to such a policy maker. Instead, the determination of optimal policies may serve to uncover possible trade-offs and provide information about which policy instruments are most appropriate for achieving particular targets. The best interpretation considers the determination of optimal policies with an econometric model as a joint simulation of the model with a particular objective function, where the latter is a proposal to be shown to a policy maker to find out, in a trial-and-error manner, their preferences concerning different objective variables. At best, this procedure could be used to enter into a dialogue with a policy maker about alternatives for the design of their policy. We have done so for Slovenia before the COVID-19 pandemic (Blueschke et al. forthcoming) and hope to continue this investigation in the near future, including the pandemic experiences.

In the present context, we assumed an (admittedly arbitrary) objective function and determined the optimal paths of the fiscal policy variables in addition to the policies the Slovenian government had implemented (which are already assumed for the – a priori nonoptimal – policies in the two simulation scenarios considered) under this particular objective function. This is a dynamic version of a multicriteria decision problem; cf. Wallenius (1982). The objective function contains as arguments a relatively long list of variables of interest for the hypothetical policy maker (objective variables), which include real GDP, its growth rate, potential output, its growth rate, real consumption, real investment, employment, the unemployment rate, the inflation rate, the debt-to-GDP ratio, the budget balance, the current account, and all the instrument variables. Three state variables (real GDP, the unemployment rate, and the debt-to-GDP ratio) are considered to be of major importance and are given a higher weight. In addition, three control variables (government consumption, government investment, and the income tax rate) are given higher weights as a surrogate for inequality constraints not available in the algorithm (these variables cannot easily be changed beyond a certain limit in reality). All other variables have the same weight (adjusted for their dimension), and the aim of the policy maker consists in minimising the squared deviations of these variables from "ideal" or target values, aggregated by the weights and over time. The time paths of the target values for most variables are constructed under the assumption of an annual growth rate of 3%

for the real variables and 3% plus the target rate of inflation of 1.5% for the nominal variables. The target for the government budget surplus is 0, the public-debt-to-GDP ratio is targeted to decrease towards the Maastricht target of 60% and the unemployment rate to decrease gradually towards 3.35% in 2030.

Technically, we assumed a quadratic intertemporal objective function with an annual discount factor of 3% and solved the resulting nonlinear-quadratic optimal control problem approximately by using the OPTCON algorithm (Blueschke et al. 2021). The analysis starts from the initial year 2019 and the optimisations run over the time period 2020 (the first year of the pandemic) to 2030. As a first step, we had to calculate a simulation over the same time period without active policies ("non-controlled simulation"), using the target paths of the instrument variables and the paths of the exogenous variables from the forecast described in the previous section. This serves as a reference path for the optimisations; it shall simulate a policy of "fixed rules" as opposed to the discretionary policies from the optimisations. Penalising the deviations of the variables in the non-controlled simulation path from their target values according to the assumed objective function gives a value of 17,124.57 as a measure of the costs (relative to the objective function chosen) of following the non-optimal policy. Using the OPTCON algorithm allows us to find better paths for the control variables, which lead to an objective function value of 2,271.55. Thus, our optimal control algorithm significantly reduces the welfare loss and brings the economy closer to the desired state.

The results of these optimisation exercises are shown in Figs. 9, 10, 11, 12 and 13, 15, 16 and 17 for the optimistic scenario and in Fig. 14 for the pessimistic scenario. Other details of the results are omitted for lack of space and can be obtained from the authors. In the figures, we show the assumed target paths (diamonds), the paths of the non-controlled simulations (triangles), and the optimal paths (squares) of the objective variables. The optimisation is deterministic and assumes that the econometric model has constant parameters and is not subject to shocks, except for the COVID-19 shock as modelled here.

The results show that in the optimistic scenario, there is a chance to improve upon the non-controlled simulation results. This is achieved by more active variation in the instrument variables in a Keynesian way: more expansionary policies in the pandemic and somewhat more restrictive policies in the years after. They lead to higher employment and growth and a lower unemployment rate during the pandemic than in the uncontrolled scenario. However, there is a remarkable difference between the policy mixes of the two scenarios. While the task of driving output and employment closer to their target paths is mainly performed by public investment, human capital investment, and especially public R&D investment on the expenditure side coupled with income taxes and social security contributions on the revenue side, transfers and VAT act in a restrictive way to achieve smaller government budget deficits and lower public debt during the pandemic and after. As the former instruments have an influence not only on the demand side but also on the supply side of the economy, they contribute not only to GDP and its components but also to potential GDP, thereby reinforcing the demand-side effects.

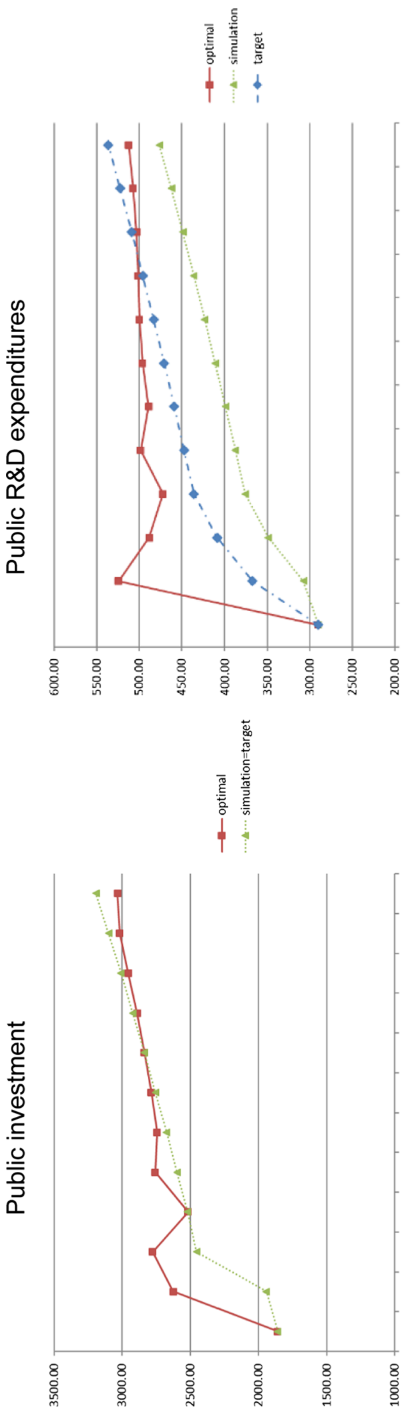



**Fig. 9** Optimistic scenario: policy instruments. *Source*: authors' calculations and illustrations

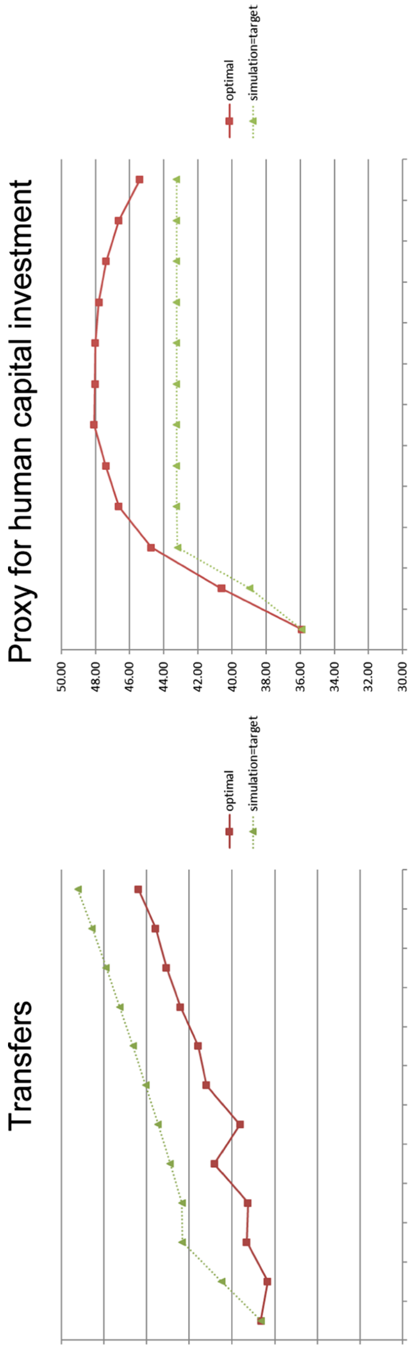



**Fig. 10** Optimistic scenario: policy instruments *Source:* authors' calculations and illustrations

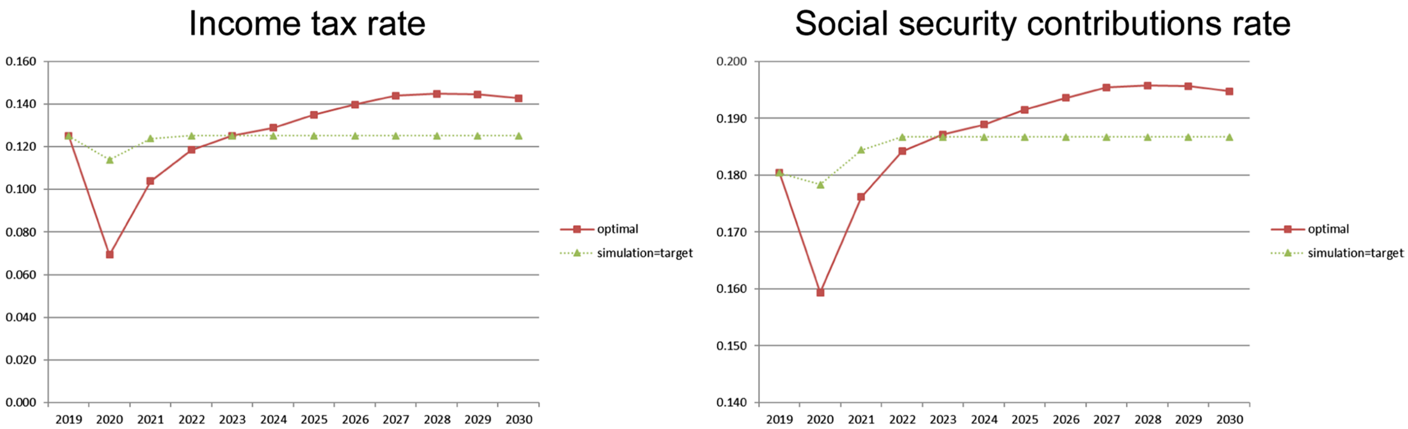



**Fig. 11** Optimistic scenario: policy instruments *Source*: authors' calculations and illustrations

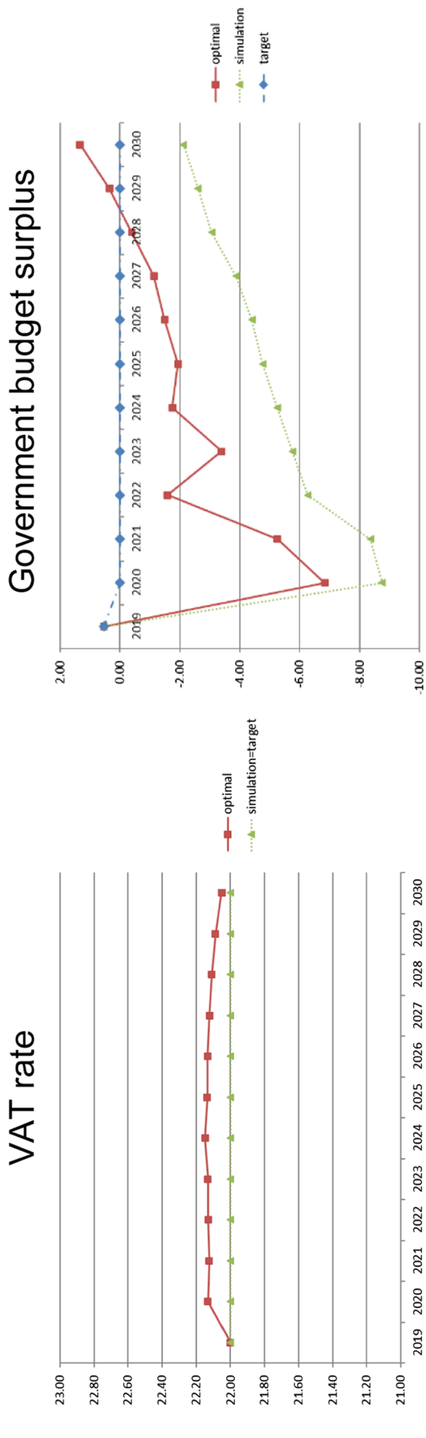



**Fig. 12** Optimistic scenario: VAT rate and budget surplus *Source*: authors' calculations and illustrations

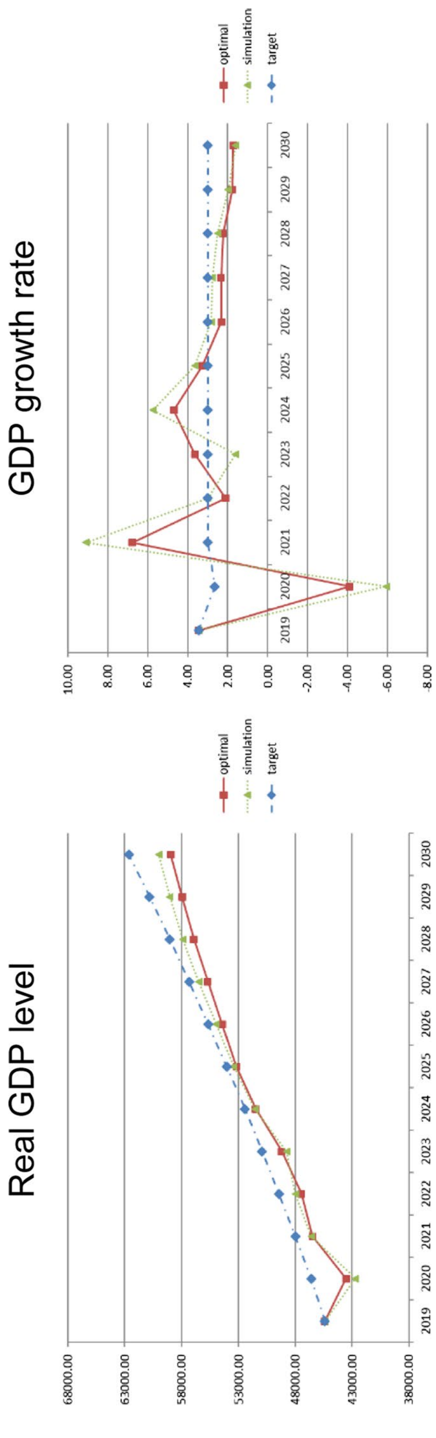
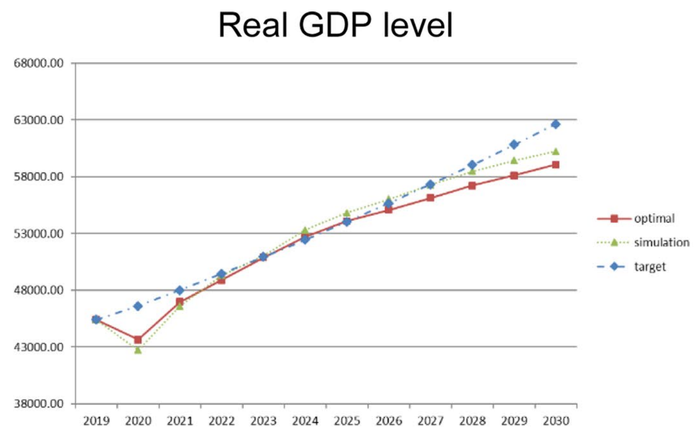



**Fig. 13** Optimistic scenario: real GDP (level and growth rate) *Source*: authors' calculations and illustrations



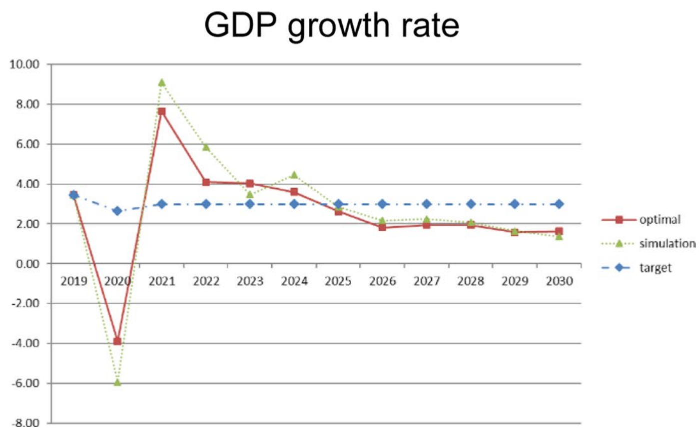




**Fig. 14** Pessimistic scenario: real GDP (level and growth rate). *Source*: authors' calculations and illustrations

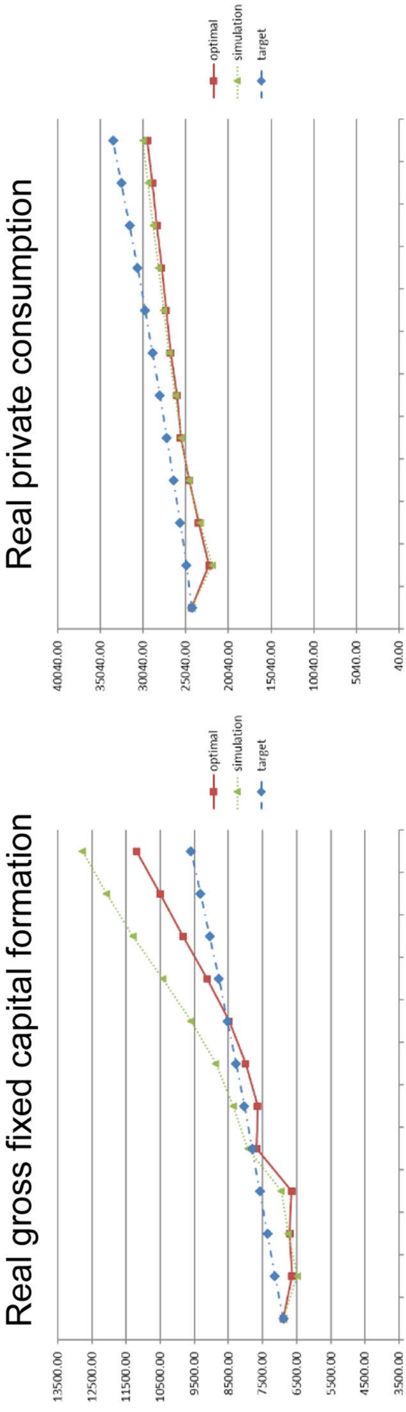



**Fig. 15** Optimistic scenario: investment and consumption. *Source*: authors' calculations and illustrations

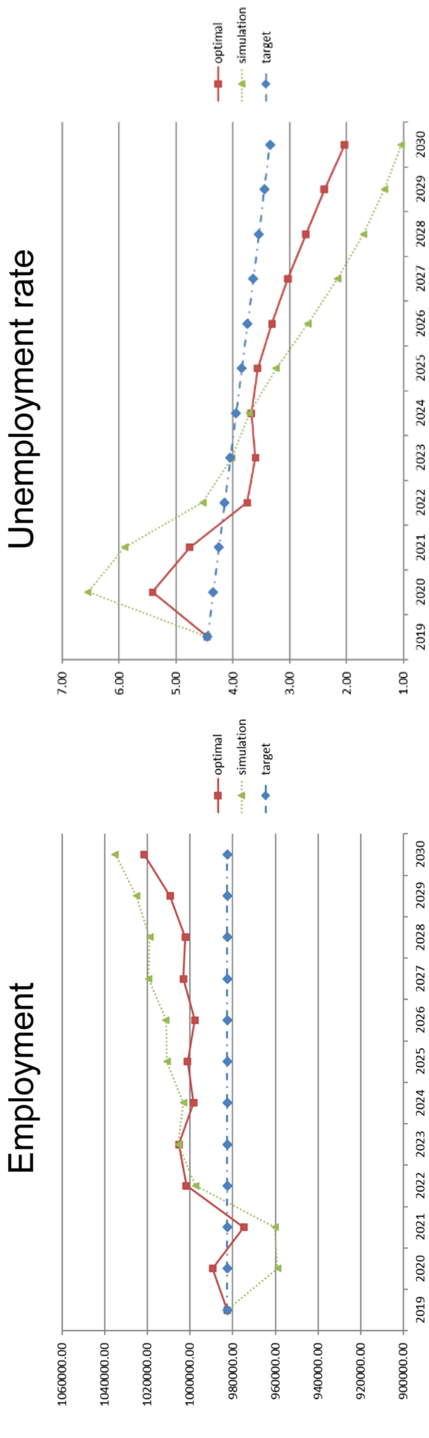



**Fig. 16** Optimistic scenario: labour market. *Source*: authors' calculations and illustrations

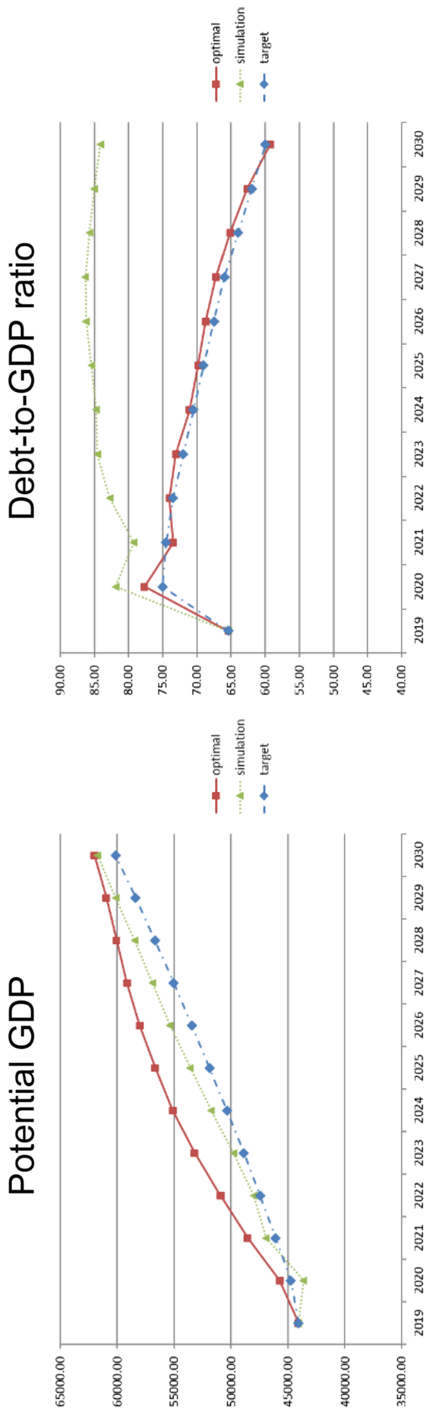



**Fig. 17** Optimistic scenario: potential output and debt-to-GDP ratio. *Source:* authors' calculations and illustrations

Even for a shock like COVID-19, which is predominantly a demand-side shock, expansionary fiscal policies are well designed if they concentrate on investment instead of transfers or public consumption. This confirms our results, obtained with previous versions of the SLOPOL model, that public spending measures which entail both demand- and supply-side effects, i.e. public investment and especially spending on R&D, are more effective at stimulating real GDP than pure demand-side measures. On the revenue side of the government budget, the optimal policy calls for reductions in income taxes and social security contributions to boost employment and relies on a modest increase in VAT and a stronger increase in revenues which do not directly affect income and employment.

The time paths of the active instruments are more volatile in the optimised scenario but those of the endogenous variables, and especially those of the main target variables, are less so. Thus, the trade-off between the stability of instruments and targets is solved in favour of the target variables by the optimal policies, and the trade-off between stabilising output and employment on the one hand and the government budget on the other is resolved by a combination of expansionary measures also acting on the supply side and more restrictive measures without supply-side effects.

In the pessimistic scenario, the results are very close to those in the optimistic scenario, both in terms of the instruments and the target variables. The only difference is a slower return to a less expansionary course of fiscal policies, but even this is very minor and results in nearly the same paths for the endogenous variables, as the example of GDP in Fig. 14 shows. Therefore, we do not present more details of this scenario here.

## 6 Concluding remarks

In this paper, we investigated the macroeconomic effects of the COVID-19 pandemic for the small open Euro Area member Slovenia. We used simulations with the econometric model SLOPOL11, a medium-sized model based on the cointegration approach, and optimisations of an objective function to determine optimal fiscal policies for Slovenia during the 2020s. Although the future development of the pandemic is still uncertain, one robust result is the emphasis on both supply-side and demand-side fiscal policies and the importance of public investment and especially government expenditure on R&D, even in times of a crisis that ostensibly seems to call primarily for transfers and subsidies as instruments of fiscal policy.

## Appendix: Timing and content of COVID-19 related fiscal measures in Slovenia

| Package | Adoption | Financial value |
|---|---|---|
| 1 | 11 April 2020 | 3 billion EUR |
| | Measures to preserve jobs, improve the social situation of people, provide emergency assistance to the self-employed, maintain operations, improve corporate liquidity, and support research projects to combat the pandemic, reduce attendance fees, wages, and exemptions from distribution services, aid to agriculture and public procurement measures | |
| | For details, see GOV.SI (2020a) and GOV.SI (2020b) | |
| 2 | 1 May 2020 | 2 billion EUR |
| | Measures to ensure the liquidity of the economy and adjustments to the first package. It was basically a guarantee scheme for Slovenian companies and entrepreneurs, which was exploited only partially and funds had to be (partially) repaid according to a prescribed set of criteria | |
| | For details, see GOV.SI (2020c) | |
| 3 | 1 June 2020 | 1 billion EUR |
| | Measures in the fields of labour, public finance, economy, tourism (tourist vouchers), agriculture, forestry and food, scholarships, subsidies for student meals, higher education, infrastructure, and public procurement | |
| | For details, see GOV.SI (2020d) | |
| 4 | 11 July 2020 | 400 million EUR |
| | Extension of the measure of waiting for work, determination and payment of compensation for stay-at-home quarantine orders, financing of additional staff in social welfare institutions in the public network and introduction of a mobile health protection app informing about contacts with an infected person | |
| | For details, see GOV.SI (2020e) | |
| 5 | 24 October 2020 | 420 million EUR |
| | Measures in the fields of health, labour, social protection, the economy, education, the enforcement of criminal sanctions and justice, agriculture, forestry and food, and infrastructure | |
| | For details, see GOV.SI (2020f) | |
| 6 | 28 November 2020 | 1 billion EUR |
| | Subsidising waiting for work, extending the moratorium on loans, subsidising part-time work, financing allowances for hazards and special burdens, partially compensating fixed costs for affected economic operators, postponing rent payments to tenants of office buildings or business premises, providing health services and facilities | |
| | For details, see GOV.SI (2020g) | |
| 7 | 31 December 2020 | 550 million EUR |
| | Crisis allowance for pensioners, students, new-borns, recipients of child allowance, parents with several children, older farmers and low-income employees, monthly basic income for religious employees. Aid for carrying out rapid tests in the economy, aid for carriers. and aid to fire brigades | |
| | For details, see GOV.SI (2020 h) | |
| 8 | 5 February 2021 | 320 million EUR |
| | Solidarity allowance for students over the age of 18 and students studying abroad and the disabled. Extension of the measure for waiting for work and subsidising the minimum wage | |
| | For details, see GOV.SI (2021) | |

| Package | Adoption | Financial value |
|---|---|---|
| 9 | 14 July 2021 | 243.5 million EUR |
| | New vouchers for citizens, assistance to the meetings and events industry, extension of the part-time compensation measure and compensation measure for employees due to stay-at-home quarantine orders, health measures | |
| | For details, see GZS (2021a) | |
| 10 | 29 December 2021 | 240 million EUR |
| | Solidarity allowances for the most vulnerable, liability for vaccination complications, reimbursement of the costs of rapid tests for companies, extension of tourist vouchers 2020 | |
| | For details, see GZS (2021b) | |

A preliminary list of the fiscal packages was compiled already by Murko (2021). It has to be pointed out, though, that the actual payments from the budget were lower than the allocated funds: around 2.6 billion EUR out of available 6.4 billion EUR by October 2020 (STA 2020) and around 3 billion EUR out of available 7.8 billion EUR by January 2021 (STA 2021). A preliminary analysis of the effectiveness of anti-COVID measures was performed by Franca et al. (2020), with recommendations on how to modify and design further measures.

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## References

Acemoglu D, Chernozhukov V, Werning I, Whinston MD (2021) Optimal targeted lockdowns in a multi-group SIR model. Am Econ Rev Insights 3(4):487–502

Auerbach AJ, Gale WG, Lutz B, Sheiner L (2020) Effects of covid-19 on federal, state, and local government budgets. Brook Pap Econ Act 2020(3):229–278

Bank of Slovenia (2020) Macroeconomic projections for Slovenia. Ljubljana, June 2020. https://bankaslovenije.blob.core.windows.net/publication-files/macroeconomic-projectionsfor-slovenia-june-2020_ii.pdf
Banka Slovenije (2022a) Polletni pregled gospodarskih in finan nih gibanj. Apr 2022. Ljubljana: Banka Slovenije
Banka Slovenije (2022b) Polletni pregled gospodarskih in finan nih gibanj. Oct 2022. Ljubljana: Banka Slovenije
Baqaee D, Farhi E (2021) Keynesian production networks and the COVID-19 crisis: a simple benchmark. Am Econ Rev Pap Proc 111:272–276
Baqaee D, Farhi E (2020) Supply and demand in disaggregated Keynesian economies with an application to the COVID-19 crisis. NBER working paper no. 27152
Bartik AW, Bertrand M, Lin F, Rothstein J, Unrath M (2020) Measuring the labor market at the onset of the COVID-19 crisis. Brookings papers on economic activity 50, special edition: COVID-19 and the economy, part one: 239–268
Blueschke D, Blueschke-Nikolaeva V, Neck R (2021) Approximately optimal control of nonlinear dynamic stochastic problems with learning: the OPTCON algorithm. Algorithms 14:181
Blueschke D, Weyerstrass K, Neck R, Majcen B, Srakar A, Verbič M (2019) Budget consolidation in a small open economy: a case study for Slovenia. Post-Commun Econ 31(3):325–348
Blueschke D, Weyerstrass K, Neck R, Verbič (forthcoming). How can preferences of policy-makers be operationalised in optimum control problems? Unpublished manuscript, Department of Economics, University of Klagenfurt
Bonadio B, Huo Z, Levchenko AA, Pandalai-Nayar N (2021) Global supply chains in the pandemic. NBER working paper no. 27224
Cardani R, Croitorov O, Giovannini M, Pfeiffer P, Ratto M, Vogel L (2022) The Euro area's pandemic recession: a DSGE-based interpretation. J Econ Dyn Control 143:104512
Caulkins JP, Grass D, Feichtinger G, Hartl RF, Kort PM, Prskawetz A, Seidl A, Wrzaczek S (2021) The optimal lockdown intensity for COVID-19. J Math Econ 93:102489
Chetty R, Friedman JN, Hendren N, Stepner M, The Opportunity insights team (2020) How did COVID-19 and stabilization policies affect spending and employment? A new real-time economic tracker based on private sector data. NBER working paper no. 27431
Chudik A, Mohaddes K, Pesaran MH, Raissi M, Rebucci A (2020) A counterfactual economic analysis of COVID-19 using a threshold augmented multi-country model. NBER working paper no. 27855
Damijan JP (2020) Economics of corona pandemic in Slovenia. Friedrich Ebert Stiftung, Apr 2020
EBRD (2021) Coronavirus response in 2021: building back better. Update on Slovenia (2021). European Bank for Reconstruction and Development, London
European Commission (2022b). Slovenia's recovery and resilience plan. https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-andresilience-facility/slovenias-recovery-and-resilience-plan_en (Oct 22, 2022)
European commission (2022a) Recovery and resilience facility https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-andresilience-facility_en (Oct 22, 2022)
Franca V, Domadenik P, Redek T (2020) Raziskava o učinkovitosti protikoronskih ukrepov PKP. Združenje delodajalcev Slovenije, Ljubljana
GOV.SI – Government communication office (2020a), Vlada sprejela #protiKoronapaket. Accessible at https://www.gov.si/novice/2020-03-29-vlada-sprejela-protikoronapaket, Sept 25 2020
GOV.SI – Government communication office, (2020b) Prvi paket ukrepov za omilitev posledic epidemije. Accessible at https://web.archive.org/web/20200921165015/https://www.gov.si/teme/koronavirus-sars-cov-2/vladni-ukrepi/prvi-paket-ukrepov-za-omilitev-posledic-epidemije, Sept 25, 2020
GOV.SI – Government communication office, (2020c) Vlada Republike Slovenije sprejela #PKP2: Predlog zakona o interventnem ukrepu zagotovitve dodatne likvidnosti gospodarstvu za omilitev posledic epidemije COVID-19. Accessible at https://www.gov.si/novice/vlada-republike-slovenije-sprejela-pkp2-predlog-zakona-o-interventnem-ukrepu-zagotovitve-dodatne-likvidnosti-gospodarstvu-za-omilitev-posledic-epidemije-covid-19, Sept 25, 2020
GOV.SI – Government communication office, (2020d) Vlada potrdila tretji protikoronski paket. Accessible at https://www.gov.si/novice/2020-05-20-vlada-potrdila-tretji-protikoronski-paket, Sept 25, 2020
GOV.SI – Government communication office, (2020e), Vlada sprejela PKP4. Accessible at https://www.gov.si/novice/2020-06-28-vlada-sprejela-pkp4, Sept 25, 2020

GOV.SI – Government communication office, (2020f) 5. sveženj protikoronskih ukrepov osredotočen na trg dela ter področje zdravstva. Accessible at https://www.gov.si/novice/2020-09-24-5-svezenj-protikoronskih-ukrepov-osredotocen-na-trg-dela-ter-podrocje-zdravstva, Sept 25, 2020
GOV.SI – Government communication office, (2020g) Šesti paket ukrepov za omilitev posledic epidemije (#PKP6). Accessible at https://web.archive.org/web/20201121015607/https://www.gov.si/teme/koronavirus-sars-cov-2/odpravljanje-posledic-epidemije/sesti-paket-ukrepov-za-omilitev-posledic-epidemije-pkp6, Nov 12, 2020
GOV.SI – Government communication office, (2020h) Sedmi paket ukrepov za omilitev posledic epidemije (#PKP7). Accessible at https://web.archive.org/web/20201229102325/https://www.gov.si/teme/koronavirus-sars-cov-2/odpravljanje-posledic-epidemije/sedmi-paket-ukrepov-za-omilitev-posledic-epidemije-pkp7, Dec 29, 2020.
GOV.SI – Government communication office, (2021) Osmi paket ukrepov za omilitev posledic epidemije (#PKP8). Accessible at https://web.archive.org/web/20211211115200/https://www.gov.si/teme/koronavirus-sars-cov-2/odpravljanje-posledic-epidemije/osmi-paket-ukrepov-za-omilitev-posledic-epidemije-pkp8, Feb 5, 2021
GZS – Chamber of commerce and industry of Slovenia (2021a) Pregled aktualnih ukrepov za omilitev posledic epidemije #PKP9. Accessible at https://www.gzs.si/zbornica_racunovodskih_servisov/vsebina/Za-%C4%8Dlane/Podpora-pri-poslovanju/Koronavirus/Aktualni-ukrepi-za-omilitev-posledic-epidemije-PKP9, July 20, 2021
GZS – Chamber of commerce and industry of Slovenia (2021b), Pregled aktualnih ukrepov za omilitev posledic epidemije #PKP10. Accessible at https://www.gzs.si/zbornica_racunovodskih_servisov/vsebina/Za-%C4%8Dlane/Podpora-pri-poslovanju/Koronavirus/Aktualni-ukrepi-za-omilitev-posledic-epidemije-PKP10, Jan 10, 2022
ILO (2021) COVID-19 and the world of work: country policy responses. Accessible at https://www.ilo.org/global/topics/coronavirus/regional-country/countryresponses, Jan 10, 2021
IMAD (2019) Institute of macroeconomic analysis and development, republic of Slovenia, Autumn forecast of economic trends 2019. Ljubljana, Sept 2019 https://www.umar.gov.si/fileadmin/user_upload/napovedi/jesen/2019/Angleska/aJNGG_2019 -v_objavo.pdf
IMAD (2020) Autumn forecast of economic trends 2020. Ljubljana, September 2020. https://www.umar.gov.si/fileadmin/user_upload/napovedi/jesen/2020/angleski/Autumn_foreca st_2020.pdf
IMAD (2021a) Autumn forecast of economic trends 2021. Ljubljana, Sept 2021. https://www.umar.gov.si/fileadmin/user_upload/napovedi/jesen/2021/angleski/JNGG_2021
IMF (2008) World economic outlook, Oct 2008, Chapter 5, Washington, DC
IMF (2022) World economic outlook, October 2022, Washington, DC
Leskovar M, Cizelj L (2022) Robust and intuitive model for COVID-19 epidemic in Slovenia. Stroj Vestn J Mech Eng 68:213–224
Lucas R (1976) Econometric policy evaluation: a critique. In: Brunner K, Meltzer A (eds) The Phillips curve and labor markets, Carnegie-rochester conference series on public policy 1. Elsevier, New York, pp 19–46
Ludvigson SC, Ma S, Ng S (2020) COVID-19 and the macroeconomic effects of costly disasters. NBER working paper no. 26987
Mathieu E, Roser M (2021) How do death rates from COVID-19 differ between people who are vaccinated and those who are not? Our world in data. https://ourworldindata.org/coviddeaths-by-vaccination
McKibbin WJ, Fernando R (2020) The global macroeconomic impacts of COVID-19: seven scenarios. CAMA working paper 19/2020
Milani F (2021) COVID-19 outbreak, social response, and early economic effects: a global VAR analysis of cross-country interdependencies. J Popul Econ 34:223–252
Murko, E. (2021), Tax and fiscal policy measures in Slovenia in response to the COVID-19 pandemic. In: Aristovnik, A., Ravšelj, D., Tomaževič, N. (eds.), *Tax and fiscal policy measures in digital transformation era during COVID-19 pandemic: International experiences*, European Liberal Forum EUPF & Zavod 14, Brussels, 194–219
Neck R, Weyerstrass K, Blueschke D, Majcen B, Srakar A, Verbič M (2018) How to achieve the take-off into sustained growth? A case study for Slovenia. Int Adv Econ Res 24:109–121
Neck R, Weyerstrass K, Blueschke D, Verbič M (2021) Demand-side or supply-side stabilisation policies in a small Euro Area economy: a case study for Slovenia. Empirica 48:593–610
Pichler A, Farmer JD (2021) Simultaneous supply and demand constraints in input–output networks: the case of COVID-19 in Germany, Italy, and Spain. Econ Syst Res 34(3):273–293

STA – Slovenian press agency (2020), Vrednost protikoronskih ukrepov proti sedmim milijardam evrov. Accessible at https://www.sta.si/2818612/vrednost-protikoronskih-ukrepov-proti-sedmim-milijardam-evrov, October 13, 2020

STA – Slovenian press agency (2021), Gospodarstvu letos za 660 milijonov evrov razvojnih spodbud. Accessible at https://www.sta.si/2853590/gospodarstvu-letos-za-660-milijonov-evrov-razvojnih-spodbud, January 11, 2021

Sargan JD (1964) Wages and prices in the United Kingdom. A study in econometric methodology. In: Hart PE, Mills G, Whitaker JK (eds) Econometric analysis for national economic planning. Butterworth, London, pp 25–59

Slovenian chamber of commerce (2021). COVID-19: uporabne informacije in povezave. https://www.gzs.si/zbornica_komunalnega_gospodarstva/vsebina/Covid-19/Uporabnepovezave, Jan 10, 2021

Štebe J, Vovk T (2021) Gender inequality on display in the flexibilization of employment during the COVID-19 crisis in Slovenia. Teorija Praksa 58:576–597

Wallenius H (1982) Optimizing macroeconomic policy: a review of approaches and applications. Eur J Oper Res 10:221–228

Weyerstrass K (2011) SLOPOL, a macroeconometric model of the Slovenian economy. IB Revija XLV 1–2:57–66

Weyerstrass K, Neck R, Blueschke D, Majcen B, Srakar A, Verbič M (2018) SLOPOL10: a macroeconometric model for Slovenia. Econ Bus Rev 20(2):269–302

Weyerstrass K, Neck R, Blueschke D, Majcen B, Srakar A, Verbič M (2020) Stabilisation policies in a small Euro Area economy: taxes or expenditures? A case study for Slovenia. Int J Comput Econ Economet 10(4):309–327

Weyerstrass K (2021) Fiscal policies during the COVID-19 crisis in Austria-A macroeconomic assessment (No. 32). ifo Institute-Leibniz Institute for Economic Research at theUniversity of Munich. https://www.econpol.eu/sites/default/files/2021-11/EconPol-PR32_Fiscal-Policies_0.pdf