ICAE Working Paper Series - No. 133 - November 2021

Is a 10 trillion euro European climate investment initiative fiscally sustainable?

Jakob Kapeller, Stuart Leitch and Rafael Wildauer

JOHANNES KEPLER UNIVERSITÄT LINZ

ICAE
INSTITUTE FOR COMPREHENSIVE ANALYSIS OF THE ECONOMY

Institute for Comprehensive Analysis of the Economy
Johannes Kepler University Linz
Altenbergerstraße 69, 4040 Linz
icae@jku.at
www.jku.at/icae

Is a €10 trillion European climate investment initiative fiscally sustainable?

Jakob Kapeller (University Duisburg-Essen and Johannes Kepler University Linz)

Stuart Leitch (University of Greenwich)

Rafael Wildauer[1] (University of Greenwich)

This version: November 2021

Abstract

This policy study asks to what extent large-scale public investment efforts could be a viable tool to provide the necessary infrastructure to break Europe's dependency on fossil fuel and carbon emissions more broadly. We estimate semi-structural VAR models for the EU27. These are used to study the impact of permanent as well as 5-year long public investment programmes. Three key findings emerge: First, government investment multipliers for the EU27 are large and range from 5.12 to 5.25. Second, debt-to-GDP ratios are likely to fall in response to the strong economic impulse generated by additional public investment spending. The study therefore classifies additional public investment spending in the EU27 as sustainable fiscal policy. Third, single country investment initiatives will likely lead to smaller economic expansions when compared to coordinated EU-wide investment, due to Europe's strong intra-member state trade flows. A coordinated approach to fiscal policy is thus substantially more effective not only when it comes to delivering network-dependent infrastructure (rail, grid) but also with respect to the economic stimulus it creates.

JEL Keywords: E62 Fiscal Policy; H63 Sovereign Debt

[1] Corresponding author.

1 Introduction

While investment in the future carries positive connotations, the narrative changes abruptly when the conversation shifts to public investment projects. The costs and the potentially associated increase in public debt are then emphasised, and the latter is framed as "a burden on future generations".[2] **This rather negative perception of public debt resulting from bold investment initiatives lies in stark contrast to the lack of green infrastructure needed for a credible transformation of Europe into a carbon-neutral society**. The last two decades have shown that private sector investment will not suffice to provide the necessary infrastructure – an upgraded and integrated grid, wind and solar electricity generation, efficient public transport as an alternative to cars and air travel, improved energy efficiency in the existing building stock, to name just a few key areas. While the European Commission acknowledges the need for public investment, and also provides some funding via the Next Generation EU recovery fund, nevertheless, **the scale of this funding remains well below what is realistically needed**. For example, the Recovery and Resilience Facility, which constitutes the heart of the Next Generation EU fund, amounts to €85 billion annually over a decade. In contrast, Wildauer et al (2020) estimate that to adhere to the Paris agreement credibly, the EU27 requires additional investment spending of €855 billion annually, excluding the transport sector. The European Commission estimates that upgrading the existing building stock to a net-zero standard would require additional investment of almost €500 billion annually (European Commission 2019). Nevertheless, in its recent proposals, the Commission is confident that the private sector will do the heavy lifting when it comes to (infrastructure) investment (European Commission 2021a). **The Commission's Fit for 55 proposals**, which provide the legal and regulatory basis for implementing the Green Deal, **focus heavily on providing the correct incentives and price signals via expanding and reforming the emissions trading system (ETS)** (European Commission 2021b). The assumption being that the new combination of incentives and pricing of externalities should bring private sector activity in line with a carbon neutral economy. Given the poor performance of this 'incentive approach' in the past and given that critical infrastructure like the energy grid or international high-speed rail network requires cross-border coordination unlikely to be achieved by individual private companies, the question arises as to **why the public sector is not actively pursuing this infrastructure investment** itself? With the world running out of time in its fight against climate change, as pointed out by the latest Intergovernmental Panel on Climate Change (IPCC) report, it is not clear why waiting for the private sector to respond to price signals is the best approach for tackling climate change. **A crisis situation requires serious consideration of all the available options. One of these is direct public sector**

[2] For example, by the former German finance minister Wolfgang Schäuble: "Europe's social peace requires a return to fiscal discipline", *Financial Times*, 2 June 2021.

provision, which would allow the EU and its member states to make the necessary investment quickly and at the ambitious scale required.

However, an ambitious public investment initiative to tackle the climate crisis is often perceived as incompatible with a 'prudent' or 'responsible' approach to macroeconomic policymaking, and most notably to fiscal policymaking, unless paired with substantial increases in government revenues. Yet while there is some potential for increasing taxes without jeopardising recovery from the Covid-19 pandemic (Kapeller et al 2021), delivering the required infrastructure without any debt-financed public investment spending seems unrealistic. **Against this background of the climate crisis and Europe's infrastructure needs, there is thus a need to reassess what constitutes 'responsible' fiscal policy**. Our policy study therefore sets out to estimate the long-term effects of a publicly funded investment initiative on the public finances of the EU27. In essence, our study connects investment in sustainable infrastructure with the sustainability of government debt. **Our policy study estimates the impact that a public investment initiative to shape the climate transition is likely to have on the overall economy and economic growth** and thereby also considers the second-round effects on government budgets and public debt. These effects are extremely important given that economic activity has a direct and immediate impact on public finances. Government revenues such as VAT or income tax vary with economic activity, as does government expenditure on areas such as unemployment support and training. Our approach allows us to estimate **the long-term impact of a public investment initiative on GDP and public debt levels given that these contribute to the assessment of the viability of such an initiative for the fight against climate change**. The remainder of our policy study is organised as follows. Section 2 provides a brief discussion of fiscal policy and how to judge its sustainability. Section 3 discusses Europe's green investment gap and how it can be measured. Section 4 describes the method and empirical approach. Section 5 presents the results, and Section 6 concludes.

2 Sustainable fiscal policy

While most economists agree that a fiscally sustainable government ought to avoid defaulting on its debt, judging whether public finances are in line with this aim is less straightforward. One reason is that there is some empirical uncertainty about how to value publicly owned assets (which makes it difficult to compare debt with gross wealth in the public sector) as well as about the determinants of long-term developments in public finances (which casts doubt on the simple extrapolation of current trends). Another reason is that the answer will also depend on the prevailing institutional characteristics and on the assumptions that we are willing to make regarding the exact functioning of these institutions. For instance, economists such as Kelton (2020) argue that governments which take on debt in their own currency and can rely on their central bank's support face no risk of bankruptcy whatsoever. However, given that the European Central Bank (ECB) is not mandated with preventing its members from defaulting, Kelton's argument does not directly apply to the eurozone in its current form. Acknowledging the possibility of default therefore, the question of what constitutes sustainable fiscal policy in Europe thus remains a matter of debate and of ongoing research among macroeconomists.

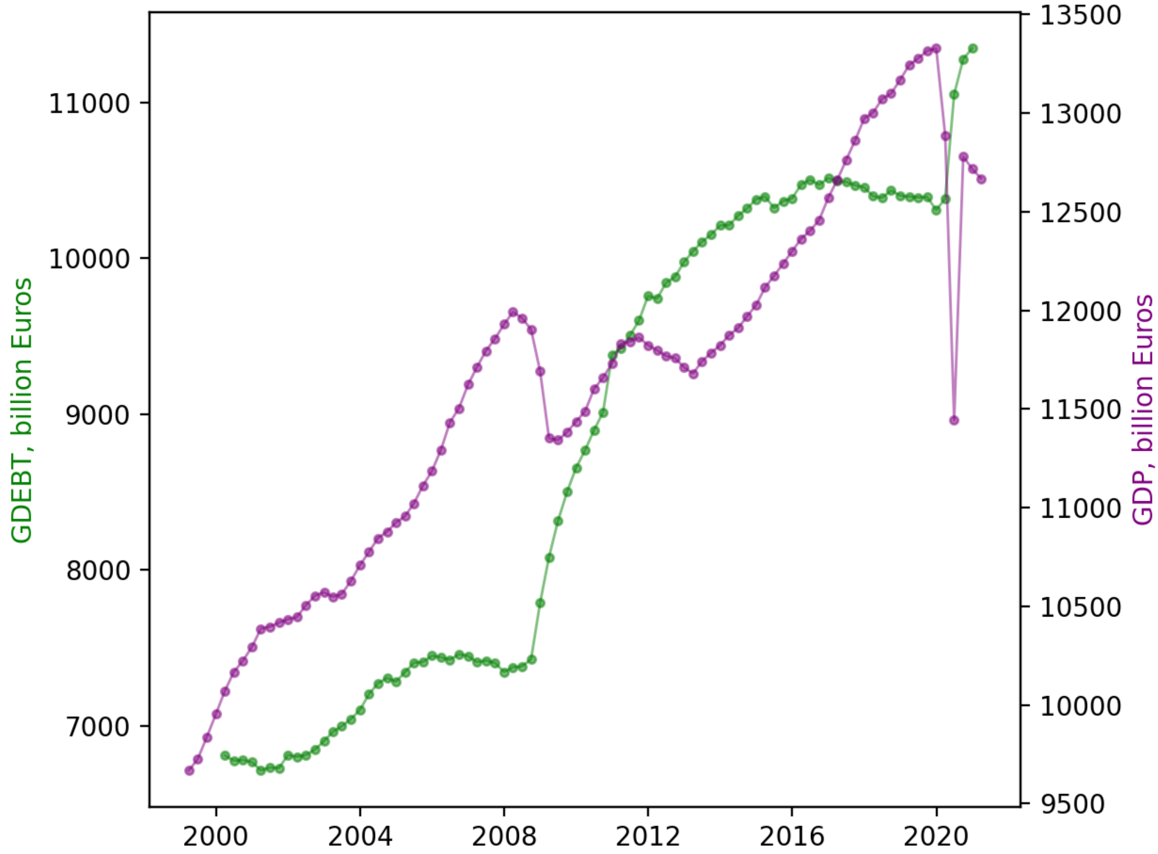
Figure 1 shows the evolution of real government debt and real GDP for the EU27 based on quarterly data from 2000 Q1 to 2020 Q4, both deflated with the GDP deflator. Two events characterise the evolution of the European economy over the past two decades: the financial crisis of 2008-09 and ensuing sovereign debt crisis; and the Covid crisis of 2020. In the former event, government liabilities started to climb strongly in the fourth quarter of 2008. Initially the increase was mainly due to the economic stimulus packages but as the financial crisis deepened, rescue packages for failing financial institutions and a slowing recovery due to over-eager fiscal consolidations drove public borrowing up further. More recently, the historically unprecedented size of the Covid recession and its related economic support measures have led to a sharp rise in public sector borrowing since the second quarter of 2020, when GDP collapsed due to the lockdowns imposed to contain the virus.

Based on Figure 1 alone, any judgement regarding the extent to which European governments pursued 'responsible' fiscal policy is impossible. Three standard approaches for evaluating fiscal policy are discussed in the macroeconomic literature (Ramey 2019). **First, fiscal sustainability can be evaluated by taking the total amount of outstanding government debt (per capita) as the basis**. The EU27's nominal government liabilities stood at €10.8 trillion in 2019 before rising to €12.1 trillion in 2020 in response to the Covid recession. These liabilities amount to a debt level of €24,200 and €27,000 per capita respectively.[3] However, numbers like these are not very informative by themselves. Focusing solely on government liabilities without considering public assets is thus the first shortcoming of this approach, as it only considers one part of the relevant balance sheet. Indeed, such an approach is effectively akin to asking whether a company with €100 million in outstanding liabilities is overly indebted. Without taking the asset side of the company's balance sheet into account, this is a rather meaningless question. In addition, government revenues out of which these debts are serviced are closely tied to the size of the economy, which may again depend on the size of the public sector. The interaction between the development of the public sector and overall economic development must

[3] Based on Eurostat data on general government gross consolidated debt (Eurostat table gov_10dd_edpt1) and population data (Eurostat table demo_pjan).

therefore be taken into account explicitly. Overall, absolute levels of (per capita) government debt do not provide a sound basis to judge fiscal sustainability.

Figure 1: Real government debt and real GDP in the EU27



Second, fiscal sustainability can be evaluated by invoking arbitrary thresholds, as in the case of the Maastricht criteria or Reinhart and Rogoff's (2010) once famous but now discredited (Herndon et al 2013) argument on how debt will stifle growth if it grows larger than 90% of current GDP. According to the Maastricht criteria, which are the cornerstone of the eurozone's fiscal framework, governments should aim to keep deficits below 3% of GDP and the debt-to-GDP level below 60%. However, there is hardly any robust empirical basis on which politicians can rely when choosing deficit or debt targets. Such targets are largely arbitrary, and adherence to them is very likely to act procyclically as well as to have the potential to worsen governments' financial positions if economic downturns are prolonged due to premature fiscal tightening (Truger 2013, Heimberger and Kapeller 2017). This implies that governments adhering to budgetary rules such as the Maastricht criteria cannot be considered a valid assessment of the fiscal responsibility of governments.

Third, fiscal sustainability can be evaluated by model-based assessments of fiscal policy. The simplest form is potentially the following law of motion for government debt:[4]

$$\Delta d_t = (e - t) + (i - g)d_t \tag{1}$$

where Δd_t is the change in the government debt-to-GDP ratio, $(e - t)$ is the difference between government primary expenditure and revenues in percent of GDP (primary budget balance), $(i - g)$ is the difference between the average nominal interest on government debt and the nominal growth rate of the economy, and d_t is the current debt-to-GDP ratio. The first important takeaway arising from this law of motion is that the debt-to-GDP ratio will depend not only on the government's decision on taxation and expenditure $(e - t)$ but also on how well the overall economy is doing and the interest rate a government has to pay on its liabilities $(i - g)$. Additionally, it matters how indebted the country already is (d_t). This means if the economy grows strongly (high g) and/or interest rates are very low, potentially at the zero lower bound, budget deficits might still be compatible with a stable or even declining debt-to-GDP ratio. However, this equation (1) ignores the impact of fiscal policy $(e - t)$ on the growth rate of the economy (g). This is often motivated by the assumption that economic growth in the long term is not driven by aggregate demand and thus fiscal policy has no impact on it. While this assumption is questionable in general, even limiting fiscal policy only to short- and medium-term effects makes this law of motion unsuitable to track the budgetary impact of spending decisions because it ignores an important interaction between spending (e), taxation (t), and successive growth (g). Equation (1) can thus at best serve as a crude long- run rule of thumb which ignores crucial short- and medium-term effects.

Given that there are problems associated with all three approaches, our policy study abandons the search for an optimal fiscal policy rule or target, and instead starts from the simple principle that public sector spending will result in one of three outcomes for the public debt-to-GDP ratio – it will either rise, fall or remain constant. **We regard a falling or unchanged debt ratio as sustainable conduct of fiscal policy**. However, assessing whether an increase in the debt-to-GDP ratio is sustainable is different from asking whether it is desirable, as desirability requires a careful consideration of the benefits and costs. A debt ratio that fares worse in terms of sustainability may still be desirable if it leads to a substantial reduction in carbon emissions. Making this judgement call is ultimately a political and not an economic question.

The response of the public debt-to-GDP ratio to public (investment) spending can be understood as the effect that each euro of public investment has on both public debt and GDP (multiplier) over the period in question. As most theoretical approaches have difficulty in tracking this independently, we

[4] A derivation of Equation (1) can be found in the technical appendix.

resort in this policy study to an empirical approach that looks at the net effects of additional public investment, as discernible from past data. **Ultimately, estimating the impact of government investment spending on the economy and on public finances comes down to a careful estimate of fiscal multipliers**. Although fiscal multiplier research began to fall out of favour amongst most economists since the 1970s, research on fiscal policy in general, and fiscal multipliers in particular, has seen renewed interest since the onset of the 2007-2009 global financial crisis and ensuing European debt crisis. Since the focus of this policy study is on statistical estimation, in contrast to the simulation of theoretical models, we present a brief summary of the empirical literature on fiscal multipliers.

Gechert (2015) provides a meta-regression analysis of 104 fiscal multiplier studies and surveys a wide variety of empirical and theoretical model classes. However, in what follows we only consider the surveyed results from the statistically estimated models. Gechert's key findings are: i) different techniques used for estimating, modelling or simulating a given fiscal policy may yield highly contrasting results; ii) public investment multipliers have the largest impulse out of all the fiscal policies surveyed, with the average investment-GDP multiplier between 1.4 and 2.1 for empirical studies; (iii) international trading relationships affect the multiplier: regions with higher import shares have lower public expenditure multipliers; and (iv) general public expenditure multipliers are higher than those obtained from tax cuts and increasing transfers.[5] Hebous and Zimmermann (2013) for their part estimate the effects of coordinated fiscal actions across the eurozone in contrast with actions of equal magnitude taken by individual member states. Their research finds that coordinated actions have a greater impact in comparison to member states acting in isolation – which is well in line with the overall observation that multipliers depend on import propensities.

In summary, the magnitude of a given public investment multiplier depends on a variety of factors such as openness to trade, the proximity of the central bank policy rate to the zero lower bound, the extent to which fiscal policy action is coordinated multilaterally between neighbouring states, the phase of the business and asset price cycles, the level of public indebtedness and perceived creditworthiness, and the interaction of these variables. Auerbach and Gorodnichenko (2017) find that increased government spending does not necessarily lead to worsening public debt ratios or increased financing costs for developed countries even when initial debt ratios are high. Moreover, they report that increases in public spending may serve to improve fiscal sustainability during times

[5] In addition, Auerbach et al (2012) find that public expenditure multipliers are stronger during recessions than in economic expansions. The authors estimate public investment multipliers of 2.27 (expansion), 3.42 (recession), and 2.39 (combined) for the USA (1947 Q1-2008 Q4).

of sluggish growth. However, they also acknowledge that there are limits to borrowing and that not all countries are endowed with the same degree of latitude by creditors.

3 Green investment gap and data

The European Union currently lacks the infrastructure required to reduce its greenhouse gas emissions quickly and substantially and to reach the goal of limiting global warming this century to well below 2°C compared to pre-industrial levels. This lack of infrastructure can be seen in an energy grid which is not capable of transferring excess wind and solar energy created in some parts of the European Union to other parts which need additional reserves (Grams et al 2017). More fundamentally, the EU27 lacks wind and solar power generating capacity (Cherp et al 2021). In addition, other areas which require major investment are public transport alternatives to air travel, as well as a reduction of the carbon footprint of buildings (European Commission 2019). Overall, the European Commission itself estimates that additional investment expenditure of €350 billion annually (European Commission 2021a) is needed to tackle climate change. Wildauer et al (2020) estimate that the Commission's assessment is most likely a grave underestimation of the true investment requirements. The Commissions own research shows that making Europe's buildings energy efficient by 2050 will involve a threefold increase in current insulation and heat pump installation efforts, requiring an estimated €490 billion annually (European Commission 2019). Currently the electricity sector[6] renews and replaces about 4% of its gross capital stock annually. Increasing this rate to 9% a year, and thus more than doubling current efforts in order to establish a sustainable electricity infrastructure, will require additional investment expenditure of €84 billion annually (Wildauer et al 2020: 25). The investment requirements of the industrial sector[7] are extremely difficult to assess but simply increasing the investment rate by three percentage points of the existing capital stock from the current 8% would require additional annual investments of €80 billion (ibid). Furthermore, since many zero carbon technologies do not exist yet or are not yet ready for large-scale application, a substantial increase in research and development (R&D) expenditure is most likely needed. The Europe 2020 Strategy,[8] announced in 2010, included a goal to spend 3% of GDP on research and development as part of the EU's long-term economic strategy. However, the EU has failed to achieve this. Reaching this 3% R&D goal would require an increase in spending of €75 billion annually, while increasing the goal to 4% would require €201 billion in additional research spending each year (ibid). **Taken together**

[6] Sector D in NACE Rev. 2.
[7] Sector B and C in NACE Rev. 2.
[8] European Commission (2010).

this amounts to additional investment expenditure of €855 billion per year – and it does not include the transport sector.[9]

Table 1: Gross fixed capital formation data

Breakdown	Subclasses	Availability
by sector	S11 Non-financial corporations S12 Financial corporations S13 General government S14 Households S15 Non-profit institutions serving households S2 Rest of the world	annually [nasa_10_nf_tr] quarterly [nasq_10_nf_tr]
by asset (AN.11 produced non-financial fixed assets)	AN.111 Dwellings AN.112 Other buildings and structures AN.113 Machinery and equipment AN.114 Weapons systems AN.115 Cultivated biological resources AN.116 Costs of ownership transfer on non-produced assets AN.117 Intellectual property products	annually [nama_10_an6] quarterly [namq_10_an6]
by industry (classification of economic activity, NACE Rev. 2)	A Agriculture, forestry and fishing B Mining and quarrying C Manufacturing D Electricity, gas, steam and air conditioning supply etc.	annually [nama_10_a64_p5]
by industry by asset	Cross tabulation for industry by asset cells	annually [nama_10_nfa_fl]

The most comprehensive source of data on investment spending in an economy (gross fixed capital formation, GFCF) is the national accounts. In the case of the European Union, these are compiled by the national statistical agencies and distributed by Eurostat. There are at least three dimensions along which GFCF data can be disaggregated – by sector, by assets and by industry. Disaggregation by sector sheds light on **who incurred the investment expenditure** and allows a distinction between the public sector, firms, households, and entities in other countries (see Table 1). Disaggregation by industry provides a different angle on the same question and sheds light on the industry which undertook the investment project. Industry classifications are based on the EU's Statistical Classification of Economic Activities in the European Community (NACE), which distinguishes between activities according to a rough categorisation of the final products produced by different industries (Table 1). This

[9] See Wildauer et al (2020) for details, Table 8 for an overview.

categorisation is typically available for different levels of granularity. Thirdly, disaggregation by asset sheds light on **what kind of investment project was undertaken** and distinguishes between investment in categories such as dwellings (residential buildings), other buildings and structures (offices, government buildings, schools and bridges, railways etc) and machinery and equipment (see Table 1). Cross tabulations, where GFCF data is disaggregated along the lines of two or more of the above categories at the same time, are only available on an annual basis and only for an industry-asset breakdown.

Against this background it becomes clear that **the direct identification of green public investment in national accounts data is difficult because of the lack of a quarterly cross tabulation of GFCF data by sector and by industry**. Cross tabulation by industry would ideally be down to NACE level 3 precision. Moreover, some information on the more specific purpose of the investment (eg, whether construction expenditure is for the expansion or insulation of existing buildings) is not collected in national accounts. It cannot therefore be determined from the quarterly data whether a given amount of public investment has been spent on installing wind turbines, building a coal power plant, or on some other combination. **We are thus forced to assume that one euro of government investment in green infrastructure will have the same economic impact as one euro of government investment of the average type prevailing over the last two decades**. Obviously investing in wind vs investing in coal would have a fundamentally different impact on Europe's ability to meet its climate targets. However, since our policy report is dedicated to exploring the impact of green infrastructure investment on economic activity and public finances and not emissions, we consider that this assumption (of one euro spent on green infrastructure having the same impact as one euro of government investment of the average type over the last two decades) is a meaningful way to overcome the existing data limitations. Indeed, it should be noted that other recent contributions in the literature are forced to adopt very similar assumptions. The Organisation for Economic Cooperation and Development (OECD) for example published an extensive report in 2017 about public investment in the context of the climate transition (OECD 2017). The two models the OECD used for its predictions (YODA and GEM) were simply based on general public investment without any distinction between green and other infrastructure (YODA). The GEM model distinguishes between investment in different sectors, especially in the oil and gas sector – but is unable to distinguish between public and private actors. Despite the discussed shortcomings, the national accounts data we use in this policy study provide a fully representative picture not only of the overall economy but also of the government sector. This is a clear advantage compared to non-representative data (eg, from industry bodies or non-representative surveys). **The national accounts data therefore allow us to draw conclusions about**

government investment spending that are representative at the EU and national member state level, and that can thus inform policymaking decisions.

4 Estimating fiscal multipliers

In order to quantify the long-run effects of government investment on the economy and public finances we estimate semi-structural vector autoregressions (VARs) of the following form:

$$B_0 y_t = m_0 + m_1 t + \sum_{i=1}^{s} m_{2,i} S_i + B_1 y_{t-1} + \cdots + B_p y_{t-p} + \omega_t \tag{1}$$

where for Model A, y_t is a vector consisting of real government investment spending (GINV) and real gross domestic product (GDP), both measured in billion euros. For Model B we also add the real stock of government debt (GDEBT) to the system. Similar models are widely used in the literature to model the effects of monetary policy (Bernanke and Blinder 1992; Christiano et al 1996; ibid 2005; Uhlig 2005) and oil price shocks (Edelstein and Kilian 2009). A detailed description of the data and the methodological approach of our study can be found in the technical appendix. Most importantly, **the crucial assumption of our analysis is that government investment spending takes more than one quarter to be implemented and thus within a quarter there is no feedback from the other variables in the system (GDP and GDEBT) on public investment**. Given that large-scale investment projects do not only involve a substantial planning effort but often also require additional legislation, this is a standard assumption in the empirical literature on fiscal multipliers and has been widely used since being popularised by Blanchard and Perotti (2002). It is especially suitable for identifying exogenous movements in government investment spending. **The second crucial assumption we make is that the financial crisis and the euro crisis were disruptions of historic proportions which cannot be sufficiently explained by normal business cycle fluctuations**. Since the focus of our policy study is on the conduct of fiscal policy and not on the question of how financial crises and bubbles form, we have modelled these events as exogenous. To do this, we used the so-called step-indicator approach of Castle et al (2015). Full details of this can be found in the technical appendix.

Within this framework we start out in Section 5.1 by estimating the effects on GDP and public debt of a permanent increase in government investment spending. To do this we use so-called orthogonalised **cumulative impulse response functions (CIRFs)** and **long-run multipliers (LRMs).**[10] CIRFs allow us to quantify the response of GDP, public debt and government investment to an increase in government investment. LRMs go one step further and allow us to judge how strong the response of GDP is in relation to the investment impulse by calculating the ratio of the cumulative deviation of GDP from

[10] Also called cumulative multipliers.

the baseline trajectory relative to the additional public investment spending due to the assumed permanent increase in government spending. In Section 5.2 we address the slightly different question of the effect on GDP and public debt, if government investment increases by a certain amount for a given period, instead of permanently. We use what we call orthogonalised **semi-permanent impulse response functions (SPIRFs)** to provide an answer to this question.[11] SPIRFs allow us to track the adjustment of the economy to a sustained increase in government spending which lasts for a given period (eg, five years) and then falls back to the baseline trajectory. Finally, in Section 5.3, we use our model and our dataset to quantify the difference between a **coordinated and an uncoordinated approach to public investment**. Since we observe our time series of public investment, GDP and public debt at the aggregate level for the EU27 as well as at the individual country level, we can re-estimate our model separately for each EU member country. The LRMs from these individual country models are based on variations in fiscal policy of that country only. By contrast, the LRMs from the EU27 model are based on variations in fiscal policy across all member countries. Comparing the differences between these two sets of results provides insights into the difference between coordinated and uncoordinated fiscal policy and thereby answers the question of whether and to what extent organising a joint effort among the EU27 will make a difference in terms of achievable outcomes.

5 The long-term effects of a European investment initiative

This section provides **estimates of the long-term effects of exogenous changes in government investment spending**. Such exogenous changes are called shocks in the scientific literature on fiscal policy. Specifically, we are interested in the effects of an exogenous investment shock on economic growth, the government budget, and the level of government debt. An **exogenous investment shock** in this context means that we are looking at the effects of changes in government investment spending which cannot be explained by the past and current trajectory of the economy (GDP), government debt (GDEBT) or government investment (GINV) itself. **We therefore interpret these shocks as active decisions by policymakers to increase or reduce government investment spending**. A detailed methodological discussion on this can be found in the technical appendix.

5.1 Permanent or long-run effects of government investment

Our analysis starts with **a scenario in which a government implements an initial increase in public investment spending of €100 billion above its baseline trajectory**. The baseline trajectory is the trajectory of the economy without an exogenous increase in public investment. We are interested in **the effect of this initial €100 billion investment on output and government finances**. The two vector

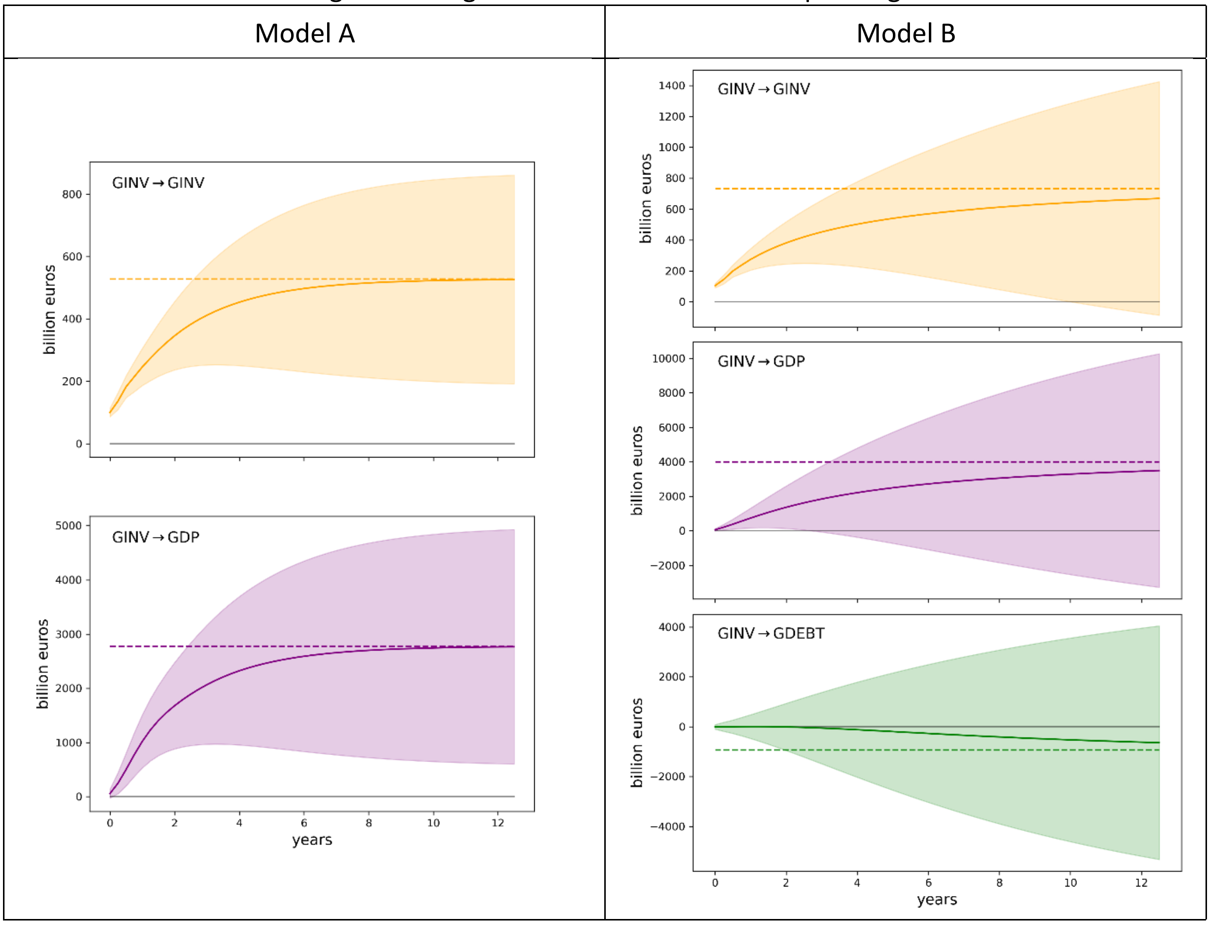
[11] We define SPIRFs in the appendix. They consist of CIRFs up to year five and then we trace the adjustment back to the baseline after year five, which is when the exogenous investment impulse recedes.

autoregressive (VAR) models we use for the EU27 allow us to see this effect in the form of orthogonalised **cumulative impulse response functions (CIRFs)**, shown in Figure 2. Starting with Model A (left-hand column of Figure 2), an initial increase in government investment (GINV, yellow graph, upper left of Figure 2) of €100 billion beyond the baseline leads to a slow increase in investment spending, which reaches €526 billion 12 years after the initial impulse. The reason for this gradual increase in investment spending beyond the initial €100 billion is that, as stated earlier, investment projects take time to implement and most public investment projects are not finished within one quarter. The long-run effect of €526 billion (dashed line) represents the total increase in investment spending over 12 years. **That means based on Model A, roughly 20% of an investment project is therefore spent in the first quarter and the remaining 80% is spent over the next decade**.[12] To provide some context, public investment spending across the EU27 amounted to €404 billion in 2019.[13] The scenario analysed with Model A thus represents an initial boost of 25% of public investment spending, which grows into more than double (+ 132%) the EU27 public investment spending beyond the baseline trajectory ten years after the initial impulse. The lower left graph in Figure 2 shows the response of GDP to such a public investment impulse. As investment spending increases gradually over time, so does GDP. While the immediate impact is quite small (€57 billion above baseline on impact), the economy expands strongly until GDP reaches an expansion of €2,763 billion (long-run effect, dashed line) beyond the baseline trajectory 12 years after the initial investment impulse.

Model A therefore predicts a strong economic expansion triggered by additional public investment spending. Both the investment responses and those of GDP are statistically significant at the 10% level since the confidence band, represented by the shaded area, does not include the zero line. While Model A does not explicitly take the government budget into account, the **strong expansion of GDP suggests that increasing public investment does not lead to any medium- or long-term problems for public finances. On the contrary, the stronger economic activity is likely to reduce public costs (unemployment payments, furlough schemes) and increase tax and other government revenues**.

[12] €100 billion is roughly 20% of €526 billion.
[13] Based on seasonally adjusted data.

Figure 2: Long-run effects of investment spending



Solid lines represent CIRFS to a €100 billion increase in GINV in year 0. Dashed lines represent the long-run effect, and shaded areas represent 90% confidence intervals. Responses are depicted as deviations from the baseline trajectories.

While the results discussed thus far already provide an idea of the relative size of the investment impulse and the expansion of the economy, it is nevertheless also useful to compare the volume of additional output to the volume of investment spending that leads to this output expansion. A systematic way of carrying out such a comparison is to compute **long-run multipliers (LRMs)** by dividing the increase in GDP x years after the initial investment impulse by the increase in investment x years after the initial increase. These long-run multipliers are reported in Table 2. On impact, which is the quarter in which government investment starts to increase, the multiplier is about 0.56 in both models, which means that in the first quarter additional government investment of one euro would lead to an increase in GDP of €0.56. After one year the multiplier is 4.15 and 2.7 respectively and after ten years, the multiplier is 5.25 in Model A and 5.12 in Model B. **Ten years after increasing government investment permanently, each additional euro spent on government investment therefore leads to an increase in GDP of €5.25 and €5.12 respectively**.

Table 2: Long-run multipliers (LRMs)

Horizon	Model A	Model B
Impact	0.57	0.56
1 year	4.15	2.70
5 years	5.18	4.62
10 years	5.25	5.12

LRMs are calculated as the ratio of the GDP deviation x years after the investment impulse, relative to the GINV deviation x years after the impulse.

These multipliers are just another way of looking at the results presented in Figure *2* and they emphasise how powerful public investment can be in stimulating the economy. These large effects warrant three comments. Firstly, the results are highly robust across both models. Meaningful differences only occur in the short term, specifically in the first year of the shock. Secondly, these multiplier estimates are well in line with previous results in the empirical and theoretical literature. Baxter and King (1993), for example, show that investment multipliers can be as high as seven in a theoretical model, and Leduc and Wilson (2012) report peak multipliers of eight for the USA. Benetrix and Lane (2009) find investment multipliers between 2.3 and 3.7 in a panel of 11 European countries, which is the same range reported by Auerbach and Gorodnichenko (2012) for the USA. Thirdly, the fact that we obtain large GDP multipliers explains why public debt does not increase in response to higher public spending. As pointed out previously, a large economic expansion in response to additional government investment will reduce government expenditure and increase revenues. A large economic expansion will thus improve public finances compared with a baseline scenario without additional government spending.

5.2 A five-year green investment initiative

The pressing political question at hand is not so much about the effects of a permanent increase in government spending, but rather about the effects of a sustained investment initiative which is focused on delivering transformative infrastructure for a prolonged period. This section of our policy study therefore estimates the effects of a sustained five-year public investment initiative using orthogonalised **semi-permanent impulse response functions (SPIRFs)**.[14] Figure 3 displays the SPIRFs for GDP, government investment (GINV) and the budget balance based on Model A. **We have scaled the investment impulse so that over the entire 12-year period of Figure 3, investment of €10 trillion (€10,406 billion) beyond the baseline is undertaken. This corresponds to €800 billion annually over 12 years**. This latter amount represents roughly the additional investment requirement for a green transition estimated in earlier work (Wildauer et al 2020). The yellow line in Figure 3 represents the

[14] A precise definition can be found in the technical appendix.

investment SPIRF. The line increases gradually because implementing investment projects takes time, and the associated expenses occur over several years. The same mechanism explains why investment spending does not immediately drop back to the baseline (the zero line) after five years. In other words, while no new projects are started after five years, the existing ones take time to be completed and require outlay over the following years. From year five onwards we therefore see a gradual decline in investment spending above the baseline trajectory. Over the entire 12-year period, public investment (GINV) increases by €10,406 billion above the baseline trajectory, with €6,958 billion of this occurring over the first five years.

The purple line in Figure 3 depicts the GDP response to such a semi-permanent increase in public investment. The economy expands strongly over the first five years, before then returning gradually to the baseline trajectory. Over the entire 12-year period, additional output of €54,625 billion is realised due to the investment stimulus. This healthy expansion is logical given that in the previous section we saw Model A implying a long-run multiplier of more than five. While Model A, on which Figure 3 is based, does not include government debt or government finances directly, **we have calculated an implied budget balance by assuming that government revenues are constant at 30% of GDP and by assuming that government expenditure other than public investment remains unaffected** (which means ignoring positive second-round effects due to lower social security spending in an economic boom). The change in the budget balance, depicted as a green line in Figure 3, is then obtained as revenues (30% of the GDP trajectory) minus expenditure (the cost of public investment spending). This is expressed in Equation (2).

$$Budget\ Balance_t^{Figure\ 3} = 0.3 \cdot\ GDP_t - GINV_t \qquad (2)$$

In Figure 3 we see that the budget balance improves strongly. At its peak after five years it implies a reduction in the stock of government debt by €2,982 billion. After 12 years this amount grows to €5,956 billion. **This means that a sustained public investment initiative has the potential to decrease the stock of public debt due to the strong economic expansion that the investment triggers**. The additional revenues due to the economic boom outweigh the costs, and the budget balance improves compared with a baseline scenario in which no additional investment spending occurs. Within the first five years the investment impulse generates additional government revenues which are 1.4 times the volume of the additional investment spending. After 12 years this increases to 1.6 times the investment impulse. Within the framework of Model A, which assumes that government revenues are a fixed rate of 30% of GDP, we obtain the result that a sustained government investment initiative would not only have a strong growth effect but would also lead to falling government debt in the long run. **According to our criterion from Section 2, a sustained five-year public investment initiative would lead to falling debt-to-GDP ratios and would therefore constitute responsible fiscal policy**.

Figure 3: Semi-permanent IRF model A

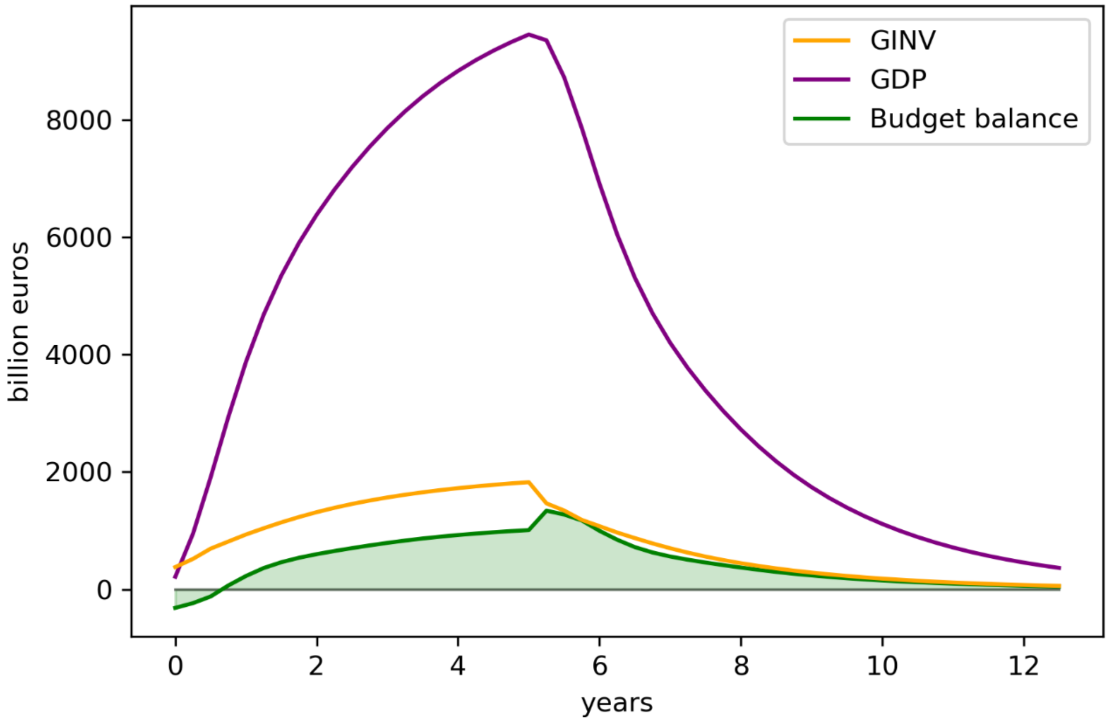
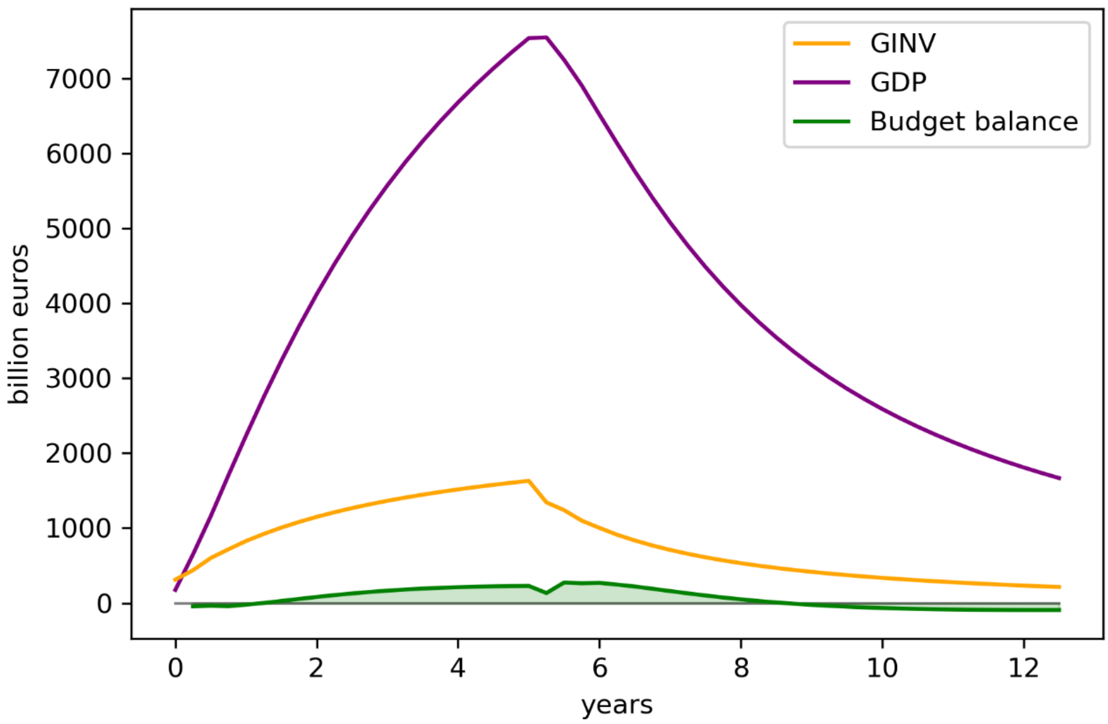


Figure 4 shows the orthogonalised **semi-permanent impulse response functions (SPIRFs)** for the EU27 economy to a sustained five-year public investment impulse based on Model B, which directly incorporates the stock of government debt. For ease of comparability, we have transformed the response of the stock of debt into the budget balance by simply looking at the negative change of the debt stock as expressed in Equation (3). In this way an increase in the stock of debt shows up as a negative budget balance (deficit) and a decrease in the stock of debt is depicted as a positive budget balance (surplus).

$$Budget\ Balance_t^{Figure\ 4} = GDEBT_{t-1} - GDEBT_t \quad (3)$$

As in Figure 3, we have rescaled the five-year investment impulse in Figure 4 so that additional government investment of €10 trillion is undertaken over the entire period. On average, this amounts to €800 billion annually. As was the case with Model A, we obtain a sizeable economic expansion in response to the additional government investment spending from the SPIRF of Model B. This result is logical, given the large multipliers we have found for both models (Table 2). The key difference between Model A and Model B is that in the latter the implied budgetary effects are much smaller. This is in line with the fact that the long-run cumulative IRFs for the government debt stock for Model B are not statistically different from zero. On the basis of Model B, we should thus expect a minor improvement in government finances over the entire period of Figure 4 in response to the expansion of public investment spending. After 12 years, government liabilities would be €890 billion lower compared with a situation in which there is no additional government investment spending. **This means that, like Model A, Model B predicts sharply falling debt-to-GDP ratios in response to a five-year public investment initiative, allowing us to label the investment initiative clearly as fiscally sustainable and thus as sustainable fiscal policy, according to our simple criterion of stable or falling debt ratios for sustainable fiscal policy.**

Figure 4: Semi-permanent IRF model B



5.3 Coordinated vs uncoordinated fiscal efforts

In Sections 5.1 and 5.2 we estimated Models A and B with aggregate data for the EU27. An extremely relevant policy issue in the European context is to **understand the potential benefits of coordinated fiscal action compared with isolated or uncoordinated initiatives**. The European Union and the eurozone represent a highly integrated economy with large cross-border trade flows. While this makes the European Union similar to large and highly integrated (nation) states like the USA, the key institutional difference is that fiscal policy is mainly carried out at the federal level in the USA but at the state level in the EU. An EU-wide fiscal impulse of the order of magnitude discussed above, requires substantial political coordination between member states. In order to help achieve such coordination a clear understanding is needed of the benefits of coordinated action and the costs of coordination failures.

In Table 3 we compare the long-run multipliers from Model A for the EU27 with averaged long-run multipliers obtained from estimating Model A for each of the 27 member countries. Column (1) in Table 3 reproduces the long-run multiplier for the EU27 from Section 5.1, which we will interpret as a measure of coordinated fiscal policy since it is estimated from variations in government investment spending across the EU27. Column (2) of Table 3 contains a GDP-weighted average over 20 EU country-specific long-run multipliers that we obtained from the single country models.[15] We interpret these as a measure of the effectiveness of uncoordinated fiscal policy since they are obtained from variations in individual country investment spending only. The averaging of the individual country results allows us to condense the 20 country-specific multipliers into a single number which we can readily compare with the coordinated fiscal policy baseline in column (1). Lastly, column (3) of Table 3 contains a long-run multiplier which is obtained by aggregating the GDP and investment responses across all 20 countries before calculating the multiplier as the ratio of the two. Full details of this can be found in the technical appendix. We also interpret this as a measure of the effectiveness of uncoordinated fiscal policy since the individual country results are based on country-specific investment variations. Column (2) and column (3) therefore simply represent different ways of summarising the results for 20 individual countries in a single multiplier, which we can compare with the coordinated fiscal policy case based on aggregate EU27 data.

Table 3: Investment multipliers (Model A)

Horizon	(1) EU27 investment impulse (EU27 data)	(2) Individual country investment impulse (GDP-weighted)	(3) Individual country investment impulse (aggregated marginal effects)
Impact	0.57	1.13	0.51
1 year	4.15	2.99	2.37
5 years	5.18	3.64	3.90
10 years	5.25	3.71	4.14

The picture which emerges from Table 3 is that firstly the differences between the two aggregation methods are minor. On impact the GDP-weighted average yields a multiplier of 1.13 and the multiplier based on aggregated deviations from the baseline is 0.51. However, this gap closes at the five- and ten-year horizon. Importantly, the following conclusions about the differences between coordinated and uncoordinated fiscal policy do not depend on the aggregation method. Secondly, **the uncoordinated fiscal policy multipliers in columns (2) and (3) are consistently smaller than the multipliers based on simultaneous or coordinated government investment impulses reported in**

[15] We excluded seven countries from the average because they failed to pass standard statistical specification tests for residual autocorrelation and unit roots. These are: Bulgaria, Greece, Latvia, Romania, Slovakia, Slovenia and Spain.

column (1). The differences are large. After ten years, an additional euro of public investment spending generates €5.25 in additional output in the coordinated case but only between €3.71 and €4.14 in the uncoordinated case. It is no coincidence that these uncoordinated multipliers are similar to investment multipliers for individual countries in the existing literature. Studies for individual EU countries deal with very open economies where a significant amount of additional spending ends up as imports and thus will not stimulate the domestic economy. Analysing the EU27 as a whole, as in Sections 5.1 and 5.2, is methodologically more apt because a focus on individual countries discounts positive spillover effects in the form of increased intra-European trade. **These results demonstrate the significant benefits of fiscal policy coordination in an integrated economy like the European Union**. Already large multipliers of public investment tend to become even larger if public investment is increased as part of a coordinated fiscal effort. This is an important lesson not only for the task of tackling the climate crisis but also for fiscal policy in Europe in general.

6 Conclusion

This policy study assesses the long-run effects of a public investment initiative to close the EU's green investment gap. By using semi-structural VAR models for the EU27 we produce the following main results: first, **EU27 long-run multipliers of government investment on GDP are large**. The estimates obtained in this study start at 0.56 on impact, increase to between 2.7 and 4.15 after a year and stabilise between 5.12 and 5.25 after ten years. **This means an additional euro in government investment will lead to additional GDP of €5 after ten years**. Finding large effects of government investment is in line with the existing economic literature (Auerbach and Gorodnichenko 2012; Leduc and Wilson 2012; Benetrix and Lane 2009; Baxter and King 1993). Moreover, these results are obtained on the basis of EU27 data and can thus be interpreted as the effects in a large, closed economy in contrast to a small open economy in which multipliers decline with openness to trade. Second, **additional investment spending is likely to reduce debt-to-GDP ratios in the EU27, especially at longer horizons**. Since a decline in debt-to-GDP ratios implies that governments need to spend a smaller proportion of their revenues on debt servicing costs, **additional government investment expenditure can be regarded as sustainable fiscal policy**. **This outcome is obtained before factoring in the benefits of such investment projects (eg, lower carbon emissions)**. Third, a government investment initiative consisting of an exogenous increase in public investment spending over five years produces a significant economic impulse. Public finances are considerably better off after ten years when the budgetary response is modelled proportionally to economic expansion at a fixed 30% rate, and are slightly better off after ten years when the budgetary response is fully endogenised by explicitly modelling the dynamics of the public debt stock. Fourth, by comparing GDP multipliers from a model estimated with aggregate data for the EU27 with multipliers obtained by averaging results from models estimated with individual EU member state data, we can quantify the effects of coordinating fiscal policy. **We find that multipliers based on EU-wide expansions of public investment spending are substantially larger than multipliers obtained from investment spending expansions in individual countries**. We interpret this finding as evidence that coordinating fiscal policy in the European Union would produce a larger economic stimulus and thus would ease fiscal sustainability concerns even more. Nevertheless, even with uncoordinated fiscal efforts, GDP multipliers are large ranging from 0.51 on impact to 4.14 after ten years. Fifth, **the results and especially the GDP multipliers are very robust and are consistent across our two model specifications**. The key difference between the specifications is whether government revenues are modelled as a fixed proportion of GDP (30%) or whether the stock of public debt is explicitly included in the model. Sixth, while the government investment multipliers in this study are based on general public investment spending, the extent to which public investment indeed helps to cut carbon emissions specifically depends on the chosen investment projects. This means **a successful green transition requires a strong focus on investment projects that will lead to actual long-term emission reductions**.

Based on these results we derive three policy recommendations. The **first is to 'go big'**. Following the approach of the Biden administration in the USA (and China's approach to fiscal policy in response to the financial crisis), spending large amounts to address the EU's green investment gap is unlikely to create debt sustainability problems in the EU27. By contrast, however, underinvesting due to an overly pessimistic assessment of the effects of fiscal policy risks not only missing key climate targets but also risks leaving public finances in a worse state. The **second policy recommendation is to work together**. Substantially larger fiscal multipliers for EU-wide expansions of public investment spending highlight the benefits and potential gains from coordinated action across member states. This means that a pursuit of what are perceived as 'national' interests by individual member states has the potential to leave everybody worse off than if a coordinated approach is pursued. **The third policy recommendation is to free investment spending from excessive regulatory constraints**. The large investment multipliers that we find in this study imply that any attempt to improve public finances by cutting government investment spending is highly counterproductive. In the long term, debt-to-GDP ratios would then be likely to rise. This is an important lesson which should be incorporated into the EU's fiscal rule book. A significant first step would be to exclude investment expenditure from the calculation of the Maastricht budget deficit and of the fiscal compact. The striking result of our policy study is that cutting or abstaining from government investment appears to be counterproductive even before taking into account non-economic effects such as reductions in carbon intensity.

Finally, we are aware that these results might be surprising and counterintuitive to some readers. Indeed, we think that the mechanism at work here is the paradox of thrift, applied to the government sector. This paradox is an important insight that many macroeconomists seem to have forgotten between the 1980s and the financial crisis. Nevertheless, since governments are large in relation to the economy, any attempt to spend more (or less) has considerable knock-on effects via the multiplier mechanism. The multiplier mechanism thus produces results for an economy which would not hold for a small actor such as an individual firm or household. It is therefore ill-advised to apply to the government sector the same ideas of 'prudence' or 'financial responsibility' that might be desirable for an individual actor.

References

Auerbach, A.J. and Gorodnichenko, Y. (2012) 'Measuring the output responses to fiscal policy', *American Economic Journal: Economic Policy,* 4(2): 1–27.

Auerbach A.J. and Gorodnichenko, Y. (2017) 'Fiscal Stimulus and Fiscal Sustainability', NBER Working Papers 23789, National Bureau of Economic Research, Inc. (https://ideas.repec.org/p/nbr/nberwo/23789.html)

Baxter, M. and King, R. (1993) 'Fiscal Policy in General Equilibrium', *American Economic Review,* 83: 315–34.

Bénétrix, A.S. and Lane, P. (2009) 'Fiscal Shocks and the Real Exchange Rate', Institute for International Integration Studies Discussion Paper 286.

Bernanke, B.S. and Blinder, A. (1992) 'The federal funds rate and the channels of monetary transmission', *American Economic Review*, 82: 901–921.

Blanchard, O. and Perotti, R. (2002) 'An empirical Characterisation of the Dynamic Effects of Changes in Government Spending and Taxes on Output', *The Quarterly Journal of Economics*, Vol. 117(4): 1329–1368.

Castle, J., Doornik, J., Hendry, D. and Pretis, F. (2015) 'Detecting Location Shifts during Model Selection by Step-Indicator Saturation', *Econometrics*, 3(2): 240–264.

Cherp, A., Vinichenko, V., Tosun, J., Gordon, J. and Jewell, J. (2021) 'National growth dynamics of wind and solar power compared to the growth required for global climate targets', *Nature Energy*, Vol 6: 742–754.

Christiano, L.J., Eichenbaum, M. and Evans, C.L. (1996) 'The effects of monetary policy shocks: Evidence from the flow of funds', *Review of Economics and Statistics*, 78: 16–34.

Christiano, L.J., Eichenbaum, M. and Evans, C.L. (2005) 'Nominal rigidities and the dynamic effects of a shock to monetary policy', *Journal of Political Economy*, 113: 1–45.

Edelstein, P. and Kilian, L. (2009) 'How sensitive are consumer expenditures to retail energy prices?', *Journal of Monetary Economics*, 56: 766–779.

European Commission (2010), A strategy for smart, sustainable and inclusive growth, COM(2010) 2020.

European Commission (2019), Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU, Luxembourg: Office for Official Publications of the European Communities (DOI: 10.2833/14675).

European Commission (2021a), Strategy for Financing the Transition to a Sustainable Economy, COM(2021) 390 final.

European Commission (2021b), 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality, COM(2021) 550 final.

Gechert, S. (2015) 'What fiscal policy is most effective? A meta-regression', Oxford Economic Papers, 67(3): 553–580.

Gechert, S. and Mentges, R. (2018) 'Financial cycles and fiscal multipliers,' *Applied Economics*, 50(24): 2635–2651 (DOI: 10.1080/00036846.2017.1403563).

Grams, C., Beerli, R., Pfenninger, S., Staffell, I. and Wernli, H. (2017) 'Balancing Europe's wind-power output through spatial deployment informed by weather regimes', *Nature Climate Change*, 7(8): 557–562.

Hebous, S. and Zimmermann, T. (2013) 'Estimating the effects of coordinated fiscal actions in the euro area', *European Economic Review*, 58(1): 110–121.

Heimberger, P. and Kapeller, J. (2017) 'The performativity of potential output: Pro-cyclicality and path dependency in coordinating European fiscal policies', *Review of International Political Economy*, 24(5): 904-928.

Herndon, T., Ash, M. and Pollin, R. (2013) 'Does high public debt consistently stifle economic growth? A critique of Reinhart and Rogoff', *Cambridge Journal of Economics*, Vol. 38(2): 257–279.

Kapeller, J., Leitch, S. and Wildauer, R. (2021) 'A European wealth tax for a fair and green recovery', Greenwich Papers in Political Economy, No. 8.

Kelton, S. (2020) *The deficit myth*, London: John Murray.

Leduc, S. and Wilson, D. (2012) 'Roads to Prosperity or Bridges to Nowhere? Theory and Evidence on the Impact of Public Infrastructure Investment', *Macroeconomics Annual*, Vol. 27: 89–142.

OECD (2017) *Investing in Climate, Investing in Growth*, Paris (https://doi.org/10.1787/9789264273528-en)

Ramey, V.A. (2019) ‘Ten Years after the Financial Crisis: What Have We Learned from the Renaissance in Fiscal Research?’, *Journal of Economic Perspectives*, 33(2): 89–114.

Reinhart, C. and Rogoff, K. (2010) ‘Growth in a Time of Debt’, *American Economic Review*, Vol. 100(2): 573–78.

Truger, A. (2013) ‘Austerity in the euro area: the sad state of economic policy in Germany and the EU’, *European Journal of Economics and Economic Policies: Intervention*, Vol. 10(2): 158–174.

Uhlig, H. (2005) ‘What are the effects of monetary policy on output? Results from an agnostic identification procedure’, *Journal of Monetary Economics*, 52: 381–419.

Wildauer, R., Leitch, S. and Kapeller, J. (2020) ‘How to boost the European Green Deal’s scale and ambition’, Greenwich Papers in Political Economy, No. 76.

Is a €10 trillion European climate investment initiative fiscally sustainable?
-
Technical appendix

Rafael Wildauer, Stuart Leitch and Jakob Kapeller

June 2021

Contents

1 Introduction

This appendix outlines the VAR model and the data which was used to produce the results of the main document. Most importantly it provides an exact definition of the key concepts such as the **long run multipliers (LRMs)**, the **cumulative impulse response functions (CIRFs)** and the **semi-permanent impulse response functions (SPIRFs)**. The appendix also outlines how long run multipliers were averaged across EU27 member states and provides a brief derivation of the standard law of motion for government debt used in section 2 of the main report.

2 Data

The results are based on quarterly data for government investment spending ($GINV$)[1], output (GDP)[2] and the stock of government debt ($GDEBT$)[3]. All three series have been obtained

[1]Gross fixed capital formation for the general government sector from Eurostat table *gov_10q_ggnfa*
[2]From Eurostat table *namq_10_gdp* in chain linked volumes.
[3]General government consolidated gross debt from Eurostat table *gov_10q_ggdebt*

from Eurostat, where possible already seasonally and calendar adjusted, and deflated with the implicit GDP deflator. The $GINV$ and $GDEBT$ series were seasonally and calendar adjusted with Python's statsmodels x13 package. The quarterly GDP and $GINV$ series were transformed into annualized rates (i.e. multiplied by 4) to achieve easier comparison with annual data. All three series are plotted for the EU27 below.

Figure 1: EU27 real GINV and real GDP (chain linked volumes)

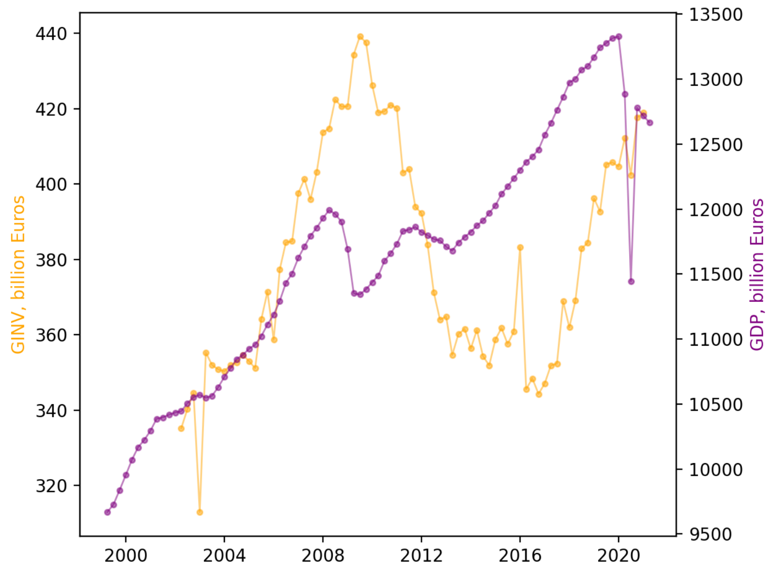
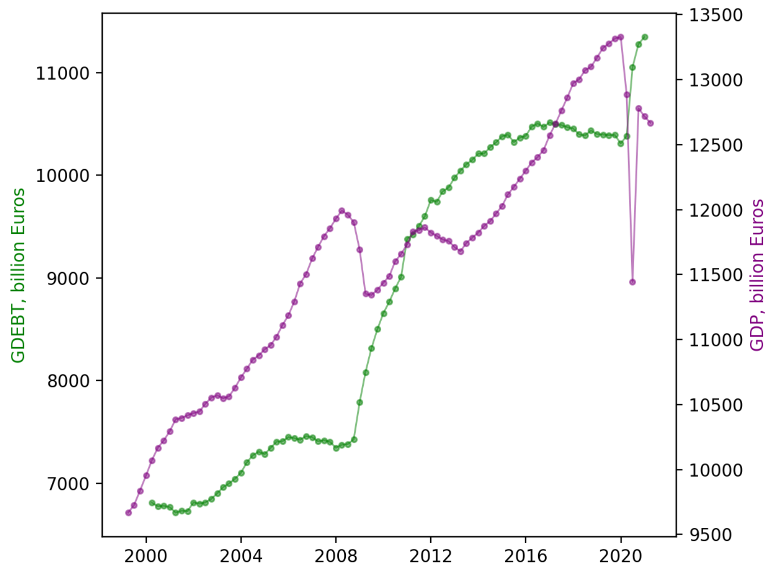


Figure 2: EU27 real GDEBT and real GDP (chain linked volumes)



3 The modelling and identification approach

We are working with a structural VAR model of the following form:

$$B_0 y_t = B_1 y_{t-1} + \cdots + B_p y_{t-p} + m_0 + m_1 t + \sum_{i=1}^{s} m_{2,i} S_i + \omega_t \tag{1}$$

where p is the lag length, y_t is a vector of K endogenous variables of the dimensions $K \times 1$, the B matrices are $K \times K$ coefficient matrics, m_0 is a $K \times 1$ vector of constants, m_1 is a $K \times 1$ vector of time trends and $m_{2,i}$ are a $K \times K$ coefficient matrices for s step indicators represented by the $K \times 1$ vectors S_i. We use two models, in the first $K = 2$ and $y_t = [g_t,\ x_t]'$ and in the second $K = 3$ and $y_t = [g_t,\ x_t,\ d_t]'$ where g_t is government investment spending, x_t is GDP and d_t is the stock of government debt. All variables are deflated by the GDP deflator and in logarithms. We will discuss identification first and then introduce the step indicator approach.

3.1 Identification approach

The contemporaneous effects matrix B_0 is of a lower triangular form (for the three variable case):

$$B_0 = \begin{bmatrix} c_{11} & 0 & 0 \\ c_{21} & c_{22} & 0 \\ c_{31} & c_{32} & c_{33} \end{bmatrix} \tag{2}$$

Our identification approach relies on one main assumption which is that government investment does not react within the period to either GDP or government debt. Which means we order the variables within y_t in the following form:

$$y_t = \begin{bmatrix} g_t \\ y_{2,t} \\ y_{3,t} \end{bmatrix} \tag{3}$$

Since we are only interested in the causal effects of government investment spending (g_t) but do not attempt to identify other demand or supply shocks or shocks to government debt, the ordering of the remaining variables in the system does not affect the government investment impulse response functions.

3.2 Step Indicators

The significant slowdown of the trend growth rate after the 2009 financial crises and the 2012 Euro crisis, is not just a temporary deviation from an otherwise unchanged long term trend (captured by the included time trends). This phenomenon has received substantial attention in the literature where it was discussed under the labels of *secular stagnation*, *hysteresis* and *austerity*. In order to strike a balance between keeping the model relatively simple and trackable while being required to take this crisis of historic proportion into account, we model these crises as exogenous events by incorporating *step-indicator saturation* as discussed by Castle et al. (2015). The idea of step indicator saturation is to saturate the model with step indicators S_i for each quarter t where S_t is equal to 1 from the first quarter up to quarter t and zero afterwards:

$$S_t = (\underbrace{1, \ldots, 1}_{\text{t times}}, \underbrace{0, \ldots, 0}_{\text{T-t times}}) \tag{4}$$

This means step indicator S_t allows for a permanent shift (i.e. a step) in the time series. The estimated coefficient matrix $m_{2,s}$ determines the sign and size of this shift for each of the K endogenous variables. We estimate the model by including 1 step indicator and then re-estimate it with the next step indicator. We repeat this process for all $T - 1$ step indicators. The finally selected model is estimated with those step indicators which are statistically significant at the 1% level and up to a maximum of 7 step indicators (10% of the sample).

4 Investment spending policy shocks

The MA representation of the model is given by:

$$y_t - y_t^p = \sum_{i=0}^{\infty} \phi_i u_{t-i}$$

$$y_t - y_t^p = \sum_{i=0}^{\infty} \phi_i B_0^{-1} B_0 u_{t-i}$$

$$y_t - y_t^p = \sum_{i=0}^{\infty} \Theta_i \omega_{t-i} \tag{5}$$

where y_t^p is the particular solution or the steady state of the system, $\Theta_i = \phi_i B_0^{-1}$ and $\phi_i = J\boldsymbol{A}^i J'$ where $\boldsymbol{A}$ is the companion matrix of the VAR(p) process (Kilian & Lütkepohl 2017, p. 25). The Θ_i matrices are $K \times K$ with elements $\theta_{jk,i}$ where j indicates the row and k the column. This means we have an MA representation in the structural shocks ω_t rather than the reduced form errors u_t. The structural impulse response function (SIRF) to a one off (temporary) structural shock is given as:

$$\frac{\partial y_{j,t}}{\partial \omega_{k,0}} = \text{SIRF}_{jk,t} = \theta_{jk,t} \tag{6}$$

Therefore $\theta_{jk,t}$ gives the deviation from the steady state or particular solution of variable j, t periods after a structural shock ω hit variable k in period 0. We can calculate the cumulative structural IRF (C-SIRF) at horizon t as:

$$\text{C-SIRF}_t = \sum_{i=0}^{t} \theta_{jk,i} \tag{7}$$

For an infinite horizon C-SIRF$_\infty$ becomes the effect of a permanent change in the intercept:

$$\frac{\partial y_{j,t}^p}{\partial m_{k,0}} = \sum_{i=0}^{\infty} \theta_{jk,i} = \text{C-SIRF}_\infty \tag{8}$$

Thus we can use the C-SIRF to compute the effect of a permanent exogenous change in investment spending ($m_{g,0}$), for example due to a policy change, on the steady state (particular solution) of the system. Overall the SIRF enables us to trace the effect of a one-off or temporary shock through the system and the C-SIRF enables us to trace the effect of a permanent shock through the system. What is less straightforward is how to trace a shock through the system which occurs for more than 1 period but is not permanent. In the next section we will combine C-SIRFs to do that.

5 Semi-permanent structural IRFs (SP-SIRF)

Let's say we want to track the effect of a shock to variable k on variable j and let's assume this shock lasts for a specific number (l) of periods. First, we can rely on the C-SIRFs to calcualte the deviation from the steady up to period l. From period $l + 1$ onward the shock recedes and the endogenous adjustment back to the steady state begins. We can track the full adjustment using the following formula:

$$y_{jk,t} - y_{jk,t}^p = \sum_{j=t}^{t-l} \theta_{jk,j} = \sum_{j=0}^{t} \theta_{jk,j} - \sum_{j=0}^{t-l-1} \theta_{jk,j} = \text{C-SIRF}_{jk,t} - \text{C-SIRF}_{jk,t-l-1} = \text{SP-SIRF}_{jk,t} \tag{9}$$

and we will call it a semi-permanent structural impulse response function (SP-SIRF). The formula for calculating SP-SIRFs can be derived from using the MA representation $y_t - y_t^p = \sum_{i=0}^{\infty} \Theta_i \omega_{t-i}$ and plugging in a specific sequence of shocks such as $(\dots, 0, 0, 0, \omega_0, \omega_1, \dots, \omega_l, 0, 0, \dots)$ and collecting terms.

6 Marginal effects and multipliers

In the example of fiscal policy, we are interested in linking the size of the impulse and the endogenous response of the fiscal instrument to the size of the output response triggered by the fiscal impulse. Fiscal multipliers are a way of achieving exactly that by condensing this relationship into a single number. If the data vector y_t consists of or contains time series in logarithms, the IRFs represent elasticities or percentage deviations from the steady state. In this context prior to calculating fiscal multipliers, these elasticities need to be transformed into marginal effects. IRFs expressed in marginal effects (ME) represent the deviations from the steady state of variable j not in percentages but in levels. For this purpose it is common in the fiscal multiplier literature Ramey (2019), Gechert et al. (2021) to multiply the SIRFs with the sample mean of the underlying response variable j. Alternatively the sample end, or start or any other period could be used instead of the sample average:

$$ME_{jk,t} = \bar{y}_j \theta_{jk,t} \tag{10}$$

In our application the marginal effect of a one standard deviation shock to government investment spending (g, the k-varible) on GDP (x, the j variable) is:

$$ME_{xg,t} = \bar{x} \theta_{xg,t}$$

$ME_{xg,t}$ is given in the units of measurement of x which are billion Euros. The cumulative fiscal multiplier (CFM) at horizon t is then given as:

$$CFM_t = \frac{\sum_{i=0}^{t} ME_{xg,i}}{\sum_{i=0}^{t} ME_{gg,i}} \tag{11}$$

which is the ratio between the total deviation of GDP from the steady state and the total deviations of the fiscal variable from steady state in response to a permanent increase in the fiscal variable.

7 Coordinated and uncoordinated fiscal policy

We have aggregate data for the EU27 and in addition data for all 27 member states individually. This allows us to compare the effectiveness of fiscal policy between periods of coordinated (or simultaneous) expansions and periods of isolated expansions. For this purpose we calculate the cumulative fiscal multiplier based on aggregate EU27 data and label it as:

$$CFM_t^{EU27} \tag{12}$$

This multiplier can be interpreted as a measure of fiscal policy effectiveness based on simultaneous fiscal expansions in the EU27. We can compare that with country specific fiscal multipliers based on individual country data:

$$CFM_t^c$$

where $c = (\text{AT}, \dots, \text{SK})$. CFM_t^c represents the effectiveness of fiscal policy in country c based on an isolated fiscal expansion in country c. In order to compare the effects of isolated or uncoordinated fiscal expansions we summarise the 27 individual multipliers in order to easily compare them to CFM_t^{EU27}. The first way of summarising them is to calculate a GDP weighted average to take the different sizes of the member states' economies into account:

$$CFM_t^{AV1} = \sum_{c=AT}^{SK} \frac{x_t^c}{x_t^{EU27}} CFM_t^c \tag{13}$$

When calculating CFM_t^{AV1} we define $x_t^{EU27} = \sum_{c=AT}^{SK} x_t^c$ because it will slightly deviate from x_t^{27} due to the non-summability of national accounts data in chained volume indeces. The second way of summarising the individual responses is to aggregate the marginal effects:

$$CFM_t^{AV2} = \frac{\sum_{c=AT}^{SK} \sum_{i=0}^{t} ME_{xg,i}^c}{\sum_{c=AT}^{SK} \sum_{i=0}^{t} ME_{gg,i}^c} \tag{14}$$

The first approach is more intuitive because it is a simple (GDP-weighted) average across 20 individual fiscal multipliers. The second approach is more accurate because it correctly adds up the deviations from the particular solutions for each country and only as the last step takes the ratio. We report both approaches, the results are qualitatively similar.

8 A law of motion for government debt

In order to derive a simple law of motion for government debt we start by defining government debt $B(t)$ as well as real GDP $Y(t)$ as functions of time. Further we define the debt to GDP ratio as $b = \frac{B(t)}{Y(t)}$. Taking the derivative of b with respect to time by applying the chain rule yields:

$$\frac{db}{dt} = \dot{b} = \frac{\dot{B}Y - B\dot{Y}}{Y^2} = \frac{\dot{B}}{Y} - b\frac{\dot{Y}}{Y} = \frac{\dot{B}}{Y} - b\hat{y} \tag{15}$$

variables with dots represents derivatives of these variables with respect to time and $\hat{y}$ is the growth rate of real GDP. Next we will make use of the following accounting identity:

$$\dot{B} = E - T + iB \tag{16}$$

where E-T is the primary deficit and i is the current interest rate on government debt. It states that the change in government debt $\dot{B}$, is equal to the primary budget deficit plus the interest rate payments on the outstanding public liabilities. Combining equations (15) and (16) yields:

$$\dot{b} = (e - t) + (i - \hat{y})b \tag{17}$$

where g-t is the primary deficit in percent of GDP and $(i - \hat{y})$ is the difference between the real interest rate and real output growth rate[4]. The stability of this differential equation is given iff:

$$\frac{\partial \dot{b}}{\partial b} = (i - \hat{y}) < 0 \tag{18}$$

which means if the growth rate is above the interest rate. Then the steady state d^* is given by:

$$b^* = \frac{t - e}{i - \hat{y}} \tag{19}$$

As discussed in the main text, this way of looking at public sector dynamics ignores any feedback from government spending E on output Y itself. Thus this law of motion is at best a crude long run rule of thumb if one is prepared to assume that the growth of the economy is driven by factors such as demographis or technological change with themselves are not affected by government spending.

[4]The discrete time version of this equation becomes $\Delta b_t = (e - t) + (i - g)b_t$ where $g = \frac{\Delta Y}{Y}$ is the growth rate of output. This is equivalent to equation (1) in the main text.

References

Castle, J., Doornik, J., Hendry, D. & Pretis, F. (2015), 'Detecting location shifts during model selection by step-indicator saturation', *Econometrics* **3**(2), 240–264.

Gechert, S., Paetz, C. & Villanueva, P. (2021), 'The macroeconomic effects of social security contributions and benefits', *Journal of Monetary Economics* **117**, 571–584.

Kilian, L. & Lütkepohl, H. (2017), *Structural Vector Autoregressive Analysis*, Cambridge University Press.

Ramey, V. A. (2019), 'Ten years after the financial crisis: What have we learned from the renaissance in fiscal research?', *Journal of Economic Perspectives* **33**(2), 89–114.