Is there a trade-off between ecological and fiscal sustainability? The case of the European Green Deal

Abstract

This paper asks to what extent a large-scale public investment initiative is a suitable tool to scale up the infrastructure necessary to decrease Europe's dependency on fossil inputs. A review of the European Green Deal (EGD) shows that it (1) seriously underestimates the EU's green investment gap, (2) downplays the direct provision of infrastructure and the use of fiscal policy and (3) relies heavily on market-based mechanisms to ensure the required funding. This neglect of fiscal policy risks leaving a crucial policy tool underused. Against this background, we estimate semi-structural VAR models for the EU27 to study the impact of public investment programmes on the fiscal sustainability of such spending initiatives. 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. Third, single country investment initiatives exhibit smaller multipliers compared to coordinated EU-wide investment, due to Europe's large 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 Codes: E62 Fiscal Policy; H63 Sovereign Debt

Keywords: Green fiscal policy, public debt sustainability

1 Introduction

At the time of writing Western Europe is suffering from another heatwave with temperatures exceeding 40°C in countries as far north as the UK. Despite the increasing urgency and visibility of the climate crisis, the European Union's climate policy framework relies primarily on one tool: market-based solutions, most importantly providing 'correct' incentives to the private sector via carbon pricing, to ensure sufficient (private) funding for financing a socio-ecological transformation towards a carbon-neutral Europe.

> "The Sustainable Europe Investment Plan will mobilise through the EU budget and the associated instruments at least EUR 1 trillion of private and public sustainable investments over the upcoming decade. […]. However, more is needed to master the challenges ahead. Private actors will need to provide the scale." *European Green Deal Investment Plan (EC 2020a, p. 1)*

In this context, EU authorities deliberately bracket out public responsibility – ironically, they do so by pointing to the great scale of the challenges involved, which would allegedly overwhelm the resources available to public authorities.

> "As the scale of investment required is well beyond the capacity of the public sector, the main objective of the sustainable finance framework is to channel private financial flows into relevant economic activities." *Strategy for Financing the Transition to a Sustainable Economy (EC 2021a, p. 2)*

The use of fiscal policy and public investment to build the infrastructure required for decarbonisation is of secondary importance in the EU's framework. This paper argues that the emphasis of private sector incentives via carbon pricing is firstly, based on an outdated view of fiscal policy focussed on its limitations, e.g. by reference to small multipliers, and has a strong tradition in European fiscal governance. Secondly it is the result of the European Commission's (EC) overly optimistic assessment of current policies' ability to decarbonise the economy and a corresponding underestimation of aggregate investment requirements up to the year 2050. The EC views fiscal policy is largely ineffective as demonstrated by Górnicka et al. (2020). The latter report the fiscal multipliers implied by recommendations under the EU's excessive deficit procedure between 2009 and 2015. The average is squarely below 1 at 0.67 while even reaching negative values in 2010. Regarding fiscal policy as ineffective is derived from economic models which exhibit (1) forward-looking households reducing spending in response to fiscal expansions (Ricardian equivalence), (2) full resource utilization quickly leading to inflationary pressures and aggressive central bank responses as well as (3) strict intertemporal budget constraints which prevent governments from running intertemporal deficits[1] and (4) focus on unproductive government expenditures. For example, Barro (1981) argues that government multipliers are strictly below 1, Baxter and King (1993) report negative multipliers if

[1] What we mean is that a standard budget constraint such as the one discussed by Romer (2012, p. 587) forces a government to "[…] run primary surpluses large enough in present value to offset its initial debt." (ibid), meaning a government cannot increase its initial debt stock in net present value terms.

government spending increases are temporary and are financed via lump sum taxes, Woodford (1998) argues that public debt limits akin to the Maastricht treaty are necessary for price stability and Uhlig (2010) argues that increased government spending has negative long term output effects. Heterodox authors have long challenged these conclusions and the underlying modelling assumptions. In Post-Keynesian macroeconomic models for example, fiscal policy is effective due to the existence of excess capacity, while inflation results primarily from distributional conflict rather than excess demand and supply bottlenecks and household behaviour is driven by simple heuristics such as proportionally consuming one's income. Textbook treatments of such an approach can be found in (Lavoie 2014, Hein 2014, Blecker and Setterfield 2019), while medium and large scale models include Dafermos and Niolaidi (2021), Godin and Yilmay (2020) and Caiani et al. (2016), to name a few. However, also neoclassical authors increasingly acknowledge the shortcomings of the traditional mainstream view of fiscal policy. For example, it has become increasingly common to introduce so-called hand-to-mouth consumers who spend a proportion of their current income into New-Keynesian models and thus relax the strong results of Ricardian equivalence (Farhi and Werning 2016, Galí, et al. 2007, Furceri and Mourougane 2010). Furthermore, the research agenda on heterogeneous agents does not only embrace hand-to-mouth consumers but assigns a much greater role to fiscal policy in general (Bilbiie 2020, Kaplan et al. 2018).[2] In addition, there are now several empirical (Christiano et al. 2011, Gechert 2015, Leeper et al. 2017) as well as theoretical (Farhi and Werning 2016, Davig and Leeper 2011) papers which emphasize the importance and effectiveness of fiscal policy especially during periods of economic slack and the central bank at the zero-lower-bound. Altogether there is broad agreement between heterodox and mainstream authors, that fiscal policy can be a highly effective policy tool. Despite this increasing agreement however, the policy debate about fiscal policy in general and the use of fiscal policy in the context of climate change in particular, is still heavily influenced by the idea of fiscal policy ineffectiveness. A very prominent argument in this context is of direct relevance to this paper. Thereby, it is asserted that fiscal expansions in general – and, hence, also those dedicated to building the green infrastructure in particular – lead to increasing public debt and present a challenge to 'sound public finances' with only a minimal benefit (due to assuming small multipliers). Therefore, such a policy effectively represents a burden on future generations (Uhlig 2010, Schäuble 2021).

This paper aims to contribute to a better-informed public debate and eventually a more effective policy mix by estimating public investment multipliers in the European Union. We assess the medium-term effects on economic growth and public finances of an ambitious, publicly funded expansion of

[2] Most importantly monetary policy is more effective in these models compared to representative agent models because of fiscal expansions in response to monetary policy induced relaxing of governments budget constraints. Thus, while fiscal policy is important, the mechanism is highly questionable.

green public infrastructure in the European Union. We find that fiscal policy is not only an effective tool for putting this infrastructure in place quickly and at scale but in addition public finances are likely to improve, i.e. debt-to-GDP ratios decline, in response to an ambitious investment initiative. Our findings are very much in line with heterodox and recent neoclassical contributions as discussed above and thus add to the growing evidence that the EU's current policy mix and focus on carbon pricing unnecessarily discards direct public investment as an effective decarbonisation tool. As a consequence, de-emphasizing fiscal policy and direct provision of public infrastructure in the face of the current climate emergency is effectively hindering our decarbonisation efforts. The resulting warming is the true burden future generations will face.

In addition to this core finding, the paper makes the following supplementary contributions to the literature. First, we compare the effects of coordinated and uncoordinated fiscal policy in the EU. We find that coordinated fiscal expansions result in significantly higher multipliers than uncoordinated efforts. Second, we use step indicator saturation (Castle et al. 2015) to allow for a drop in trend growth after the 2009 financial crisis, which we interpret as a hysteresis effect, without explicitly incorporating a complex financial sector into our model. Third, to the best of our knowledge, we are the first to introduce the concept of semi-permanent impulse response functions. These allow us to track the response of the model economy to a sustained but transitory (e.g. 5 years) increase in public investment spending.

The remainder of the paper is organized as follows. Section 2 discusses the empirical evidence on public investment multipliers and the measurement of Europe's green investment gap. Section 3 describes the methods used and the empirical approach. Section 4 presents the results, and Section 5 concludes.

2 Investment multipliers and the EU's green investment gap

While there is broad agreement on a theoretical level that fiscal policy can be an effective tool for stimulating the economy as well as for achieving specific policy goals (redistribution, social and physical infrastructure etc.), there is also a growing body of empirical literature on government spending multipliers supporting this view. This section will first contextualise our paper within this empirical literature on investment multipliers and will then provide an overview over the EC's current assessment of the green investment gap which the EU is facing.

2.1 Empirical evidence on investment multipliers

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 the ensuing European debt crisis. We provide a brief overview in what follows. Gechert (2015) provides systematic review of the literature by means of a meta-regression analysis of 104 fiscal multiplier studies. The 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 at 2.1 for empirical studies; (iii) international trading relationships affect the multiplier: regions with higher import shares have lower public expenditure multipliers; (iv) general public expenditure multipliers are higher than those obtained from tax cuts and increasing transfers; (v) specifications which allow for a crisis scenario where the central bank hits the zero lower bound yield systematically higher multipliers. This latter finding also finds support from Auerbach et al (2012) who estimate 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). More recently Boitani et al. (2022) qualify this finding and argue that state dependent multipliers only manifest in deep recessions but not over the normal business cycle. Deleidi (2022) estimates investment multipliers for Italy by means of an SVAR and reports a peak investment multiplier of 4.72 and 5.32 after taking fiscal foresight into account. Deleidi et al. (2020) estimate investment multipliers for a panel of 11 Eurozone countries by local projections and find multipliers between 1.9 and 3.4 after 6 years and between 2.5 and 4 for a pre-financial crisis sample. When it comes to differentiation between coordinated and uncoordinated fiscal expansions Hebous and Zimmermann (2013) find that coordinated actions in the Eurozone 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 and also supported by Obst et al. (2020) who find larger multipliers for coordinated fiscal expansions in the EU15 compared to isolated ones. 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 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.

In summary, the magnitude of public investment multipliers 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 potential interaction of these variables. Overall, estimates of cumulative public investment multipliers in the literature are significantly above 1. Based on a meta regression Gechert (2015, Table

5) reports a mean value of 2.1 for VAR based estimates with a maximum of 3.8 in his sample. This means studies reporting low or even negative (investment) multipliers such as Boehm (2020) and Uhlig (2010) should not be considered representative of the wider literature or representative of the opinion of academic economists. The latter point is highlighted by the most recent survey of the American Economics Association's members (Geide-Stevenson and La Parra Perez 2021) which shows that 94.1% of respondents agree or agree with proviso with the statement 'Fiscal policy has a significant stimulative impact on a less than fully employed economy' and 66% of respondents disagree with the statement that 'Management of the business cycle should be left to the Federal Reserve; activist fiscal policies should be avoided'. Indeed, one of the main findings of the survey is that a new consensus is emerging in favour of an active fiscal policy stance.

2.2 The EU's green investment gap

The EU's flagship climate change policy instrument is the European Green Deal (EGD) which was announced in December 2019 (EC 2019b) and supplemented by the Fit for 55 (FF55) package of policy proposals in July two years later (EC 2021b). To achieve net zero by 2050 the EU's targets for 2030 are a 55% reduction in greenhouse gas emissions compared to 1990, a 40% share of renewables in energy production and a 40% improvement in energy efficiency. Historically the EU27 has invested €683 billion annually in its energy system including the transport sector (see row 1 in Table 1). Based on its current impact assessment (EC 2020b, 2020c) the European Commission assumes that the current policy framework without further measures[3], will increase energy system investments to €947 billion annually in the current decade and to €981 billion annually in the two decades from 2031 onwards (see row 2 in Table 1). Reaching the EU's 2030 goals and achieving net zero by 2050 would require annual energy system investments of €1,055 billion and €1,196 billion respectively (see row 3 in Table 1). What this means is that the European Commission assumes that between 60% (€298 out of 513€ billion) and 70% (€264 out of €371 billion) of the EU's green investment gap will be closed with the current policy framework, without any further action. The remaining investment gap (between the net zero target and the current policy framework) stands at €108 billion annually up to 2030 and at €215 billion annually from 2031 onwards. It is this gap which the EGD and FF55 are designed to close.

The historic development of renewable energy production casts doubt on the ability of the current policy framework to close 60% of the gap between historic investment rates and the rates required to reach net zero by 2050. To put this in context, in the three years before the pandemic (2017-2019), the share of energy from renewable sources increased on average by 0.6 percentage point p.a. and

[3] The current policy framework (referred to as baseline) is defined in EC (2020b) sections 5.4 and 9.3.3, and consists of three main pieces of legislation. First the EU Emission Trading System (ETS) directive, second the Effort Sharing Regulation (ESR) and third the Land Use, Land Use Change and Forestry (LULUCF) Regulation.

stood at 19.89% in 2019[4]. Continuing at this rate would mean falling short of 30% renewables by 2030 and only achieving a 40% share of renewables by 2050. In addition, a closer look at the estimated investment requirements for the 2050 net zero goal, reveals three reasons why the EC is likely to severely underestimates the necessary investment expenditures (and thus the investment gap).

Table 1: EU total energy system investment gap decomposition

	Investment in total energy system (billion Euros, 2015 prices)	**2011-2020 average**	**2021-2030 average**	**2031-2050 average**
(1)	historic annual investment	683		
(2)	annual investment current policy scenario		947	981
(3)	annual investment net zero scenario		1,055	1,196
= (2) - (1)	Difference between current policy and historic		264	298
= (3) - (2)	Gap between net zero and current policy		108	215
= (3) - (1)	Gap between net zero and historic trend		371	513

Source: EC (2020c) Table 46, the policy scenario depicted here is ALLBNK which includes emissions from international shipping and aviation.

First, recent scientific evidence concludes that staying below 1.5°C requires more ambitious action from the EU than currently planned (Anderson et al. 2020). The reason is that the EU's Paris-compliant energy-only carbon budget is estimated to lie between 21 and 27 GtCO2 (from 2020 onwards), allowing nine years at most at current emissions (ibid). Staying within this budget would require annual emission reduction rates of 10 percent by 2025 and they would need to increase to 20 percent by 2030. Energy production across all sectors would need to be zero carbon by 2035-2040. A key reason for the lower carbon budget estimates by Anderson et al. (2020) is that the authors take the global equity considerations of the Paris agreement seriously. This means allowing poorer nations more time before phasing out of carbon emission, for instance, to build vital infrastructure which is energy intense with currently no alternatives (cement). The flip side is if the world as a whole is to reach net zero by 2050, rich nations need to decarbonise faster. Rich nations have not only been emitting greenhouse gases for much longer than most low- and middle-income countries and has thus contributed more to the problem over time, but it is also rich nations that have the resources to act quickest. This means while FF55 represents an increase in the EU's climate ambitions, taking the Paris Agreement seriously requires further action.

Second, sectoral level analysis of investment requirements often yields much higher estimates than the aggregate analysis employed by the European Commission (EC). EC (2019a) for example estimates

[4] See Eurostat data table [NRG_IND_REN__custom_3105220].

that decarbonising the EU's building sector requires a threefold increase of the annual energy saving rate achieved by renovations and thermal insulations which currently stands at around 1% per annum. The resulting additional annual investment costs over historic rates in the building sector are between €324 and €150 billion in contrast to the EC's estimated €145 billion[5]. Another example is the industrial sector. Increasing investment spending in the latter by 3 percentage points to 11 percent of the existing capital stock annually to implement carbon neutral processes and technologies amounts to €80 billion of additional annual investment spending. This compares to the Commission's estimate of €8 billion which amounts to annual replacement and upgrade of merely 0.3% of the existing capital stock per year. When it comes to research and development (R&D) spending the EU is currently missing its target of spending 3 percent of GDP on R&D. Since this target was set in 2010 with much less ambitious climate targets, a 4 percent target might be better suited. Hitting such a 4 percent R&D target over the 2020-2030 period would require an additional €201 billion of R&D investment. Altogether, Wildauer et al. (2020) estimate that the EU's green investment gap (compared to historic rates) stands at €850 billion annually compared to the EC's estimate of €267 billion (where both numbers are excluding the transport sector).

Third, EU climate policy does not adequately take the fundamental uncertainties attached to the climate system into account. Given that climate models are simply best guesses which have proven to be overly optimistic in the past (IPCC 2022), planning for a precision-landing of reaching net zero by 2050 is a risky bet. The approach should be to err on the side of caution and reach net zero well before 2050. Every tonne of CO2 not emitted will make it more likely that humanity succeeds in limiting warming to 1.5°C.

Overall, this discussion shows the need for the EU to increase its climate ambition. Patting itself on the shoulder that the current goals are significantly more ambitious than anyone had expected 10 years ago, as the authors were told numerous times by various former and current representatives and members of the European Commission and the European Parliament, misses the point. Taking the deep decarbonisation and global equity commitment of the Paris agreement seriously requires a higher level of ambition and, most importantly, fast and at scale delivery. Against the scale of these challenges, it would be unwise to discard fiscal policy outright due to an outdated view of long-term effects on public finances. The remaining sections are dedicated to testing the contrasting views on fiscal policy which were discussed in the introduction.

[5] The latter is averaged over the 2021-2050 period, EC (2020c) Table 46, ALLBNK scenario.

3 Estimating fiscal multipliers

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

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

where for Model I, 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 II 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 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 our focus 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 public investment and GDP. To do this, we use the so-called step-indicator approach of Castle et al (2015). Full details of this can be found in the appendix.

Within this framework we start out in section 4.1 by estimating the effects of a permanent increase in government investment spending on GDP and public debt. To do this we use orthogonalised cumulative impulse response functions (CIRFs) and long-run multipliers (LRMs).[6] 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 the baseline trajectory relative to the additional public investment spending due to the assumed permanent increase in government spending. In Section 4.2 we address the slightly different question

[6] Also called cumulative multipliers.

of the effect of an increase in government investment spending on GDP and public debt, when the investment impulse lasts for several years but is not permanent. We use what we call orthogonalised semi-permanent impulse response functions (SPIRFs) to provide an answer to this question.[7] SPIRFs allow us to track the adjustment of the economy to a sustained increase in government spending which lasts for a given period (here: five years) and then falls back to the baseline trajectory. Finally, in Section 4.3, 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.

4 The long-term effects of a European investment initiative

This section provides estimates of the long-term effects of exogenous changes (shocks) in government investment spending. 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.

4.1 Permanent or long-run effects of government investment

Our analysis starts with a scenario in which a government implements a permanent 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 these additional €100 billion investment on output and government finances. The two vector 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 1. Starting with Model

[7] 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.

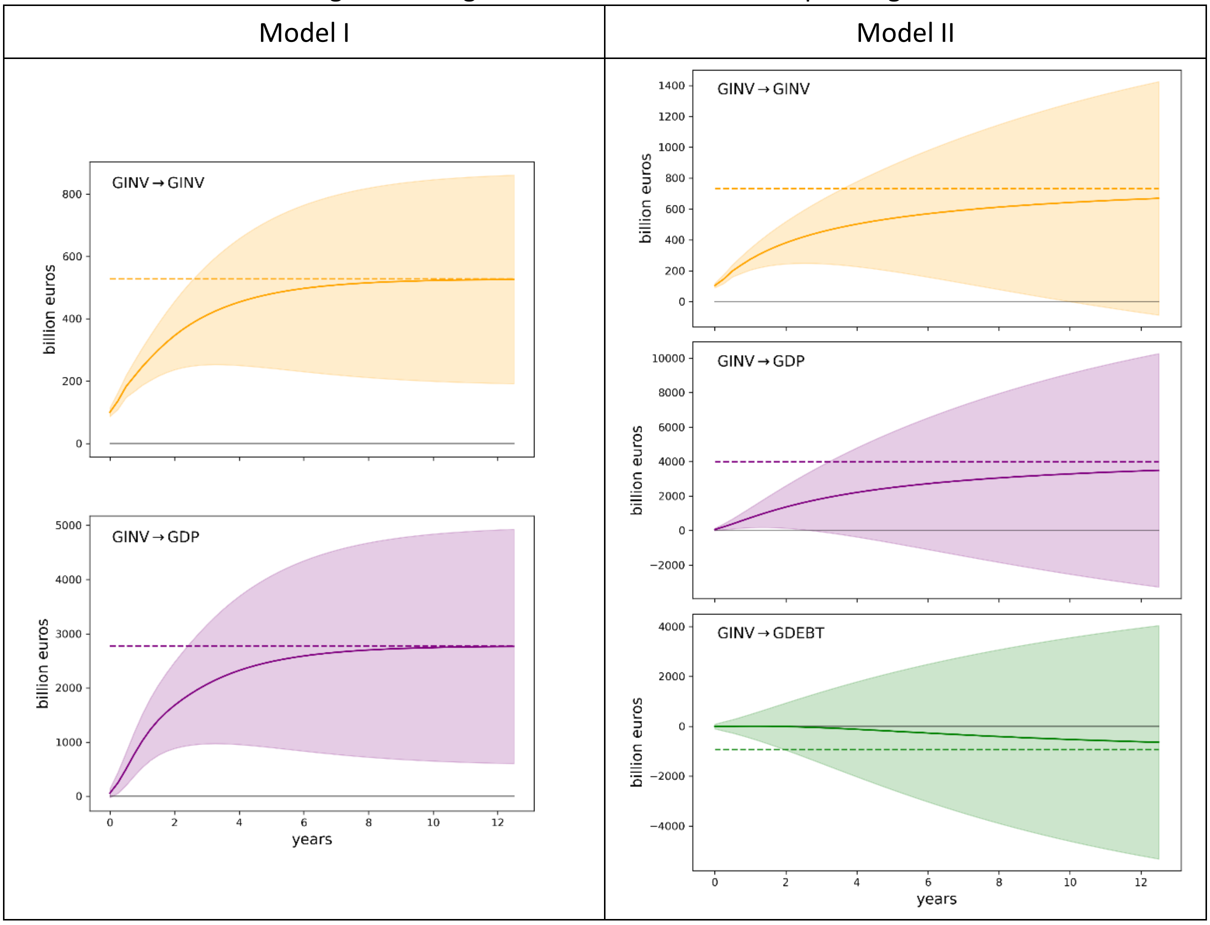
I (left-hand column of Figure 2), a permanent increase in government investment (GINV, yellow graph, upper left of Figure 1) of €100 billion beyond the baseline leads to a slow increase in investment spending, which reaches €526 billion after 12 years. The reason for this gradual increase in investment spending beyond €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 I, roughly 20% of an investment project is therefore spent in the first quarter and the remaining 80% is spent over the next decade as follow-up investment induced by the original stimulus.[8] To provide some context, public investment spending across the EU27 amounted to €404 billion in 2019.[9] The scenario analysed with Model I 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 after 12 years. The lower left graph in Figure 1 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 after 12 years. Model I 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 I 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.

In Model II (right-hand column of Figure 2), a permanent increase in government investment (GINV, yellow graph, upper right of Figure 1) of €100 billion beyond the baseline leads to a slow increase in investment spending, which reaches €664 billion after 12 years. As investment spending increases gradually over time, so does GDP. The immediate impact of €58 billion is small, but the economy expands strongly over time until GDP reaches an expansion of €3,459 billion beyond the baseline trajectory after 12 years. Model II therefore also predicts a strong economic expansion. The stock of public debt reacts very little to the investment impulse and starts to decline slowly from the 8th quarter onwards. It falls €620 billion below the baseline trajectory after 12 years. This decline in public debt is in line with a strongly expanding economy and thus increasing government tax revenues and declining

[8] €100 billion is roughly 20% of €526 billion.
[9] Based on seasonally adjusted data.

expenditures on transfers. The investment trajectory in Model II is statistically significant for 10 years, the GDP trajectory is statistically significant for 3 years and the trajectory of public debt is not statistically significant.

Figure 1: 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 permanent investment impulse by the total increase in investment x years after the permanent 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 I and 5.12 in Model II. 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 I	Model II
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 *1* and they emphasise how powerful public investment can be in stimulating the economy. These large effects warrant four 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. Bénétrix 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. More recently Deleidi et al. (2020) estimate investment multipliers for a panel of 11 Eurozone countries by local projections and find multipliers between 1.9 and 3.4 after 6 years and between 2.5 and 4 for a pre-financial crisis sample. Thirdly, this is one of the few studies which investigates the EU27 as a whole. Given the high trade volume between member states, single country studies are likely to find lower investment multipliers. For example, in 2018 the external balance of the EU27 was 3.9% of GDP compared to 6.2% for Germany. We will come back to this issue in section 4.3. Fourth, the fact that we obtain large investment 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.

4.2 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 therefore estimates the effects of a sustained five-year public investment initiative using orthogonalised semi-permanent impulse response functions (SPIRFs).[10] Figure 2 displays the SPIRFs for GDP, government investment (GINV) and the budget balance based on Model I. We have scaled the investment impulse so that over the entire 12-year period of Figure 2, 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 2 represents the 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 outlays over the following years. From year five onwards we therefore see a gradual decline in investment spending towards 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 2 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 strong expansion is somewhat expected given that in the previous section we saw Model I implying a long-run multiplier of more than five. While Model I, on which Figure 2 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 2, 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 2 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

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

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 I, 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. This means, a sustained five-year public investment initiative would lead to falling debt-to-GDP ratios and would therefore constitute responsible fiscal policy.

Figure 2: Semi-permanent IRF model I

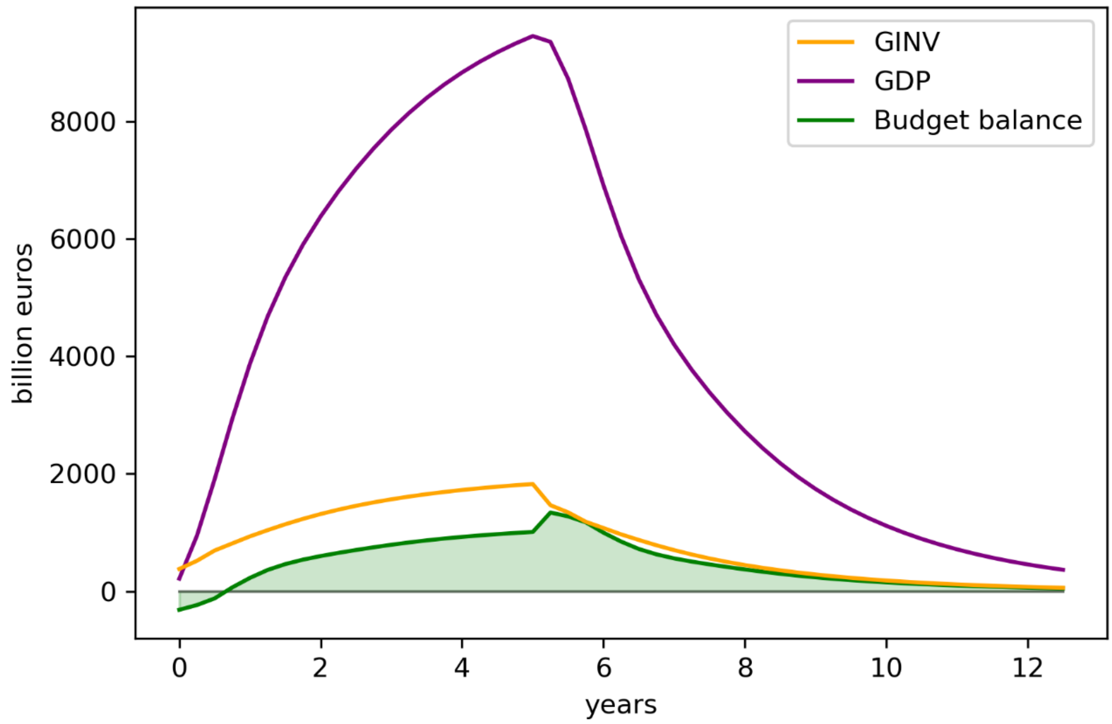


Figure 3 shows the orthogonalised semi-permanent impulse response functions (SPIRFs) for the EU27 economy to a sustained five-year public investment impulse based on Model II, which directly incorporates the stock of government debt. For ease of comparability, we have transformed the response of the 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).

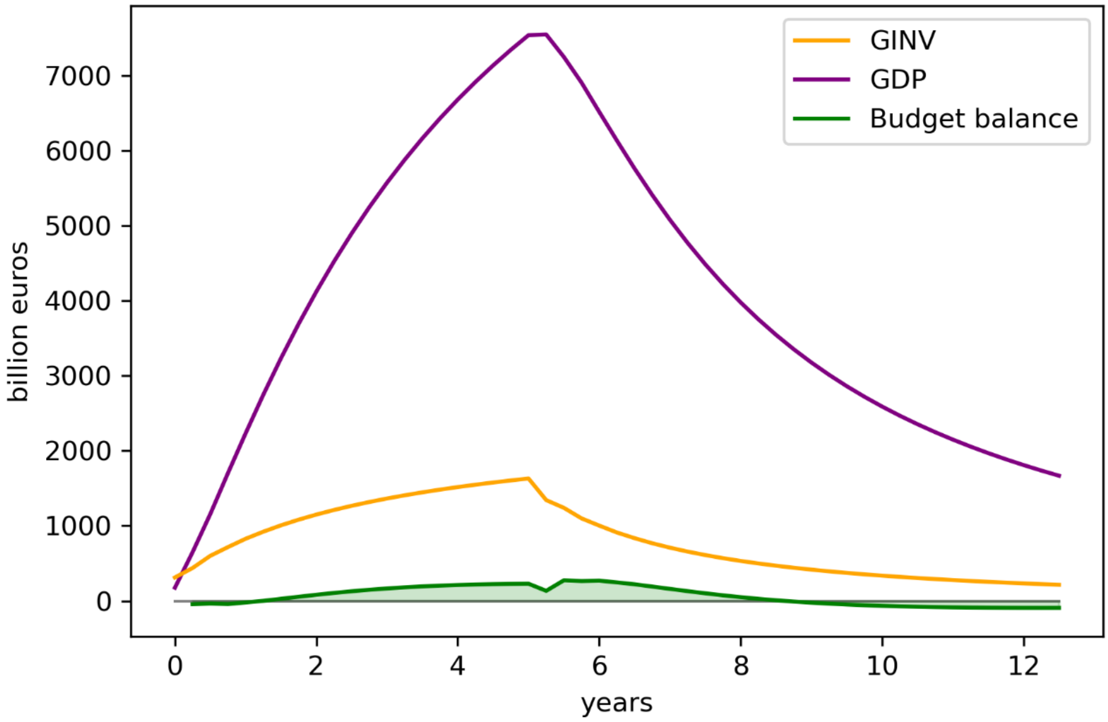
$$Budget\ Balance_t^{Figure\ 4} = GDEBT_{t-1} - GDEBT_t \tag{3}$$

As in Figure 2, 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 I, we obtain a sizeable economic expansion in response to the additional government investment spending from the SPIRF of Model II. This result is logical, given the large multipliers we have found for both models (Table 2). The key difference between Model I and Model II 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 II are not statistically different from zero. On the basis of Model II, we should thus expect a minor improvement in government finances over the entire period of Figure 3 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 I, Model II 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.

4.3 Coordinated vs uncoordinated fiscal efforts

In Sections 4.1 and 4.2 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.

Figure 3: Semi-permanent IRF model II



In Table 3 we compare the long-run multipliers from Model I for the EU27 with averaged long-run multipliers obtained from estimating Model I 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.[11] 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 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

[11] 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.

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 I)

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 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 4.1 and 4.2, 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.

5 Conclusion

This paper 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; Bénétrix and Lane 2009; Baxter and King 1993, Deleidi et al. 2022). 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 long 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.

Based on these results we derive three policy recommendations. The first is to 'go big'. 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 weakens public finances in a comparative perspective. The second policy recommendation is to aim for coordinated policy-action. 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 all members 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 without taking into account the impact such spending might have on reducing carbon intensity.

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Is there a trade-off between ecological and fiscal sustainability? The case of the European Green Deal - Appendix

July 2022

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 from Eurostat, where possible already seasonally and calendar adjusted, and deflated with the

[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*

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)

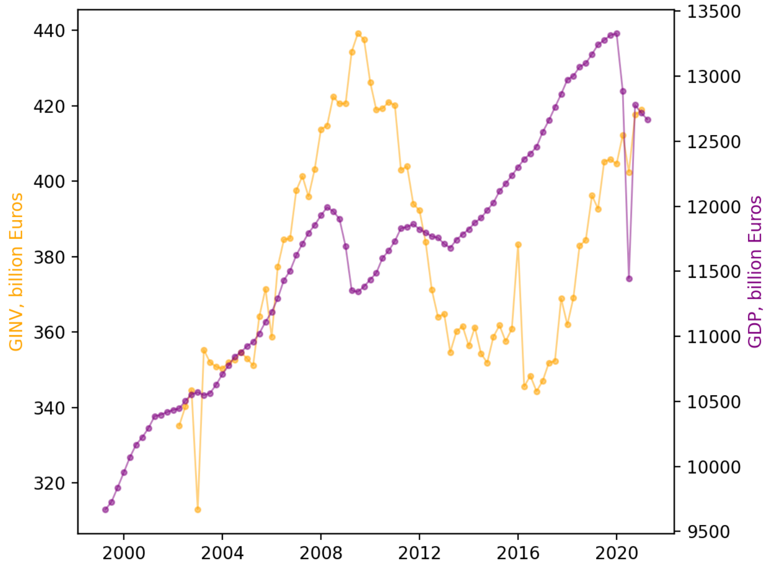
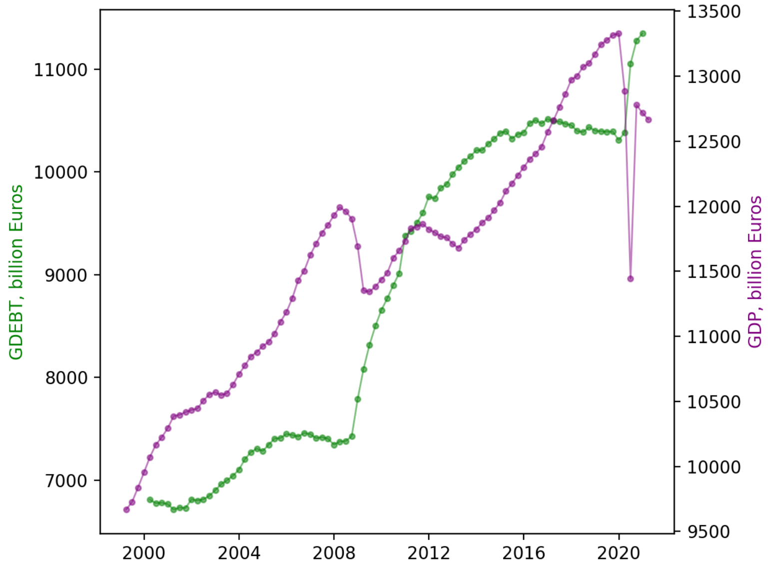


Figure 2: EU27 real GDEBT and real GDP (chain linked volumes)



3 The modelling and identification approach

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

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

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 $(\ldots, 0, 0, 0, \omega_0, \omega_1, \ldots, \omega_l, 0, 0, \ldots)$ 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 $c = (\text{AT}, \ldots, \text{SK})$. 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.

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