WIFO ■ WORKING PAPERS

646/2022

Macroeconomic Effects of Green Recovery Programmes

Conceptual Framing and a Review of the Empirical Literature

Angela Köppl
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WIFO Working Papers 646/2022
April 2022

Abstract

As governments spend unprecedented sums of public money on pandemic related rescue and recovery measures, while humankind is facing mounting long-term challenges – and above all the climate crisis –, the question whether and to what extent COVID-19 recovery programmes contribute to countries' commitments to a sustainability oriented recovery is gaining increasing urgency. We argue that overcoming the economic and social impacts of the pandemic require deeper structural changes than a return to a more or less business as usual scenario to limit the impacts of climate change. Recovery packages should therefore be designed in such a way as to avoid fossil lock-in effects and take into account that the social and technological actions taken today will unfold their effects in the climate system with a time lag only. An interesting question in this context is the effectiveness of green recovery measures not only with regard to environmental objectives, but also concerning conventional economic indicators, which are traditionally summarised under the heading "multiplier effects". Evaluations of the economic effects of green recovery measures, e.g. those implemented during the global financial crisis, are in short supply. Most of the existing empirical analyses have an ex ante focus, while ex post evaluations are scarce. This paper aims at contributing to this research gap by providing a review of the empirical evidence of the macroeconomic effects of green recovery measures.

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2022/1/W/4420

Funded by the ECFIN Fellowship programme of the European Commission, Directorate General for Economic and Financial Affairs (DG ECFIN). This document has been prepared for the European Commission, however it reflects the views only of the authors, and the European Commission is not liable for any consequence stemming from the reuse of this publication.

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1 Introduction[1])

As governments spend unprecedented sums of public money on pandemic related rescue and recovery measures, while humankind is facing mounting long-term challenges – and above all the climate crisis – the question whether and to what extent COVID-19 recovery programmes contribute to countries' commitments to a sustainability oriented recovery is gaining increasing urgency. Since the outbreak of the COVID-19 crisis, various databases have been established that focus on the green content of fiscal measures aiming at mitigating the devastating economic and social effects of the crisis. The multitude of existing green recovery trackers mirrors the – in comparison to the 2007/08 global financial and economic crisis (GFC) considerably larger – attention a green recovery is receiving from academia, NGOs and international institutions (for overviews see, e.g., UNEP, 2020, or O'Callaghan – Murdock, 2021). By attempting to quantify the share of green recovery measures in overall COVID-19-related public expenditures, the existing databases necessarily have an input oriented focus, thus implying that an increase in green spending "automatically" translates in environmental as well as economic and social benefits. An interesting question in this context, which is relevant for research as well as public policy but has received far less attention until now, is the effectiveness of green recovery measures not only with regard to environmental objectives, but also concerning conventional economic indicators, which are traditionally summarised under the heading "multiplier effects".

When attempting to assess the effectiveness of the green recovery measures implemented since the beginning of the COVID-19 crisis, the experiences from the GFC offer themselves to be drawn on. However, despite the considerable size of the GFC recovery packages and the time span that has passed since their implementation over one decade ago, evaluations of the environmental and economic effects of green recovery measures are in short supply, as Agarwala et al. (2020) point out. The authors' review of analyses of green recovery measures implemented during the GFC shows that most empirical analyses have an ex ante focus, while, as underlined also by Varro et al. (2020), ex post evaluations are scarce.

This paper aims at contributing to this research gap by providing a review of the empirical evidence of the macroeconomic effects of green recovery measures. We start by framing the need for deep structural change to limit the threat of climate change and then address three questions in particular. First, what are the most promising areas green recovery measures can address in terms of macroeconomic effects in general and regarding job creation potential in particular? Second, how do green recovery measures fare in economic terms compared to conventional recovery measures? Third, what are factors that influence the success of green recovery measures? These questions are integrated into some basic considerations regarding the upcoming challenges posed by climate change.

The paper is structured as follows: Section 2 provides some theoretical background. Section 3 presents some figures on the green content of COVID-19-related recovery measures and reviews the existing relevant empirical research with a view on the three guiding questions outlined above. Section 4 concludes by identifying research gaps which could be narrowed using the experiences from the first wave of green recovery programmes after the GFC as well

[1]) This WIFO working paper is based on the study for the DG ECFIN Research Fellowship 2020-21"Shifting Paradigms: The Quest for New Modes of Sustainable Growth and Convergence".

We are grateful to Joost Kuhlmann, Asa Johannesson Linden, Andrea Mairate and Arnaud Mercier from DG ECFIN for very helpful comments and suggestions and to Katharina Köberl-Schmid, Cornelia Schobert, and Andrea Sutrich from WIFO for careful research assistance.

as the second one implemented since spring 2020 to overcome the negative economic effects of the COVID-19 crisis.

2 Conceptual and theoretical background of the green recovery and the need for transformative change

Since the beginning of 2020 the policy focus has been, and still is, on the pandemic and on how to alleviate the social and economic impact of the COVID-19 crisis. In what follows, we argue that overcoming the health crisis and its economic and social impacts will require deeper structural changes than a return to a more or less business-as-usual scenario to limit the impacts of climate change.

Climate change and the associated impacts and risks that are already being felt represent a convincing argument for profound change in prevailing economic and social structures. The literature refers to a dual challenge, since on the one hand it is a matter of pushing structural change in a direction which goes hand in hand with a drastic reduction in greenhouse gas (GHG) emissions, and which on the other hand does not endanger prosperity (Altenburg and Rodrik, 2017). The pandemic and the associated economic crisis add a third aspect to this dual challenge, offering at the same time an opportunity through the recovery packages to initiate pathways towards less carbon intensive structures.

The current stock of technologies with the associated GHG emissions makes it unlikely, in some cases impossible, that incremental technological improvements along existing development patterns can meet these challenges. Rather, a profound structural change and a breakup of fossil-based technological and economic path dependencies is needed. The path to a decarbonised, i.e., fossil-free, economy and society is thus a transformative process that needs to be started immediately. The social and technological actions taken today will unfold their effects in the climate system with a time lag only. Against the short-term challenge to overcome the health and economic crisis, the long-term goal of net zero emissions calls for an integration of climate issues into short-term policy responses.

2.1 Deep structural change in the context of climate change and the pandemic

Green transition in Europe is driven by an ambitious climate policy agenda and the aim to make Europe the first climate neutral continent by 2050. The basic strategy for achieving climate neutrality was laid out in the Green Deal (European Commission, 2019) which puts climate policy on top of the policy agenda of the EU. This is reflected in a variety of policy initiatives and regulations, among which the Fit for 55 package and the sustainable finance agenda are to be emphasised. The EU Green Deal is seen as a growth strategy that reconciles planetary boundaries with economic prosperity, building on innovation, promoting sustainable finance and just transition (European Environmental Agency, 2021). Thus, the EU Green Deal is characterised by a broad spectrum of topics which together should trigger structural change and transformative processes. As Tagliapietra and Veugelers (2021) argue this also includes a new understanding of industrial policy. They understand green industrial policy as policy that reconciles decarbonisation with industrial policy, defining "….green industrial policy as an industrial policy where climate change mitigation becomes a binding constraint in the overall social welfare policy objective". In line with the 2050 target of climate neutrality, the European Commission (2021) presented its legislative proposals for a 55% reduction in greenhouse gas emissions by 2030 in July 2021. This regulatory package was introduced in the midst of the pandemic. It encompasses 13 proposals, comprising proposals for a reform of already existing energy and climate legislation, as well as introduction of new legislation. This comprehensive legislative package confirms the EU's understanding that a broad mix of policy instruments is needed to address the challenges of climate change. The legislations on the one hand relate to price instruments, such as emissions trading or the carbon border adjustment mechanism, and on the other hand to regulatory targets, such as the energy efficiency target or the share of renewable energy sources. Regardless of the policy instrument, the tight time horizon of 2030 and the ambitious emission reduction target of 55% pose a major challenge for implementation, especially against the challenges of the pandemic.

Green transition implies that existing fossil infrastructures need to be replaced by more resource-efficient, carbon-free substitutes. This requires massive investments in technologies, infrastructures and R&D, and is associated with a correspondingly large financing requirement. The annual investment required by the EU to achieve the 2030 targets is estimated at about 390 billion Euro compared to the previous decade. This amounts to approximately 2% of EU GDP. Public budgets alone cannot meet the needs for funding, so in recent years the focus has shifted to the question what framework conditions are needed for a re-orientation of financial flows towards green and sustainable finance[2]). Different institutional and regulatory initiatives have been launched to push the finance sector towards an active role in the transformation process (TFCD (2017), G20 (2016), NGFS (2018). Also, the EU acknowledges private finance as an important enabler of the green transition and launched its Sustainable Finance Action Plan (COM/2018/097 final) emphasising the key role of private finance and capital markets to align investments to sustainability. Of all the regulations launched under this initiative, the taxonomy regulation (EU, 2020b) and the delegated acts are probably the most important. The aim of the taxonomy is to establish a uniform and consistent classification system on what can be considered environmentally sustainable economic activities and thus helps to trigger a closing of the investment gap along the transition path[3]). According to Claringbould et al. (2019) sustainable finance has a "… strong green, environmental and social component, to support economic growth while reducing pressures on the environment …". In this sense, the action plan focuses on three areas[4]) and establishes the main building blocks for sustainable finance at EU level.

Notwithstanding the need for structural change and the closing of the finance gap to achieve net zero carbon structures by 2050, a precondition for a successful transition process is "….to leave nobody behind" (European Commission, 2019). Different sectoral structures and emission intensities by industries and regions entail that not all regions, employees and population groups are affected by restructuring needs to the same extent. To tackle this regional heterogeneity, the Just Transition Mechanism (JTM)[5]) was put into place as of 2021. The aim of the JTM is to support regions which are strongly affected by the transition process by financing projects to diversify and modernise local economic structures with a special focus on alleviating negative labour market effects. The JTM was set up to ensure that the ambitious climate targets are achieved without creating social problems at the regional level. It consists of three pillars: the Just Transition Fund, InvestEU "Just Transition" scheme and a new Public Sector Loan Facility. To qualify for JTM funds, countries must develop "Territoral Just Transition Plans" for regions with the highest carbon intensity or the largest fossil-fuel-dependent workforce. These plans comprise the specific regional transition challenges as well as the objectives and measures for socially responsible regional climate policies to be implemented

[2]) For a brief overview of the evolution of the green finance agenda see, e.g., Kletzan-Slamanig and Köppl (2021).

[3]) The taxonomy includes the "do no significant harm" criterion (Regulation (EU) 2020/852).

[4]) The three areas are: (1) re-orient finance flows towards sustainable investment, (2) mainstream sustainability risk management and (3) foster transparency and long-termism.

[5]) See https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/finance-and-green-deal/just-transition-mechanism_en.

until 2030. Financial support from the Just Transition Fund is foreseen for three areas: (1) social support, like training or re-training measures, income support; (2) projects for decarbonising regional economic structures; and (3) land restoration. In order for the JTM to successfully achieve its initial objectives, governance structures are of relevance, as Cameron et al. (2020) stress.

The green transition requires a systemic approach, integrating a variety of policy instruments and policy areas as described in this chapter. To support such a complex process, a broader perspective on economic structures with a focus on wellbeing and basic needs could be helpful. This includes a lifecycle perspective on investments and an output-oriented perspective on value chains, as argued in the next section.

2.1.1 Broadening the perspective on economic structures

The mitigation of climate change requires a profound structural change, which raises the question on how to measure a successful transformation. In this context the focus on human well-being and basic needs is taken up in the literature (see Schinko et al., 2021) as well as approaches linking human needs to material use and material efficiency (Pauliuk et al., 2021). Satisfying the demand for services like shelter or mobility can differ in terms of resource consumption and emissions over the entire product life cycle, depending on materials used (e.g., wood or concrete for housing; lightweight for vehicles) as well as the useful life of the product.

A similar approach puts the focus on functionalities as a measure for economic performance. Functionalities are based on the idea that they are the ultimate reason for economic activities and thus refer to (basic) human needs, such as housing, nutrition or mobility, which are important for human well-being. In general, they describe the interaction of stocks and flows. Stocks are capital stocks such as buildings, vehicles or transport infrastructure, flows correspond to the associated energy and material flows required and the related emissions over the investment and operating phase. A specific functionality can be provided by different combinations of stocks and flows and differs in its respective resource requirements or the emissions triggered. Combinations of stocks and flows are to be understood as pairs belonging together; for example, vehicles and their fuel consumption, or buildings and their heating energy demand (Köppl et al., 2014; Köppl and Schleicher, 2019). First attempts to integrate the perspective of functionalities into macroeconomic modelling can be found in Sommer et al. (2021) and Bachner et al. (2021). Sommer et al. (2021) integrate the outcome-oriented perspective of functionalities into an input-output framework emphasising the relevance of the stock-flow interaction. Bachner et al. (2021) show in a scenario analysis within a CGE framework that some climate-neutral transformation strategies that satisfy the underlying demand for the functionalities shelter and mobility may result in a decline of GDP, whereas well-being may be higher when taking co-benefits into account. The analysis demonstrates the importance of a broader set of indicators when assessing socioeconomic effects of climate policy and, at the same time, provides a first step towards extending state-of-the-art modelling approaches.

A common characteristic of the described approaches is the aim to put economic performance in a broader context. The fulfillment of services, functionalities or well-being can accordingly be accompanied by differing levels of resource consumption or emission intensity. Another aspect is the broadening of the perspective to include energy and resource consumption over the entire life cycle of infrastructures and products into modelling approaches.

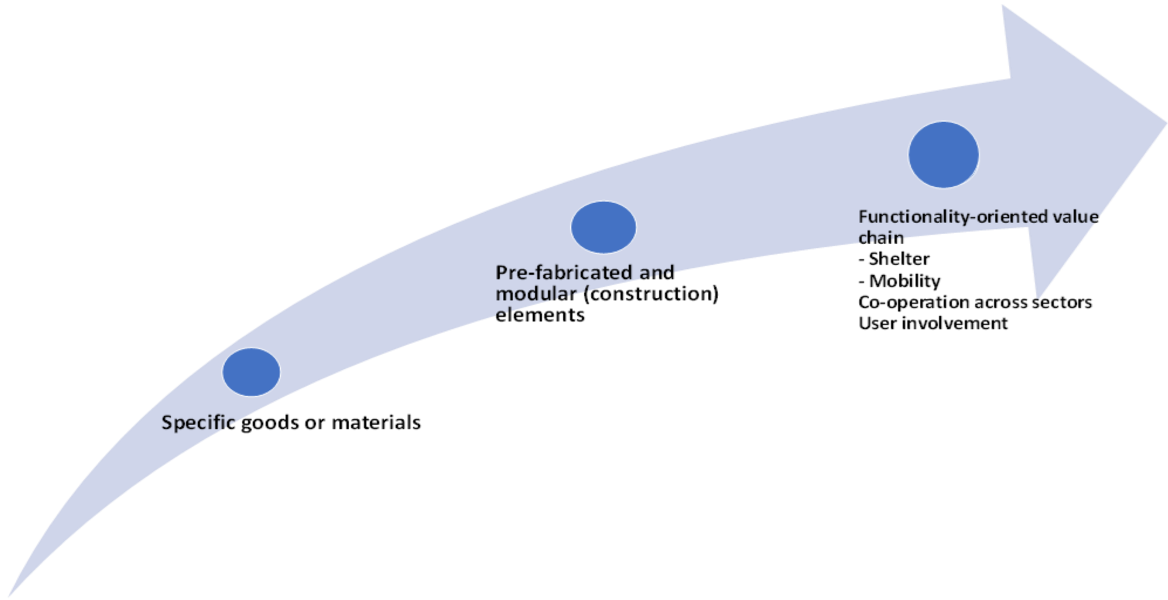
On the EU level, policy strategies and initiatives such as the Green Deal (European Commission, 2019), the EU Circular Economy Action Plan (European Commission, 2020a), the RFF (European

Commission, 2021a) and the "Fit for 55" package (European Commission, 2021b) as described above, translate the challenges society is facing into concrete policy projects. In this way, economic policy seeks to create framework conditions that drive structural change towards climate-neutrality and reduce market uncertainties about the direction of technological and behavioural change, such as through a mission-oriented innovation policy advocated by Mazzucato (2018) and others. Mazzucato (2018) defines mission-oriented policies "as systemic public policies that draw on frontier knowledge to attain specific goals" or "big science deployed to meet big problems". Climate change is one of these "big problems". In this context, technological innovation and radical technological change come into play (see Schinko et al., 2021, and the literature cited therein). Mazzucato and Skidelsky (2020) open a discussion in the context of the COVID-19 pandemic where they argue that public financing should be coupled with the role of the state regarding the stimulation of innovation and the transition of the economy. Accompanying policies to achieve the needed transformation are other market-based policies like carbon pricing or other regulatory instruments. Engström et al. (2020) mention revenue-neutral carbon tax reforms as a particularly suitable instrument for achieving long-term positive climate effects and a growth effect at the same time. They emphasise the revenue component of the tax, which creates funds for investment. According to the literature review by Köppl and Schratzenstaller (2021a) the macroeconomic effects of carbon taxes are negligible or even positive. The so-called double dividend hypothesis expects a positive employment effect if revenues from environmental or carbon taxes are used to reduce distortions of pre-existing taxes such as labour taxes.[6]) However, as Hepburn et al. (2020) emphasise, environmental taxes are one important instrument in a toolbox of available environmental policy instruments but are not sufficient to bring about a deep transition. A similar reasoning on the importance of a mix of policy instruments can be found in Pisany-Ferry (2021) who additionally stresses the need for a thorough analysis of the macroeconomics of climate policy. The need for different policy instruments is also confirmed by the impact assessment of the European Commission (2020c), that, e.g., points at different sectoral impacts of carbon pricing or an insufficient recovery for the demonstration and diffusion of innovative clean technologies by carbon pricing alone. In the case of unused capacity, a positive macroeconomic impact of an ambitious climate policy is expected.

A broader understanding of economic structures facilitates a better analysis of the impact of behavioural and technological changes that result in different resource use, i.e., the environmental effectiveness triggered by fiscal measures to combat the pandemic. This can be facilitated by an alternative perspective on value chains that goes beyond traditional sectoral thinking (see Graph 2.1.). Such a re-orientation from product- or sector-oriented value chains to functionality-oriented value chains (e.g., Köppl and Schleicher, 2019) would be well suited to capture the environmental effectiveness of economic activities and policy measures. This encompasses on the one hand cross-sectoral cooperation along the whole value chain, and on the other hand an integrated view on the investment and operating phase.

[6]) See, e.g., Bovenberg and de Mooij (1994) or Goulder (1995, 2013) on such an interaction of environmental taxes with the overall tax system.

Graph 2.1: **From product-oriented to functionality-oriented value chains**



Source: adapted from Köppl and Schleicher (2019).

2.2 Characterisation and conceptualisation of a Green Recovery or Building-Back-Better programmes

The health crisis triggered by COVID-19 has developed into a global economic and social crisis, which has been and is being countered with extensive fiscal policy packages. With the implementation of the first public aid measures the call for green recovery packages that support long-term transformation and deep structural change has already been voiced early in 2020. More or less all international institutions, e.g., OECD, IMF, and IEA, as well as climate NGOs urged decision makers and policymakers to use recovery policy to incentivise structural change and avoid a return to business as usual with structures that represent a fossil lock-in. The green recovery therefore aims to achieve social and economic recovery as well as a structural change towards environmentally-sustainable and climate-resilient structures. In principle, a variety of policy instruments is available to spur the change towards low-carbon structures[7]), even though in the context of recovery policies the existing literature mainly focuses on green investment expenditure.[8]) Andrijevic et al. (2021) conclude that transformative change needs a broader set of instruments than low-carbon energy investment spending.

Underlying this call for reform are a variety of terms. "Green recovery", "building back better" or "sustainable, resilient and inclusive recovery" are frequently used. The OECD's understanding of "building back better" includes investments and behavioural change that strengthens society's resilience against future shocks, and which focuses on well-being and inclusiveness of

[7]) See Köppl and Schratzenstaller (2021a) for a brief overview of environmental policy instruments; for the topic of instrument choice in environmental and climate policy see, e.g., Goulder and Parry (2008), Benson and Jordan (2016), or Michaelowa et al. (2018).

[8]) The various green recovery trackers suggest that indeed the existing COVID-19 recovery programmes rely mainly on (investment) spending, while tax incentives and regulatory measures appear to play a minor role; see subsection 3.1 for details.

recovery policies, not to forget alignment with climate policy goals and emission reductions (OECD, 2020a). The term green recovery has a strong focus on policy measures to combat climate change but also encompasses other relevant environmental issues, like biodiversity loss. Agrawala et al. (2020) stress that green recovery measures are very likely more suitable for the recovery over the medium term, whereas in the short run measures to help the most vulnerable households and businesses are of highest importance. An integrated assessment of policy impacts and an out-of-the-box thinking when designing recovery measures is called for by Dirth et al. (2021). The authors develop a Recovery Index for Transformative Change, which they apply to the assessment of a set of National Recovery and Resilience Plans. In order to map the transformative potential of policy measures, they propose on the one hand strict adherence to the do-no-significant-harm principle. On the other hand, the authors emphasise that only a systemic approach that does equal justice to the various sustainability challenges (economic, social, and environmental) can have a corresponding transformative effect. Rizos et al. (2020) see a move towards a circular economy for resource- and emission-intensive sectors and a corresponding alignment of policy measures within the framework of recovery programmes as an opportunity to accelerate the transformation process. Alongside, they advocate a monitoring process that continuously reviews the recovery programmes for their sustainability impact. Similarly, Chiapinelli et al. (2021) focus more strongly on the emission-intensive basic materials sectors. The authors explore options and potentials for so-called shovel-ready low emission investments in the basic materials industry (steel, chemicals, cement, aluminum). They argue that such investments as part of the recovery would ensure long-term economic development while at the same time preventing lock-ins in emission-intensive path dependencies.

Aligning recovery measures with green aspects is not a novelty in the context of the health pandemic, but has already been sought for policy responses after the GFC.[9]) Neither in the context of the recovery packages after the GFC, nor in most of the COVID-19 fiscal packages, is there a precise definition of green recovery measures. A clear definition is provided by the Recovery and Resilience Facility Regulation (RFF; European Commission, 2021a), which states that "… a contribution to the green transition should be supported by reforms and investments in green technologies and capacities, including in biodiversity, energy efficiency, building renovation and the circular economy, while contributing to the Union's climate targets, fostering sustainable growth, creating jobs and preserving energy security." In order to achieve this objective, 37% of the funds available through the RFF are targeted towards climate protection. Guidance on which measures are eligible to account as climate relevant are detailed in the Annex of the RRF Regulation.

Strand and Toman (2010) provide a comprehensive discussion on the likely effects of green recovery measures. They define green recovery as "policies and measures to stimulate short-run economic activity while at the same time preserving, protecting and enhancing environmental and natural resource quality both near-term and longer term" (Strand and Toman, 2020). Their definition captures current spending, e.g., for clean-up activities, while investment expenditures are investments for restoration like retrofitting the building stock and physical and finally new capital investment that is aligned with environment- or climate-change benefits. Their proposed assessment thus encompasses long-term growth and environmental effects, an aspect that is crucial for the deep structural change that is necessary to achieve the climate goals.

[9]) See for instance the Commission's Communication 'A European Economic Recovery Plan' COM(2008) 800 final https://ec.europa.eu/economy_finance/publications/pages/publication13504_en.pdf.

The call for green recovery packages is often based on the hypothesis that green investment measures have a higher employment impact and a higher multiplier effect than conventional ones. This is particularly argued in the context of renewable-energy investments, investments in energy efficiency, investment in improving the building stock or long-term effects of a transformation of the mobility sector (see UNEP, 2021; IEA, 2020).

Strand and Toman (2020) list three questions relevant for priority setting in decision making on recovery measures. First, what are the synergies or trade-offs between short-term economic and long-term environmental impacts? Second, are there complementarities between investments that show the highest long-term growth effect and high positive environmental effects? And finally, is there a potential for measures that show short- and long-term positive economic effects and exhibit at the same time permanent positive effects on the environment? A strict assessment into which category specific green recovery measures fall is not always straightforward, especially when comparing the conditions in the aftermath of the GFC and the current situation. When it comes to the deployment of renewable-energy technologies or storage technologies the period between 2009 and 2021 shows technological progress and drastic cost reductions (BNEF, 2020) that make them more attractive for COVID-19-related recovery measures. The environmental effect of measures often requires a broader perspective: on the one hand with regard to the system boundaries and, on the other hand, with respect to the point in time when the environmental effectiveness can be judged. Changes in e.g. the mobility system or in the building infrastructure, including the energy system, can have potentially adverse emission effects in the short term, i.e. in the investment phase, but a positive environmental effect in an integrated view over the investment and operating phase. In terms of desirable green recovery measures the potential trade-offs or synergies need to be carefully assessed from case to case. The aim of recovery measures should be to shape the use of public funds in such a way that several policy objectives are taken into account. Equally important is the objective that neither in the short- nor in the long-term other policy objectives, like the climate goals, are violated by recovery measures, e.g., by financing carbon lock-in industries or projects (Hepburn et al., 2020). The establishment of the RFF (Regulation (EU) 2021/241) takes account of this by requiring that the facility shall only support measures respecting the do-no-significant-harm principle.

Agrawala et al. (2020) as well as Jaeger et al. (2020) look at green recovery packages based on the post-financial-crisis experience. Their definition of green recovery packages essentially follows that of Strand and Toman (2011). They list indirect green recovery measures like tax cuts (e.g., tax privileges for electric vehicles) or subsidies (e.g., for retrofits of buildings) and direct infrastructure investments (e.g., infrastructure for public transport) as the most common instruments for green recovery measures. Jaeger et al. (2020) use a broad definition of green recovery which also includes, e.g., spending on nuclear energy or carbon capture and storage, and they provide an empirical assessment emphasising the difficulties when it comes to identify the green components of recovery measures. Also building on the experience of the GFC and green recovery measures Chen et al. (2020) direct the focus on the requirement of green skills which may become a limiting factor in boosting short-term employment. In that sense re-training programmes can play an important role for positive longer-term employment effects and unfold positive long-term transformation and growth potential. Clear employment effects from the American recovery plan after the global financial crisis are found by Popp et al. (2020), but the authors conclude that green recovery projects work more slowly and are thus better suited for desired structural changes in the economy than for a quick recovery impact.

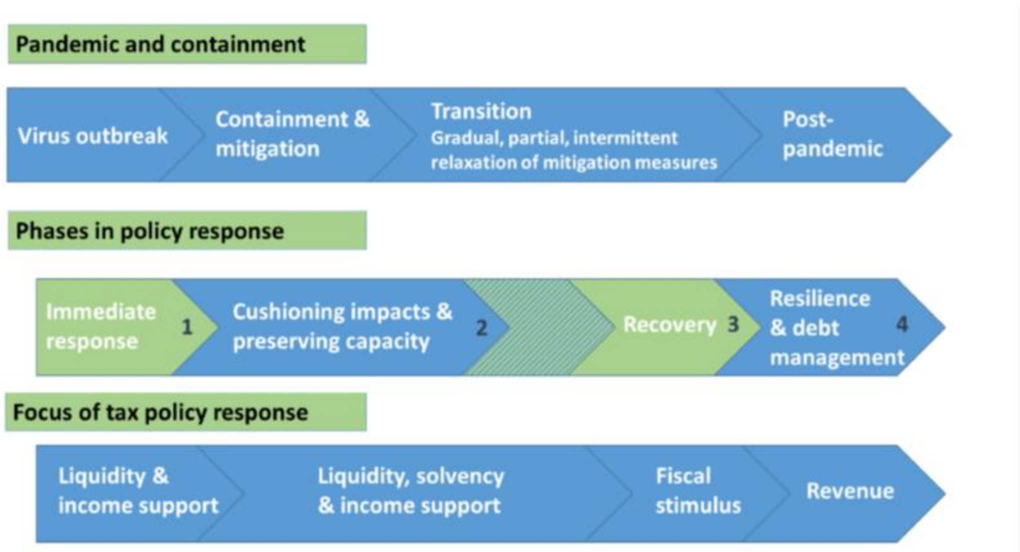
Also Kröger et al. (2020*)* propose to use experience from the GFC for green recovery policies, stating that "the additional transformative feature of a green recovery can reinforce rather than hamper the targeted and temporary effect of a conventional recovery and support its short-term objectives". They stress the need for clear environmental policy targets when designing the individual recovery measures as well as the alignment with a broader investment framework. This would guide investors towards environmental- or climate-friendly technologies and offers prospects for new markets.

2.2.1 Phases of policy response in times of crisis

Agrawala et al. (2020) point at the crucial differences between previous crises and the current economic and social crisis triggered by COVID-19. The authors refer to the timeline of the pandemic and the phases of policy responses in OECD (2020b) as illustrated in Graph 2.2. and state that phases 1 and 2, mainly focused on health and social issues as well as economic concerns, require some attention regarding environmental issues in order to avoid detrimental environmental effects. The main focus on green issues will, however, be placed best in phase 3, the recovery phase (Graph 2.2.).

Referring to the experience of the recovery packages in the aftermath of the GFC Agrawala et al. (2020) stress that in the current crisis there is room to give more weight in the recovery phase to the health and environment nexus which is underpinned by scientific evidence on increased vulnerability due to environmental stressors. They also suggest the inclusion of "just transition" aspects into recovery packages. Apart from the recovery packages, just transition is increasingly coming to the forefront of the research and policy agenda when transformation needs to tackle climate change are discussed. And finally, not only costs and availability of less emission-intensive technologies have changed largely from a decade ago, but also the regulatory framework, especially in the EU, as well as public perception with respect to future challenges.

Graph 2.2: **The COVID-19 pandemic and phases of policy response**



Source: Agrawala et al. (2020).

2.2.2 Green recovery – conceptual foundations

Based on the literature and policy discussions on green recovery, Maas and Lucas (2021) contribute with their attempt to systematically assess characteristics of green recovery programmes with respect to effectiveness, efficiency and feasibility. They identify three heterogenous green recovery concepts: (1) green recovery as a co-benefit, (2) green recovery as a necessary condition, and (3) green recovery as an opportunity.

The first category "co-benefit" strongly overlaps with the understanding of green recovery as used in Strand and Toman (2010), which concerns synergies between short-run socioeconomic recovery and environmental benefits.

The second category "necessary condition" follows the "do no significant harm" criterion in order to avoid additional future transition costs. It states that recovery measures must avoid sectors or activities that may become stranded assets and would turn out as aggravating climate change and as avoidable costs of transition.

The third underlying rationale "opportunity" encompasses the broadest definition of green recovery and sees a chance to redirect investment flows towards transformational change. The large amounts of public money to fight the pandemic are seen as an opportunity to deliberately direct investment towards sustainable pathways. In this case economic recovery and transformative change coincide[10]).

Maas and Lucas (2021) clearly put the "green" in the forefront of their argumentation and propose four assessment criteria for the success of green stimuli: effectiveness, efficiency, feasibility and overarching implementation. "Effectiveness" describes the contribution to green recovery as well as at what point in time the effects will be realised. A further aspect of effectiveness is its contribution to short-term recovery on the one hand, and how strongly it unfolds its transformational potential on the other hand. Here effectiveness also covers aspects discussed above like timing, potential synergies and trade-offs, as well as aspects of just transition. "Efficiency" is understood as cost-effectiveness, which depends on the time frame considered as well as on the costs and benefits included. The criterion "feasibility" addresses possible barriers that hinder the implementation of green stimuli, like political and societal acceptability. Finally, "overarching issues" is concerned with the overall character of the recovery packages and refers to the temporary character of the programme and how strongly it is embedded into longer-term transition strategies and the need for monitoring and adaptation, when integrated in long-term transition strategies.

2.2.3 Fiscal multipliers

Fiscal multipliers are a central theoretical concept in the context of recovery programmes. Generally, fiscal multipliers measure the effect of fiscal instruments on output. Depending on the fiscal instrument, they either measure the change in GDP due to a change in tax revenue or, analogously, a change in output due to a change in government spending. Ramey (2019) summarises the main transmission channels in different theoretical economic frameworks, like the relevance of the marginal propensity of consumption in the Keynesian model or the crowding out assumption in the neoclassical model. Besides, other factors like the concrete economic framework conditions when the intervention takes place, the timespan over which

[10]) However, regardless of the potential of the positive economic impact of green recovery investments, Pisani-Ferry (2021) emphasises that the urgency of transformation and accelerated transition to net zero carbon structures is also associated with significant macroeconomic costs like an outdated stock of capital from a climate perspective.

the government intervention is planned, whether it is a spending or tax intervention, or the financing sources are relevant.

In the context of the pandemic it is not the size of multipliers in "normal" times which is of interest, but rather the question how effective recovery measures are in times of crisis. There seems to be a consensus that government spending to relieve the economic impact in times of recession are typically larger than in "normal" times and above 1. The difference in the size of multipliers between normal times and recessions is due not least to the fact that the risk of crowding out is absent in times of recession (Baum et al., 2012).

The literature on fiscal multipliers typically focusses on the short-term effect of fiscal stimulus measures, whereas there is a lack of evidence about long-term effects of recovery measures. Long-term multiplier effects referred to in Allan et al. (2020) stem from, e.g., transformative investments in the electricity sector, in carbon-intensive sectors or in climate-resilient infrastructure, but also targeted R&D investments as well as training and re-training are considered as relevant for long-term multiplier effects. The authors thus point out that there is a range of recovery measures that exhibit both long-term multiplier effects and a positive impact on emission reductions. Similarly, Hepburn et al. (2020) argue for recovery measures that are characterised by long-term multipliers with a positive effect towards less-emission-intensive structures. According to the authors, the COVID-19 recovery decisions will have a decisive effect on the achievement of the climate policy targets.

Most of the theoretical discussion of multipliers concerns spending programs and tax measures in general and does not distinguish between green and conventional recovery investments. Gechert *(2017)* provides a good overview of the theoretical foundations of fiscal multipliers, addressing, among other things, the channels of impact, the various fiscal instruments, or the institutional factors that determine the effectiveness of recovery measures. "Greenness", however, does not play any role in the existing theoretical foundations of recovery programmes and their effectiveness. Where the green aspect is included explicitly (e.g., Jaeger et al., 2020), the contribution of the green factor is evaluated positively. In addition, two facts should be noted in comparison to the GFC. First, the climate crisis and the need to take swift and decisive action to limit climate change is more urgent than it was more than a decade ago. Second, the availability of innovative technologies in relevant areas such as clean energy, alternative mobility systems or climate-friendly building technologies features a broader range of low-cost alternatives today.

3 Empirical evidence

After presenting some data on the relevance of green spending in overall COVID-19-related recovery programmes in the largest economies worldwide, this chapter reviews the existing body of empirical evidence regarding the economic impact of green recovery measures.

3.1 Green spending in overall COVID-19-related recovery spending

As mentioned above, several databases have been established to determine the share of green elements in COVID-19-related recovery spending. Due to methodological differences, differences in the definition of "green"[11]) and in the weights attached to individual green measures (i.e., the quantification of the degree of their "greenness") as well as differing data sources (most trackers use publicly available information) and cut-off dates, the results of the

[11]) For a presentation and discussion of the concept of "green" and its social, economic and political aspects and implications see Nordhaus (2021).

individual trackers differ. Moreover, some trackers focus on specific areas only. Also, the countries or regions included differ, as well as the measures considered. However, the common conclusion that can be drawn from the available data is that until now, the contribution of pandemic spending to a green recovery is rather limited in the developed world. Table 1 gives an overview of the results of three green recovery trackers that have gained some prominence in the academic literature as well as in the policy discussion and that attempt at a comprehensive coverage of green recovery measures implemented by a relatively large number of countries: the Oxford UNEP Global Recovery Observatory, the OECD Green Recovery Database, and the Vivid Economics Green Stimulus Index.[12])

According to the Oxford-UNEP Global Recovery Observatory (O'Callaghan et al., 2020; O'Callaghan and Murdock, 2021[13]), COVID-19-related spending in the 50 largest economies[14]) so far (November 2021) amounts to about US $ 17 trillion, of which the lion's share (US $ 14.55 trillion, i.e., 86%) consists of immediate short-term rescue measures for individuals/households and firms. Only 14% (US $ 2.42 trillion) of overall COVID-19-related spending is related to recovery measures, i.e. measures of a long-term nature that support economic growth. Of these, only about 22% (i.e., US $ 760 billion of US $ 2.42 trillion) were green by November 2021. Thus, green recovery spending makes up for 4.5% of overall COVID-19-related spending.

The Oxford-UNEP Global Recovery Observatory is the green recovery tracker with the most elaborate and granular tracking methodology among the existing trackers. To identify green recovery measures, the authors in a first step develop a taxonomy distinguishing between rescue and recovery measures and defining 40 archetypes, which are again broken down into 158 subarchetypes. These archetypes serve to undertake a classification of COVID-19-related policies. The "greenness" of recovery measures depends on their potential impact on long- and short-term GHG emissions, air pollution, and natural capital. This impact is assessed based on relevant literature and input from leading experts at private, public, and research institutions; and quantified using Likert scales.[15]) This allows the identification of those measures that have a positive environmental impact (see table 3.1). Most green recovery spending in the 50 largest economies is invested in green transport, followed by low carbon energy, natural capital (e.g., reforestation), green building upgrades, and green R&D.

The OECD Green Recovery Database[16]) yields a similar result with regard to the green spending share in recovery measures. Total COVID-19-related spending in the 44 countries (OECD countries and most G20 countries) included in the database reaches US $ 17 trillion by July 2021, of which about 19% (US $ 3.2 billion) are recovery measures, and about 81% immediate rescue measures. 21% (US $ 677 billion) of COVID-19-related recovery spending of the 44 countries considered are classified as green as they have a positive environmental impact across all affected environmental dimensions.[17]) According to the classification applied by the OECD, the bulk of these measures addresses climate change through climate-change-mitigation measures, followed by air pollution, water, biodiversity, and waste management and recycling. This classification is based on "existing and emerging classification systems for environmental effects, such as the EU Taxonomy for Sustainable Activities, and OECD

[12]) See OECD (2021) for a brief comparative presentation of the methodological approaches used by these three trackers and for a brief overview of further trackers.

[13]) https://recovery.smithschool.ox.ac.uk/tracking/.

[14]) The database was expanded in March 2021 by 39 emerging market and developing economies.

[15]) For a detailed description of the methodology see O'Callaghan et al. (2021).

[16]) https://www.oecd.org/coronavirus/en/themes/green-recovery. See OECD (2021) for key findings of the latest update including data until mid-July 2021.

[17]) See OECD (2021) for methodological details.

assessments of those methods already published…" (OECD, 2020c: 4). Six types of policy measures are distinguished: Tax reductions or other subsidies (not R&D); grants or loans (including interest-free loans and guarantees); regulatory change; skills and training; R&D specific subsidies (see Table 3.1).

The Greenness of Stimulus Index provided by Vivid Economics (2021) includes the G20 and another 10 countries. In contrast to the preceding two trackers, it does not distinguish between rescue and recovery measures, but shows only the sum of COVID-19-related spending, so that the results are not comparable with those provided by the Oxford-UNEP Global Recovery Observatory and the OECD. Vivid Economics finds that 10.5% (US $ 1.8 trillion) of COVID-19-related spending announced until June 2021 (altogether US $ 17.2 trillion) are green. Hereby, green spending is defined as spending into the energy, transport, industry, agriculture, and waste sectors reducing greenhouse gas emissions or enhancing nature and biodiversity. To classify COVID-19-related recovery measures with positive environmental impact, six general policy archetypes are defined. These are specified for the five relevant sectors mentioned above (see Table 3.1).

Table 3.1: **Selected green recovery trackers**

Green stimulus tracker (cut-off date)	Countries included	COVID-19-related spending	recovery spending		green recovery spending			green spending areas	Green measures
		Total (US $ trillion)	Total (US $ trillion)	In % of total COVID-19 spending	Total (US $ trillion)	In % of recovery spending	In % of total COVID-19 spending		
Oxford-UNEP Global Recovery Observatory (November 2021)	50 largest economies[1)]	16.97	2.42	14	0.76	21.7	4.5	GHG emissions, air pollution, natural capital	green market creation, clean R&D investment, electric vehicle incentives, clean transport infrastructure investment, clean energy infrastructure investment, buildings upgrades and energy efficiency infrastructure investment, natural infrastructure and green spaces investment, electronic appliances incentives, green worker retraining and job creation
OECD Green Recovery Database (July 2021)	44 countries (OECD countries and most G20 countries)[2)]	17	3.2	18.8	0.677	21.2	4.0	energy and climate, pollution (air and plastics), water, biodiversity, waste management	Tax reductions or other subsidies (not R&D), grants or loans (including interest-free loans and guarantees), regulatory change, skills and training, R&D specific subsidies
Vivid Economics Green Stimulus Index (June 2021)	G20 countries plus further 10 countries[3)]	17.2	n.a.	n.a.	1.8[1)]	n.a.	10.5	energy, transport, industry, agriculture, waste	Bailouts with green strings attached, nature-based solutions, loan and grants for green investments, conservation and wildlife protection programmes, green R&D subsidies, subsidies or tax reductions for green products

Source: O'Callaghan et al. (2020); OECD; Vivid Economics (2021); own calculations and representation; bold: countries represented in all trackers. – 1) Argentina, Australia, Austria, Bangladesh, Belgium, Brazil, Canada, Chile, China, Colombia, Czech Republic, Denmark, Egypt, Finland, France, Germany, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Japan, Malaysia, Mexico, Netherlands, Nigeria, Norway, Pakistan, Peru, Philippines, Poland, Portugal, Romania, Russian Federation, Saudi Arabia, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, Turkey, United Arab Emirates, United Kingdom, USA. – 2) Australia, Austria, Belgium, Brazil, Canada, Chile, China, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Iceland, Ireland, Israel, Italy, Japan, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Russian Federation, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Switzerland, Turkey, United Kingdom, USA. – 3) Argentina, Australia, Brazil, Canada, China, Colombia, Denmark, Finland, France, Germany, Iceland, India, Indonesia, Italy, Japan, Mexico, Norway, Philippines, Russian Federation, Saudi Arabia, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Turkey, United Kingdom, USA.

Overall, therefore, the actual extent of greenness of COVID-19-related spending programmes is limited, albeit with considerable cross-country differences. A comparison with recovery programmes implemented during the GFC is interesting, although it has its limitations: inter alia, the tracking methodology used to determine the green content of GFC recovery measures appears to be less elaborated than the approaches applied by the three COVID-19 trackers. Moreover, even if both Robins et al. (2009a, 2009b, 2009c, 2010) in their analyses of the GFC recovery measures and the three COVID-19 trackers use a rather broad definition of greenness[18]), the individual definitions do not completely overlap. Compared to green fiscal recovery during the GFC, which reached 16.3% of total fiscal recovery (US $ 522 billion) in the EU, the US, Japan, China, and South Korea (Robins et al., 2010), the green spending share of COVID-19 fiscal measures at the national level as identified by now appears to be only slightly higher, at about 21% according to the trackers developed by the OECD and Oxford-UNEP.

It is also remarkable that green recovery measures announced and implemented, respectively, during the ongoing pandemic have a rather narrow focus, as, for example, the OECD Green Recovery Database shows: they mostly aim at climate change mitigation and air pollution – 64% of recovery measures with positive environmental impacts address climate mitigation, 44% address air pollution. Rather little attention is dedicated to biodiversity, waste, and green skills. According to the overview provided by Barbier (2010a), low carbon measures (support for renewable energy, carbon capture and sequestration, energy efficiency, public transport and rail, improving electrical grid transmission) announced during the GFC by G20 countries, 9 non-G20 EU countries[19]) and 9 non-EU non-G20 countries[20]) had an even higher weight, making up for about 80% of total green recovery measures (see also table 3.4).

Climate spending plays a more important role in the European recovery package "NextGenerationEU" (NGEU) financed by European debt, with the Recovery and Resilience Facility (RRF) as the by far largest instrument. An overall volume of € 672.5 billion can be applied for by Member States either in the form of grants or loans based on national recovery and resilience plans (NRRPs), of which 37% are to be allocated to climate protection by Member States calculated on the basis of the climate tracking methodology as defined in the RFF regulation[21]). On average, the share of climate spending for those 22 Member States whose national recovery NRRPs have been approved already by the European Commission[22]) (by the end of December, 2021) amounts to 40%; ranging from 37.5% (Italy) to 61% (Luxembourg).

The results of the various green recovery trackers need to be taken with some caution. First of all, and very generally, they are based on (differing) tracking methodologies that need to make use of certain simplifications and therefore necessarily contain inaccuracies, i.e., they can lead to an over- or underestimation of the green content of fiscal measures.[23]) *O'Callaghan et al.* (2021) mention further difficulties of such classifications. Accordingly, another source of inaccuracies is policy-level variation, which limits the cross-country comparability of individual recovery measures. Moreover, there is the so-called spending-expenditure anomaly, i.e., a potential discrepancy between the amount and structure of

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[18]) Robins et al. include investment in renewable energy; building efficiency; efficient and low carbon vehicles including electric vehicles; grid modernization; rail transportation; water management, including sewage treatment, dams and flood defenses, canal and waterways, and environmental restoration; carbon capture and storage; and nuclear energy (ILO, 2011). For the green areas and measures included in the three COVID-19 trackers see table 3.1.

[19]) Austria, Belgium, Greece, Hungary, The Netherlands, Poland, Portugal, Spain, Sweden.

[20]) Chile, Israel, Malaysia, New Zealand, Norway, Philippines, Switzerland, Thailand, Vietnam.

[21]) Regulation 2021/214 establishing the Recovery and Resilience Facility, Annex VI.

[22]) For the available national recovery and resilience plans and endorsements by the European Commission, see Recovery and Resilience Facility | European Commission (europa.eu). The NRRPs of Bulgaria, Hungary, Poland, and Sweden have not been endorsed yet by the European Commission; The Netherlands have not yet submitted a NRRP.

[23]) See OECD (2020c) on climate tracking methodologies; see Nesbit et al. (2020) for a critical review of the climate tracking methodology used for the EU budget.

announced spending and actual expenditure, which calls for ex-post evaluations complementing the results of the ex-ante trackers.

It should also be pointed out that looking only at the green content of fiscal recovery measures to assess the greenness of recovery programmes yields an incomplete picture. On the one hand, regulatory changes with positive environmental effects as part of government responses to the COVID-19 pandemic are neglected (OECD, 2021). On the other hand, recovery as well as regulatory measures with negative environmental effects counteract positive measures, which is why they are considered by all three trackers.[24])

The OECD (2021) mentions several further limitations. The distinction between environmentally positive and negative measures and measures with mixed effects is not always straightforward. There may also be an overestimation of positive measures compared to negative ones, as green measures are often easier to identify and because funding information is available for a larger share of positive measures. Not least, the coverage of recovery measures is probably better for OECD countries than for the further partner countries also included in the database.

3.2 Methodological aspects and challenges

The number of analyses studying empirically the economic impact of green policies in general and particularly of green recovery measures is surprisingly limited, considering the attention this issue has been receiving particularly from policymakers at national and international level as well as from international institutions during the GFC and now anew in the current COVID-19 crisis. Generally, the breadth of the perspective of studies researching the economic impact of green policies varies: some have a rather narrow focus on specific impact dimensions, e.g. job creation or patents, while others take a broader perspective of sustainable development (Mundaca and Luth Richter, 2015).

The small body of empirical studies evaluating the economic effects of green recovery measures can be classified along various criteria.

A first, very general distinction is between ex-ante and ex-post assessments (Agarwala et al., 2020). The bulk of empirical work consists of ex-ante simulations of specific green recovery measures or whole green recovery programmes, while there are very few ex-post evaluations. One crucial advantage of ex-post evaluations is that they deliver more reliable results compared to ex-ante simulations, which have to rely on many and often rather strict assumptions. Moreover, the actual effects of recovery measures can deviate from those determined in ex-ante simulations if actual expenditures deviate from planned ones (O'Callaghan and Murdock, 2020). Regarding the GFC green recovery measures, only 89% of the allocated sums were actually spent, in Canada this share amounted to 77% and in Australia to 34% only (Tienhaara, 2018). On the other hand, ex-post evaluations need to formulate a baseline scenario, and the validity of their results crucially hinges on the quality of data as well as their rigour and methodological approach. Moreover, ex-post evaluations of green recovery measures encounter the difficulty to disentangle their impact from other factors, e.g., from other recovery measures implemented at the same time or other relevant economic or regulatory developments (Jaeger et al., 2020), to identify their pure causal effect and to address additionality (Mundaca and Luth Richter, 2015). Not least, as many countries are affected by the COVID-19 crisis simultaneously, also green recovery programmes have been implemented simultaneously, so that cross-country comparisons are difficult.

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[24]) See section 3.3.2.5 for more details.

Ex-ante analyses usually rest on model simulations using a variety of simulation methods and models. Hereby, particularly input-output-models and computable general equilibrium (CGE) models are applied, whereas qualitative approaches, e.g., expert assessments, are less common. As model specifications, assumptions, data, and simulated scenarios may vary, the results of ex-ante simulations may differ accordingly, which makes their direct comparison difficult (Kammen et al., 2006). Ex-post evaluations of green recovery measures use a variety of methodological approaches: qualitative methods (e.g., expert interviews), descriptive statistics, case studies and simulation exercises as well as a broad range of statistical and econometric approaches can be found in the literature. A first group of ex-post evaluations compares actual and projected developments and therefore needs to formulate a baseline scenario; a second group undertakes the quantification of the impact of a green recovery measure itself. Differing methodological approaches, databases, and time periods studied may yield differing results of ex-post evaluations. Moreover, different policy designs, general macroeconomic and specific framework conditions (e.g., energy mix, skills and qualifications, consumption and production patterns, transport infrastructure, etc.) may lead to differing effects of identical or similar green recovery measures across countries.

Another criterion to differentiate between existing empirical studies on the impact of green recovery measures is their geographical scope. Most existing impact studies – regardless whether ex-ante or ex-post – cover individual countries. A minority only focuses on country groups (Agarwala et al., 2020). In addition, the time dimension is of importance – i.e., the distinction between short- and longer-run effects.

Furthermore, the existing empirical studies research various impact dimensions from an economic perspective. Some analyses focus on growth effects, others on the impact on employment, and still others on both. It is not an easy task to capture and evaluate the employment impact of green recovery measures. Employment effects can be negative in "old" sectors and positive in "new" ones, thus resulting in an overall net employment effect. In principle, potential employment effects of green fiscal measures will have different time horizons (Fankhauser et al., 2008). Accordingly, direct, indirect and induced effects can be distinguished (Harsdorff and Phillips, 2013; International Energy Agency, 2020). Direct job effects can be quantified by spreadsheet-type computations. In the medium run and still in a more static perspective, the overall economy is affected by the fiscal measure, leading to an economy-wide overall indirect net employment impact that can be estimated using input-output-models. In the long run, in a dynamic perspective the fiscal measure may result in innovation and new technologies and thus create additional employment opportunities or induced employment. To capture such induced job effects, CGE models are applied, which can account for dynamic, intertemporal effects.

3.3 Empirical results

In this section we review relevant empirical work on the macroeconomic effects of green recovery measures. This review is embedded in a brief survey of the existing empirical work on macroeconomic effects of fiscal measures in general.

3.3.1 General results for macroeconomic effects of recovery measures

A large body of empirical research on the macroeconomic effects of recovery measures has accumulated over the last few decades. These analyses primarily focus on the effects of discretionary fiscal policy on output, i.e., GDP. Usually, these effects are measured by fiscal multipliers, which are determined by relating a change in output to a discretionary change in public expenditures or revenues. Less often, the macroeconomic effect is measured in terms of employment (see, e.g., Monacelli et al., 2010). The large majority of empirical work focuses on short-run multipliers. Empirical estimates of the magnitude of multipliers can be found in the literature for both normal and crisis periods.

Already before the GFC, a consensus regarding the size of fiscal multipliers was lacking in the empirical literature. The GFC provoked a large wave of empirical studies to evaluate the effects of recovery and of fiscal consolidation measures taken in the wake of this crisis (Gechert, 2015), differentiating and extending the results of pre-GFC empirical work on the size of fiscal multipliers.

The existing estimates for fiscal multipliers lie within a broad range and are rather heterogeneous. The size of fiscal multipliers in "normal" times (as opposed to recessions or booms) is reported by Batini et al. (2014) in the range between 0 and 1, where spending multipliers are typically larger than revenue multipliers, with an average magnitude of 0.6. Ramey (2019) finds that the majority of estimates in the recent literature range between 0.6 and 1 and points out that depending on country characteristics this rather narrow range widens. Surveying 578 estimates from 68 studies, Bom and Ligthart (2014) find estimates for the elasticity of output regarding public capital between -1.7 and 2.04. The heterogeneity of fiscal multipliers can be attributed to various factors. From a methodological point of view, these factors include modelling choices (Čapek and Crespo Cuaresmo, 2020), identification strategies (Gechert, 2015; Caldara and Kamps, 2017; Čapek and Crespo Cuaresmo, 2020), different kinds of empirical models and estimation methods as well as study design in general (Gechert, 2015), and different data (Bom and Ligthart, 2014).

Apart from methodological issues, there are country-specific differences in the size of fiscal multipliers which date back to several structural determinants (Warmedinger et al., 2015). Barrell et al. (2012) and Ilzetzki et al. (2013) find that the larger trade openness is, the lower fiscal multipliers are. This finding is confirmed by the meta-analysis by Gechert (2015). A flexible exchange regime reduces fiscal multipliers (Born et al., 2013; Ilzetzki et al., 2013). Also, the institutional setting matters, and in particular labour market institutions: Cole and Ohanian (2004) or Gorodnichenko et al. (2012) show that rigid labour markets are associated with larger fiscal multipliers. A negative relationship between fiscal multipliers and the size of automatic stabilisers is found by Dolls et al. (2012). Ilzetzki et al. (2013), Kirchner et al. (2010) and Huidrom et al. (2019) find that multipliers are lower in high-debt countries. According to Miyamoto et al. (2018) and Bonam et al. (2020), government consumption and investment multipliers are higher in a situation in which interest rates are low. The few existing empirical studies accounting for the development level of countries (e.g., Kraay, 2012; Ilzetzki et al., 2013) suggest that fiscal multipliers are larger in advanced economies compared to emerging economies and low-income countries.

Several stylised facts can be derived from the empirical literature on fiscal multipliers. Hemming et al. (2002) find that spending increases are associated with larger fiscal multipliers compared to tax reductions; a finding which is corroborated by the surveys provided by Batini et al. (2014) and Mineshima et al. (2014) and the meta-analysis by Gechert (2015). Recent empirical research points to the asymmetry of multipliers across business cycle phases (Čapek and Crespo Cuaresmo, 2019; Gechert, 2015). Generally, expansionary fiscal policies are more effective during recessions and are associated with larger fiscal multipliers compared to "normal" times, regarding GDP and employment (Fatás and Mihov, 2009; Christiano et al., 2011; Freedman et al., 2009; Auerbach and Gorodnichenko, 2012A and 2012B; Baum et al., 2012; Cohen-Setton et al., 2019; Blanchard and Leigh, 2013). In their meta-regression analysis Gechert and Rannenberg (2018) find that spending multipliers are considerably higher during recessions (by about 0.7 to 0.9 units). In their survey mentioned above, Batini et al. (2014) find that the size of fiscal multipliers in "normal" times range from 0 to 1, while during downturns spending multipliers lie between 0.6 and 2.4. Similarly, Jorda and Taylor (2013) find that contractionary measures within fiscal consolidation programmes are associated with larger (negative) multiplier effects during a downturn than in an upswing. This finding of a state dependency of the size of fiscal multipliers is somewhat questioned by Ramey and Zubairy (2018) who assess the evidence of larger fiscal multipliers during recessions for the US as rather weak. According to Caggiano et al. (2015), significant differences in the size of spending multipliers exist between very deep recessions and strong expansions only.

The importance of accommodative monetary policy for the effectiveness of fiscal stimulus measures is underlined by the studies by Freedman et al. (2009) or Coenen et al. (2012). Cloyne et al. (2020) show that the fiscal multiplier is highly dependent on monetary policy, ranging between zero and 2 depending on the monetary offset. Finally, Freedman et al. (2009) conclude that the involvement of many countries enhances multiplier effects compared to unilateral stimulus measures. Such macroeconomic spillovers were quantified recently in an ex-ante model simulation study by Pfeiffer et al. (2021) for the investments financed through the European recovery plan NGEU.

It is interesting that there is relatively little empirical evidence available with regard to potential differences in fiscal multipliers for different fiscal instruments. Coenen et al. (2013), studying recovery packages implemented in the Eurozone after the GFC, find differing multipliers for different fiscal stimulus measures. According to their model simulations, public investment, while being a little less effective than government consumption in the short run, has larger multipliers in the longer run. The lowest output effects are associated with transfers to private households, and also revenue multipliers are rather modest. According to Coenen et al. (2012), the multiplier effects of additional permanent government consumption and transfer expenditures are short-lived only, whereas permanent increases in public investment result in larger and potentially even permanent multiplier effects. Similarly, Freedman et al. (2009) show that short-run multipliers for public investment are larger than those for other expansionary measures. These results are supported by the meta-analysis provided by Gechert (2015) finding that multipliers of public investment are larger compared to public expenditures in general. The meta-regression analysis by Gechert and Rannenberg (2018) shows that all spending categories except government consumption are associated with multipliers significantly above 1 in recessions. In their meta-regression analysis, Bom and Ligthart (2014) find that output elasticity of public capital is higher in the long run, and higher for core infrastructure (i.e., roads, railways, airports, and utilities).

Tax multipliers have received far less attention in the empirical literature in the past compared to spending multipliers. In particular, relatively little evidence exists on the state dependency of tax multipliers. Bonam – Konietschke (2020) explain this research gap with the pro-cyclicality of revenues, so that exogenous tax shocks are hard to identify. For a panel of 9 countries (US, Austria, United Kingdom, Germany, Portugal, the Netherlands, Japan, Spain, and Canada) covering the period from 1948 to 2017, the authors find that tax multipliers are highly dependent on the business cycle. While in – albeit only large – economic expansions a tax increase has a persistently negative impact on output, tax shocks do not result in a significant output response during a recession, neither in the short nor in the long run. This finding stands in contrast to the meta-analysis by Gechert and Rannenberg (2018), according to which the economic regime is important for spending multipliers only, not for tax multipliers, which do not differ in upswings and downturns. Alesina et al. (2018) find only small differences of the output response to tax-based fiscal consolidations between recessions and expansions for a panel of 16 OECD countries. A review of recent empirical evidence by Ramey (2019) suggests that tax multipliers are larger in expansions compared to recessions. The tax multipliers estimated by Sims and Wolff (2018) are considerably higher in expansions than in recessions – e.g., they arrive at a capital tax multiplier of 1 in recessions and almost 2 in expansions. Of interest is also the finding by Bonam and Konitschke (2020) of a non-linear output response regarding the direction of the tax shock, implying that only tax increases, but not tax cuts have an impact on output. In our context a differentiation between the multiplier effects of green and other taxes would be interesting; however, most empirical research on the size of tax multipliers does not distinguish between individual tax instruments. The few studies that undertake such a differentiated analysis (Riera-Crichton et al., 2016, Dabla-Norris and Lima, 2018, Gunter et al., 2018) mostly focus on non-green taxes. To our knowledge, the recent study by Schoder (2021) is the only one estimating green tax multipliers. These are found to be smaller compared to personal income tax multipliers, making them a fiscal consolidation measure combining positive environmental effects with smaller negative macroeconomic effects compared to increases of personal income taxes.

Often the existing empirical studies focus on short-run multipliers. Considerably fewer studies distinguish between short- and longer-term fiscal multipliers. For public infrastructure investment, Ilzetzki et al. (2013) show for a panel of 44 countries that long-term multipliers at 1.6 are considerably higher than short-term multipliers (0.4). Analyses by the IMF (2014) for a panel of advanced economies find that raising public infrastructure investment leads to output increases especially during economic downturns and for high investment efficiency, and that there are short- as well as long-term effects. According to the studies by Leduc and Wilson (2013 and 2017) and Ramey (2020) for the US, the long-run multipliers of public infrastructure investment are higher than the short-run multipliers. Leff Yaffe (2020) and Leduc and Wilson (2013 and 2017) also find small or even negative short-run effects of public infrastructure investment on employment for the US, while long-term multipliers are large. These findings are corroborated by Dupor (2017) and Ramey (2020). They are also consistent with the empirical evidence by Boehm (2020) for a panel of OECD countries, showing that the short-run multipliers of government consumption are larger compared to government investment. After a thorough review of the empirical evidence, Ramey (2020) draws the conclusion that public infrastructure investment and public investment in general has little short-run effects, with the majority of studies showing even negative short-run employment effects.

3.3.2 Macroeconomic effects of green recovery measures

The conventional theoretical and empirical studies researching the multiplier effects of stimulus measures usually do not differentiate between green and non-green fiscal measures, as the brief overview presented in the preceding section shows. This is evident, for example, in the case of infrastructure investment, which in empirical research often is dealt with in an aggregate form, although it may include a range of different concrete projects with varying climate-friendliness – e.g., construction of highways versus railways. Only recently, against the background of the increasing awareness of the climate crisis and of the urgent need for action required to contain it, a still small, but growing body of research has evolved that attempts at capturing the macroeconomic effects of green recovery measures, mostly in the wake of the GFC and inspired anew by the current COVID-19 crisis.

As indicated in the introduction, several questions are of interest: First, which green recovery measures are most promising with regard to macroeconomic effects, i.e., growth and employment? Second, do green recovery measures have larger macroeconomic effects than non-green fiscal measures? And third, which factors determine the success of green recovery measures? These are the questions motivating the review of empirical evidence which is undertaken in what follows.

We divide the growing body of empirical research in three groups. A first group of studies attempts to determine the hypothetical impact of different green recovery measures in a comparative perspective. A second strand of the relevant empirical research evaluates the green recovery measures implemented in several countries in the wake of the GFC. A third group consists of recent cross-country research on green spending multipliers. This division of the literature structures the following review. We do not include a fourth strand of the literature comprising studies aiming to determine the macroeconomic effects of green fiscal measures in general and green recovery measures in particular in specific sectors, as, for example, in the plastic recycling sector (see, e.g., Da Cruz et al. 2014), ecological restoration (see, e.g., BenDor et al., 2015), energy efficiency (Cambridge Econometrics, 2015) or in the cycling sector (see, e.g., Blondiau and van Zeebroeck 2014), due to the main focus of the paper aiming at comparing the effects of different green recovery measures and the effects of green versus non-green recovery measures, respectively.

3.3.2.1 Hypothetical macroeconomic impact of green recovery measures

A few studies published within the last decade explicitly aim at identifying policies that are most promising regarding their potential to counteract an economic recession and to reduce emissions at the same time. Based on various approaches, these analyses attempt at determining the hypothetical macroeconomic and climate impact of various policy options which could be applied within fiscal recovery programmes. In contrast to the majority of existing studies estimating the effects of green spending[25]), the analyses presented here allow a direct comparison of macroeconomic effects of green and non-green measures. Pollin and Garrett-Peltier (2009) mention several reasons why a given sum of public money spent may be associated with differing employment effects depending on the spending purpose. First, sectoral labour intensity may differ. Second, the number of jobs created also depends on domestic content, which differs across sectors. Third, if sector-specific pay levels differ, the number of jobs resulting from a given public expenditure will differ.

A rather conventional methodological approach underlies the simulation exercise by Houser et al. (2009) for the US undertaken in the context of the GFC. Using the US Energy Information Administration's National Energy Modeling System (NEMS), the authors evaluate the effects of 12 different green measures inter alia on employment, carbon emissions, and energy costs for the economy as a whole. The policy scenarios analysed were identified in exchanges with stakeholders from non-governmental organisations, industry groups, policymaking, and academia regarding the types of programmes considered potential elements of an economic recovery package. The simulation results include, inter alia, the number of direct, indirect, and induced jobs created in the year public funds flow for green expenditures or tax credits as well as annual average decreases in carbon emissions and energy expenditures for the country as a whole for the period 2012 to 2020 (Table 3.2.). On average, the scenarios modeled are associated with 30,100 jobs for every US $ 1 billion spent by the government. Most effective in terms of job creation are a cash-for-clunkers programme, smart metering, and the extension of the production tax credit. Battery R&D, followed by a cash-for-clunkers programme and green school construction, would result in the highest carbon emission reductions.

Garrett-Peltier (2017) calculates employment multipliers for spending in renewable energy (wind, solar, bioenergy, geothermal, hydro), energy efficiency measures (building weatherization, mass transit and freight rail, industrial energy efficiency, smart grid, and fossil

[25]) For brief overviews of empirical studies determining the macroeconomic effects of measures promoting a clean energy transition, see, e.g., Markaki et al. (2014), Garrett-Peltier (2011), or Dvorák et al. (2017).

fuels (gas, oil, coal) for the US, by using input-output-tables to create "synthetic" industries. Table 3.3. shows that short- tomedium-term employment effects (i.e., effects related to the expansion of the respective industries rather than to operations and maintenance) per US $ 1 million spending are several times higher for spending in renewable energy and energy efficiency measures than for spending in fossil fuels. Hereby, direct and indirect job creation are distinguished. These results confirm those obtained by Pollin et al. (2009) also for the US, who find that investment in energy efficiency leads to employment creation 2.5 to 4 times larger compared to oil and gas. Similarly, according to Wei et al. (2011), the labour intensity of renewables and energy efficiency measures per unit energy produced is higher than that for coal and natural gas in the US. According to the International Energy Agency (2020), each US $ 1 million spending for building efficiency, clean urban transport, or solar photovoltaics results in higher gross job creation than investing in fossil fuels. Of course, this only shows that green investments are more labour intensive, but does not provide evidence that they are more effective in creating added value.

Table 3.2: **Economic and climate impact of US $ 1 billion in government spending in the US**

Green programmes	Employment in job years[1)]	Energy costs in millions of US $/year	Carbon emissions in thousand tons/year
Household weatherization[2)]	25 100	207.8	440.7
Federal building retrofits	25 300	386.7	546.9
Green school construction	25 200	609.2	905.8
Production Tax Credit[3)] extension	39 100	562.5	727.7
Investment Tax Credit[4)] increase	33 300	208.7	213.4
Carbon Capture and Storage demonstration projects	28 500	225.3	341.6
Cash for clunkers[5)]	46 900	433.0	1,112.5
Hybrid tax credit[6)]	11 100	-	-
Battery R&D	22 500	1,278.8	1,332.8
Mass transit	34 500	23,6	87.3
Smart metering	40 000	918.0	207.4
Transmission[7)]	n.a.	n.a.	n.a.
Tax cuts[8)]	7 000	n.a.	n.a.
Road investment[9)]	25 000	(32.8)	(35.4)

Source: Houser et al. (2009); own representation. – 1) Fulltime jobs over one year; direct, indirect, and induced. – 2) Instalment of insulation, new windows, and better light bulbs in residential dwellings – 3) Promotes the deployment of grid-connected renewable energy. – 4) Promotes the instalment of distributed renewable generation options in businesses and households. – 5) Tax credit for purchase of new or used high-efficiency vehicle when older and less-fuel efficient vehicle is retired. – 6) Tax credit for purchase of hybrid vehicle. – 7) Construction of high-voltage transmission lines to allow for greater renewable energy penetration. – 8) Tax cut estimates assume that 35% of income returned to households will be spent that year. – 9) Figures for energy costs and carbon emissions are net increases, not reductions.

Bacon and Kojima (2011) discuss in detail the challenges to determine and compare the employment effects of investment in different energy sectors. Besides direct, indirect, and induced employment effects, employment generated in the construction, installation and manufacture phase on the one hand, and in the operation and maintenance phase, on the other hand, has to be distinguished. An issue with regard to comparability are differing life cycles, which leads to disadvantages for investment with long life cycles if employment effects are estimated as average values per year.

Table 3.3: **Employment multipliers for renewable energy, energy efficiency measures and fossil fuels in the US, in full time equivalents (FTE) per US $ 1 million**

Green programmes	Direct FTE	indirect FTE	total FTE
Oil and gas	0.70	1.49	2.20
Coal	1.18	1.92	3.10
Industrial energy efficiency	3.98	3.43	7.41
Smart grid	3.66	3.10	6.76
Wind	4.06	3.46	7.52
Solar	4.26	2.98	7.24
Hydro	4.55	2.98	7.53
Geothermal	4.67	2.73	7.40
Bioenergy	5.22	2.44	7.65
Mass transit and freight rail	6.16	2.77	8.93

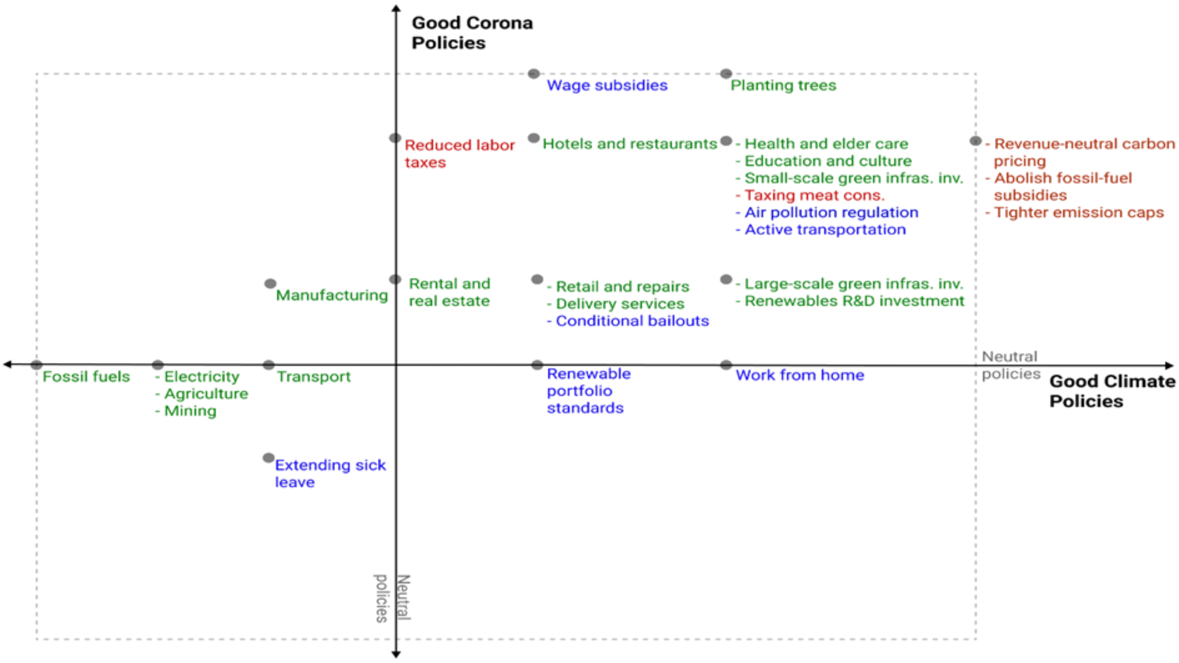
Source: Garrett-Peltier (2017); own representation

Engström et al. (2020) follow a different approach[26]). Instead of evaluating concrete measures that are designed to fit into the institutional and policy framework of a specific country (as in Houser et al., 2009) or that are based on the structure of the overall economy and the energy system of a specific country (as in Garrett-Peltier, 2017), the authors aim at the assessment of certain archetypes of stimulus measures. Using Eurostat data, the sector-specific labour intensity in terms of employees per unit of value added as well as the sector-specific emission intensity measured in terms of emissions per value added and per employee are determined for Sweden, Finland, the United Kingdom, Germany, France, and the European Union as a whole. In a next step, policies primarily motivated by the COVID-19 induced economic recession and policies primarily motivated by climate change are distinguished and classified into the categories stimulus spending, tax reform, and cross-cutting policies. The authors thus establish a framework that allows evaluating the extent to which individual policies are able to fight the recession and the climate crisis at the same time. Graph 3.1. provides a summary of the policy evaluation undertaken in the paper.

One central result of the study is that certain good climate policies, in particular small-scale labour-intensive green infrastructure projects, planting trees, and carbon pricing coupled with a decrease of labour taxes, also promote economic recovery. Moreover, supporting the service sectors, education, and the healthcare sector is not only good to fight the economic recession, but represents low emission policy at the same time. Large-scale green investment projects and green R&D investment are good instruments to fight climate change, but do not generate employment in the short run.

[26]) Such an approach in principle is also used by the various green recovery trackers presented in section 3.1, to identify in a first step stimulus measures with environmental (and in the case of the Oxford-UNEP Green Recovery Tracker also social and economic) effects.

Graph 3.1: **Summary of policy evaluation**

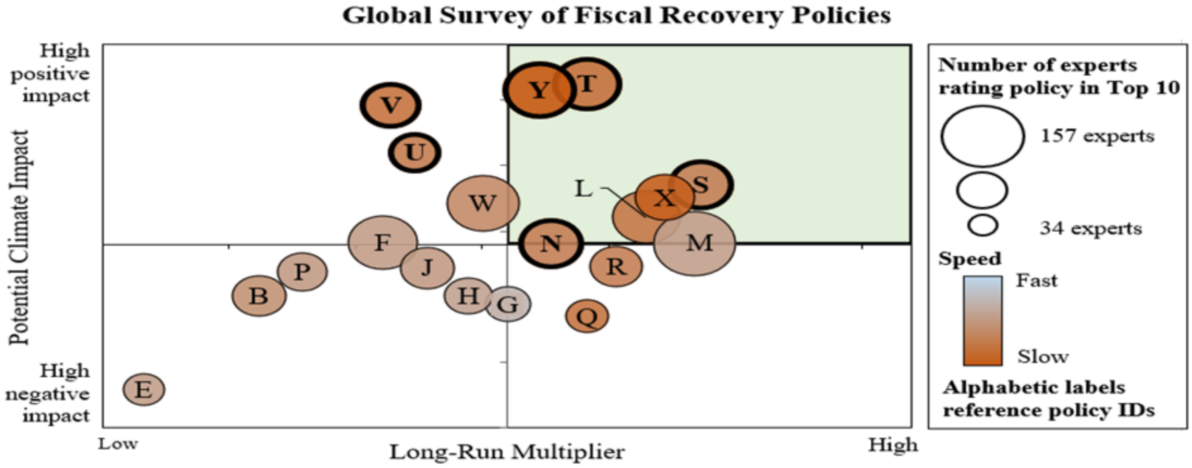


Source: Engström et al. (2020). – Green: stimulus spending policies, red: tax reform policies, blue: cross-cutting policies.

A similar, however qualitative approach is chosen by Hepburn et al. (2020). In a global survey among about 230 officials from central banks and finance ministries as well as other economic experts from G20 countries, the authors categorise 25 major fiscal recovery policies according to their relative performance regarding the long-run multiplier effect and the potential climate impact. Based on this survey, five policy archetypes with high potential on both long-run economic multiplier and climate impact are identified: clean physical infrastructure, building efficiency retrofits, investment in education and training, natural capital investment, and clean R&D spending (see Graph 3.2.).

The results of the works summarised in this section may provide useful general guidance for policymakers regarding the selection of recovery measures which allow to simultaneously stabilise the economy in a recession and achieve climate goals. Of course, such ex-ante evaluations have certain limitations (O'Callaghan – Murdock, 2020). In particular, simulation scenarios or archetypes evaluated need to be based on simplifications, and their actual impact will vary depending on the country-specific institutional and policy framework, economic and environmental conditions, as well as on the concrete design. Moreover, potential interactions between recovery measures implemented in parallel cannot be captured by such ex-ante evaluations.

Graph 3.2: **Global Survey of Fiscal Recovery Policies**



B	Assisted bankruptcy (super Chapter 11)	Q	Traditional transport infrastructure investment
E	Airline bailouts	R	Project-based local infrastructure grants
F	Not for profits, education, research, health inst. bailouts	S	Connectivity infrastructure investment
G	Reduction in VAT and other goods and services taxes	T	Clean energy infrastructure investment
H	Income tax cuts	U	Buildings upgrades (energy efficiency)
J	Business tax relief for strategic and structural adj.	V	Green spaces and natural infrastructure investment
L	Education investment	W	Disaster preparedness, capacity building
M	Healthcare investment	X	General R&D spending
N	Worker retraining	Y	Clean R&D spending
P	Rural support policies		

Source: Hepburn et al. (2020).

3.3.2.2 Evaluation of specific green recovery programmes

This section presents the results of evaluations of specific real life green recovery programmes implemented in the wake of the GFC. Barbier (2010a)[27]) gives an overview of recovery packages and green investments implemented during the GFC for those countries or regions for which ex-ante or ex-post evaluations of macroeconomic effects are provided in the (easily accessible) literature (Table 3.4.): China, Germany, South Korea, the United States, and the EU. At 3% of GDP, green recovery packages were largest in China and South Korea, while they reached (considerably) less than 1% of GDP in Germany and the US. In South Korea, the stimulus package almost exclusively consisted of green recovery measures (with a share of about 95%). The share of green recovery in the overall stimulus package was one third in China, but only 12% and 13%, respectively, in the US and Germany. For the sake of comparison: in the G20, green recovery measures made up for 16.8% and globally for 15.4% of overall stimulus packages (0.7% of GDP each). The figures included in table 3.4. should be regarded with some caution; due to differing cut-off dates, definitions, etc. figures mentioned in various publications slightly vary. Unfortunately, no detailed information is available on the methodology used to identify green measures and to determine the share of green measures in the overall stimulus packages, which makes a direct comparison with the COVID-19-related recovery packages difficult.[28]) However, the figures provide a picture of magnitudes and structures.

In what follows, we provide a brief review of evaluations aiming at determining the macroeconomic impact of green recovery measures in the US, China, Germany, South Korea,

[27]) The author draws on figures provided by Robins et al. (2009a, 2009b, 2009c) and Khatiwada (2009).

[28]) See also section 3.1.

and a selection of EU Member States. Unfortunately, a meaningful cross-country comparison of the macroeconomic effects of the various green recovery programmes is not possible. Moreover, most evaluations do not aim at identifying macroeconomic effects of green versus non-green elements in the recovery packages.

Table 3.4: **Recovery packages and green investments during the GFC in selected countries/regions (as of 1 July 2009)**

Country	total fiscal stimulus (US $ billion)	total "green stimulus" (US $ billion)			green stimulus as % of total stimulus	green stimulus as % of GDP
		low carbon[2)]	other	total		
China	647.5	175.1	41.3	216.4	33.4	3.0
Germany	104.8	13.8	-	13.8	13.2	0.5
South Korea	38.1	14.7	21.6	36.3	95.2	3.0
United States[1])	787	78.5	15.6	94.1	12	0.7
G20	2,702.20	366.3	88.4	454.7	16.8	0.7
Global total	3,016.30	373.9	89.4	463.3	15.4	0.7

Source: Barbier (2010a). – [1]) From the February 2009 American Recovery and Reinvestment Act only. – [2]) Support for renewable energy, carbon capture and sequestration, energy efficiency, public transport and rail, improving electrical grid transmission.

The American Recovery and Reinvestment Act (ARRA)

The recovery programme implemented during the GFC that has been analysed most is probably the American Recovery and Reinvestment Act (ARRA) implemented in 2009. Altogether, the "clean energy" element of ARRA amounted to between US $ 67 billion and US $ 112 billion (around 0.7% of GDP) (Barbier, 2010B; 2010C), whereby the lower figure only includes clean energy, while the higher figure also comprises water, waste and conservation funding. Mundaca and Luth Richter (2015) report that direct ARRA spending on clean energy reached US $ 92 billion, of which US $ 21 billion (i.e., 23% of ARRA clean energy spending and 2.5% of the overall recovery package) were allocated to renewable energy. The green component of ARRA comprised investment in retrofit of buildings, the expansion of mass transit and freight rail, the construction of smart electrical grid transmission systems, and the expansion of renewable energy supply (Barbier, 2010A). According to ex-ante estimations of the US Council of Economic Advisers (2010), the ARRA renewable energy and clean energy programmes created 26,600 direct and indirect jobs; including induced jobs, 33,800 jobs were supported. For the years 2009 to 2015, the Council of Economic Advisers (2016) estimated ex post that ARRA supported 900,000 job years in clean energy, whereby these gross job creation figures do not account for potential job losses elsewhere. Lim et al. (2020) in an ex-post study find that green ARRA recovery measures were successful in creating jobs in the renewable and energy efficiency sectors. Steinberg et al. (2012) estimate that the economic output created from 2009 to 2011 reached 1.2 to 2.1 times the value of the US $ 21 billion addressing renewable energy. The assessment by Pollitt (2011) of the green elements of ARRA and the Energy Improvement Extension Act adopted in 2008 (the size of which corresponds to a small fraction of ARRA only) yields rather limited effects: GDP in 2009 and 2010 was larger by about 0.7% and 0.2%, respectively, compared to the baseline. Employment effects were positive, but negligible.

According to the ex-post evaluation of green ARRA spending by Popp et al. (2020), employment gains were achieved with a time lag and more slowly compared to other recovery investments: each US $ 1 million of green ARRA investment created 15 job news in the long run, i.e. in the period from 2013 to 2017. The authors also find that the new jobs were not only temporary, but rather lasting. These job multiplier estimates fit quite well to the survey of 7 ex-post ARRA studies by Chodorow-Reich (2019) which finds estimates for job years per US $ 100,000 between 0.76 and 3.93, whereby the cross-study mean is at 2.1 and the median at 1.9. In his own analysis, the author estimates 2.01 job years per US $ 100,000 ARRA spending. Focusing on ARRA highway spending, Garin (2019) arrives at an estimate of 6 jobs in overall construction created per US $ 1 million spent. Overall, the employment effects found in these analyses focusing on the overall ARRA package are rather short-term and short-lived, while the results by Popp et al. (2020) suggest that the employment effects of green ARRA spending materialise rather in the longer run. Chen et al. (2020) therefore conclude that green recovery measures appear to be less suited as short-term recovery measures, but to have a more transformative nature with a sizeable longer-run employment impact.

A few studies aim at identifying the employment impact of green ARRA spending compared to non-green spending. According to Smart Growth America (2011), expenditures for public transit created 70% more jobs than spending on highways. Edwards et al. (2013) find that spending on coastal habitat restoration resulted in considerably more jobs compared to investment in fossil fuels.

Green recovery programmes in South Korea

Another prominent example for a green recovery package implemented during the GFC is that of South Korea, which dedicated over 95% of its recovery measures to green projects. The country allocated US $ 36.3 billion to low-carbon projects (expansion of railroads and mass transit, adoption of fuel-efficient vehicles and clean fuels, energy conservation, environmentally friendly buildings) and to water management, recycling, and ecological protection. These green investments were expected to create 960,000 new jobs altogether. Of these, 149,000 should be new construction jobs, another 334,000 jobs should be generated through energy efficiency and low-carbon projects (Barbier, 2010A).

Despite the significant attention South Korea's green recovery measures have received internationally, there is a lack of evaluations of its effects. One of the few existing ex-post assessments is provided by Mundaca – Damen (2015). The authors find that the programme was quite successful as a fiscal stimulus instrument, measured by its effects on GDP and employment. The Korean Development Institute estimates the number of jobs directly created between 2009 and 2011 at 165,000 (Jung, 2015). According to the OECD (2010), short-term public employment was increased by 276,000 jobs in 2009. Moreover, the South Korean unemployment rate in 2009 was reduced from a projected 4.3% to 3.6%. Pollitt (2011) finds that employment was increased by 0.5% in 2009 to 2010, mainly in the construction and engineering sectors. According to Chang et al. (2012) (non-stimulus) investment in renewable energy results in more jobs per US $ spent than investment in dams. The programme's environmental effects, however, were rather limited. Mundaca and Damen (2015) identify the lack of carbon pricing as one factor explaining the environmental ineffectiveness of the South Korean green recovery measures. According to a study by Sonnenschein and Mundaca (2016), short-term infrastructure investment (e.g., railways) was associated to rising demand for concrete, thus increasing emissions. Moreover, only a negligible share of the expenditures was dedicated to renewables.

Green recovery programmes in China

Also the Chinese recovery package adopted during the GFC contained an in international comparison relatively large green component, which was announced to reach about one third of overall recovery spending. China's green spending went into energy efficiency, environmental improvements, rail transport, and new electricity grid infrastructure (Barbier, 2010A). Pollitt (2011) estimates that GDP was increased above the baseline by around 4.2% in 2009 and by 3.6% in 2010 by China's investment in rail and grid networks and other green measures. Employment effects, however, were rather small. According to Jaeger et al. (2020), a large part of the Chinese green recovery measures was not additional spending, however. Moreover, as they to a considerable extent supported coal power, their actual "greenness" can be questioned.

Green recovery programmes in selected EU Member States

Pollitt (2011) assesses the economic effects of the green components of the recovery programmes adopted during the GFC, hereby inter alia focusing on the recovery programmes implemented in 9 EU Member States (Belgium, Czech Republic, Estonia, France, Germany, Portugal, Slovakia, Sweden, and the UK). The main green recovery measures adopted in the wake of the GFC comprised investment in energy efficiency, investment in transport infrastructure, vehicle scrappage schemes, investment in renewables, and support of eco-innovation. The author estimates positive macroeconomic effects. The assessment which is based on a framework combining qualitative and quantitative methodologies with the macro-econometric E3ME model shows that per US $ 1 spent for green investment, GDP at the national level was raised by US $ 0.6 to US $ 1.1 and by up to US $ 1.5 at the European level, reflecting positive spillovers. The short-term multiplier effects estimated for green measures according to Pollitt (2011) are similar to the multiplier effects resulting from any investment.

3.3.2.3 Cross-country research

The above-cited global expert survey among senior officials from central banks and finance ministries undertaken by Hepburn et al. (2020) finds that green recovery programmes are often thought to be more job-intensive and to be associated with larger multipliers compared to traditional stimulus measures. However, empirical studies comparing green and non-ecofriendly measures in a cross-country perspective are still in short supply.

Based on a survey of 13 empirical studies estimating the labour intensity of different energy industries in the US and Europe, hereby differentiating between the construction, manufacturing and installation phase and the operation phase, Kammen et al. (2006) show that per unit of energy produced, renewable energy industries (solar photovoltaic, wind and biomass) are more labour intensive than the fossil energy sectors (coal and gas), especially in the construction, manufacturing and installation phase. A shift from fossil to renewable energy sectors should therefore create positive direct static net employment effects in the short run, making such investment in renewables useful elements of recovery programmes aiming to cushion recessions. Also Blyth et al. (2014), reviewing 50 studies covering a number of countries, show that employment intensity (considering direct, indirect, and induced effects) is highest for renewable energy and particularly for solar photovoltaic. The direct job creating potential is particularly high for wind and solar photovoltaic. Concentrating solar power has a larger impact on indirect employment, induced employment is largest for solar photovoltaic. These estimates, however, typically apply a sectoral perspective and thus represent gross employment effects with a focus on the investment phase. They do not cover potential job losses in other affected sectors like the supply of fossil energy and relevant intermediate sectors of fossil energy.

In a recent study, Batini et al. (2021) are the first to estimate output multipliers for expenditures for clean energy and biodiversity conservation compared to non-ecofriendly spending in a cross-country setting. The estimation covers China, Japan, Korea, Canada, the US, Brazil, Indonesia, Mexico, Russia, Australia, New Zealand, France, Germany and Italy and the time period 2003 to 2019. Their findings show, with over 90% probability, that investment in renewable energy has considerably higher multipliers than fossil fuel energy investment both in the short and in the longer run (Table 3.5.). Moreover, while the green investment multiplier decreases only slightly over time, the non-eco-friendly energy investments multiplier falls to a larger extent between the first and the fifth year. According to Batini et al. (2021), there are three explanatory factors for the significantly higher green investment multipliers. First, the labour intensity of clean energy is larger than that of fossil fuel-based energy. Second, the domestic content of clean energy is larger. Third, jobs associated with clean energy are generally higher paid, and they cover all pay levels.

Table 3.5: **Cumulated multipliers associated to green (renewable) and non-eco-friendly (non-renewable) energy investment spending**

Horizon	Green (Renewable) Energy Investments Multiplier	Non- Eco- Friendly Energy Investments Multiplier
Impact	1.19*	0.65*
1year	1.20*	0.64*
2 years	1.19*	0.62*
3 years	1.17*	0.59*
4 years	1.14*	0.55
5 years	1.11	0.52

Source: Batini et al. (2021). * denotes multipliers with credible intervals, delimited by the 16th and the 84th percentiles, that exclude zero.

Batini et al. (2021) also estimate multipliers for green[29]) and non-eco-friendly spending for land use. The green-land-use country group includes Burkina Faso, Burundi, Cambodia, Cameroon, the Central African Republic, Chad, Ghana, Guatemala, Malawi, Mozambique, Niger, Senegal, Sierra Leone, Madagascar, Tanzania, and Uganda; the data are for the time period 1994 to 2008. The multipliers for non-eco-friendly land use are based on the period 1997 to 2016 and are estimated for China, Japan, Korea, Canada, the US, Australia, Chile, Indonesia, Mexico, New Zealand, Russia, South Africa, Colombia, Iceland, Israel, Kazakhstan, Norway, Switzerland, Turkey, and Ukraine. Table 3.6. contains the results, showing that green-land-use multipliers – in contrast to those for spending for non-eco-friendly land use – are very high after the first year and increasing over time. The authors identify several reasons for these results. First, the country group studied consists of developing countries, for which green land use spending comes from international donors. Such programmes are supplementary to domestic spending, therefore they are not associated with crowding out effects. The second reason is the high labour intensity of such programmes. Third, conservation activities raise prices for rural producers as they reduce the amount of land which is available for agricultural production.

[29]) Green land use can encompass a variety of activities. The data used in the study by Batini et al. (2021) pertain to spending on biodiversity conservation.

And conservation programmes strengthen ecosystem services on which livelihood is based, which results in additional jobs. Not least, the domestic content of green land use is large.

Table 3.6: **Cumulated multipliers associated to green and non-eco-friendly spending for land use**

Horizon	Green Land Use Multiplier	Non- Eco- Friendly Land Use Multiplier
Impact	-5.36	0.55*
1year	-160	0.85*
2 years	145*	0.95*
3 years	3.75*	0.96*
4 years	5.45*	0.95
5 years	6.67*	0.94

Source: Batini et al. (2021). * denotes multipliers with credible intervals, delimited by the 16th and the 84th percentiles, that exclude zero.

These results stand in some contrast to the findings of the small body of "conventional" empirical literature on the size of employment effects of public (infrastructure) investment which suggests that these are small or even negative in the short run, rendering them unsuitable as short-term stimulus measures in periods of economic slack. Kammen et al. (2006) themselves point out that the higher job-creation potential of renewables results from not yet being cost-effective. Meanwhile, low-carbon technologies are more mature and cost-effective, so that a shift from high-carbon to low-carbon energy sectors is very likely associated with much lower or even no net employment gains under current circumstances, i.e., 15 years after the Kammen et al. (2006) study. Moreover, Strand and Toman (2010) argue that the domestic job intensity of investment in renewables is limited, as the required equipment often is imported. Also relevant would be the overall employment effect of the investment, which also includes the installation and operating phase. In addition, the question remains whether a substitute technology in fossil technologies would perform better in an integrated perspective along the whole value chain.

3.3.2.4 Issues and questions

Our review of empirical studies on the macroeconomic effects of green recovery measures points to various challenges and issues such empirical work is confronted with. First of all, often studies are partial economic analyses only and neglect job losses in other sectors resulting from green recovery measures (Mundaca and Luth Richter, 2015; Jaeger et al., 2020), considering only direct employment effects. A comprehensive assessment of the employment effects of green recovery programmes, however, needs to focus on net employment effects by accounting for overall economic effects, including job losses in some sectors, indirect employment effects as well as induced ones. Specifically, regarding the job creation potential of the expansion of renewables, existing studies based on macroeconomic models yield inconclusive results regarding the net employment effect (see Fragkos and Paroussos, 2018, and the literature cited therein).

Second, there is the question of additionality and causality, as at least a portion of the new jobs might have been created anyway (Mundaca and Luth Richter, 2015). For example, for green ARRA spending a firm survey by Jones and Rothschild (2011) finds that some projects were funded that would have been undertaken anyway.

Third, most studies do not provide a breakdown of job gains by demographic groups, i.e., according to gender or ethnic background. However, such a differentiated evaluation would be of interest for example from a gender perspective: green recovery measures often benefit sectors in which women are underrepresented, so that direct employment effects benefit men more than women. Capturing gender-differentiated direct, indirect and induced employment effects of green recovery programmes (and of recovery programmes in general) in a comprehensive perspective is a methodological challenge that has not yet been addressed sufficiently in the empirical literature.

Fourth, there is the question of the quality of the jobs created. There is some evidence that wages and career opportunities are better in green jobs (Mundaca and Luth Richter, 2015). According to a study for the US for 2019 by E2-ACORE-CELI (2020), at US $ 23.89 hourly wages are considerably higher in green sectors (renewable energy, energy efficiency, grid modernisation and storage, clean fuels and clean vehicles) in comparison to the national median wage of US $ 19.14. Also, for the US, Muro et al. (2019) show that hourly wages in clean energy sectors are 8% to 19% above the national average. Moreover, wages are more equitable for clean-energy jobs: less than 4% of clean-energy jobs offer hourly wages below US $ 15, compared to almost one third for all jobs nationwide. On the other hand, in one of the scarce empirical analyses considering the quality of jobs created by green recovery programs, Popp et al. (2020) for the US ARRA programme find lower wages compared to the average manual-labour jobs; whereby the authors stress that it is not clear whether the relatively low wages are caused by the poor quality of the jobs created.

Finally, longer-term productivity effects of green investment beyond short- and medium-term multipliers are an under-researched issue. Related is the challenge to adequately capture productivity effects of green investment by greening productivity measurement (OECD, 2016): the conventional concept of multifactor productivity needs to be extended to account for pollution emissions and resource use, thus arriving at a sustainability-oriented concept of green total factor productivity, enhancing the production function containing capital, labour, and energy inputs by integrating emissions and resource use[30]).

3.3.2.5 Success factors

Several success factors for green recovery measures to initiate and support the necessary transition can be derived from the existing empirical research.

Generally, to be successful in bringing about deep transition, green recovery measures need to be embedded in a broader mix of green policies (Bhattacharya and Rydge, 2020) and structural reforms (OECD, 2017). Without being followed by long-term oriented and sustained green policies, green recovery measures will not be able to lead to large-scale transformation (Mundaca and Luth Richter, 2015; Carley et al., 2011; Mundaca et al., 2013). This requires the coordination and alignment of a number of different programmes and policies with different foci and also differing time perspectives that are complementary to each other. Barbier (2011) names the following complementary policies: economy-wide pricing and regulatory policies; removal of fossil fuel subsidies; prescriptive and targeted incentive programs; behavioral nudging; combined/improved design of energy efficiency programs. The design of the European RRF follows this general recommendation by requiring Member States to integrate green spending measures and complementary reforms in their NRRPs.

[30]) See Li et al. (2021) and the references cited therein.

Several complementary policies turn out to be particularly important. As evidence for the US based on evaluations of the ARRA measures suggests, green skills are a crucial success factor (Mundaca – Luth Richter, 2015). According to Popp et al. (2020), communities where green skills[31]) had existed already had a higher probability to receive green ARRA-supported investment. According to the expert survey by Hepburn et al. (2020), investment in green skills is associated with high long-term multipliers. Chen et al. (2020) stress that compensating for the losses of brown jobs by investment in training for green job is pivotal also for the public acceptability of the green transition. Fragkos and Paroussos (2018) underline the need for effective labour market policies, including measures to transform skills and retrain particularly low-skilled workers, so that new opportunities for workers can be exploited and political and social support for climate policies is secured. According to the OECD's Green Recovery Database, investment in green skills amounted to only 2% of the overall volume of recovery measures in the countries regarded (OECD, 2021).

A key complementary policy is carbon pricing and generally the use of environmental taxes. According to Peters et al. (2012), one factor supporting the quick rebound of emissions after the GFC were low energy prices. Long-term price signals are needed to accompany (green) recovery programmes (International Energy Agency, 2020), so that private investment is directed towards decarbonisation and energy price decreases resulting from the crisis are counteracted (Peters et al., 2020). Carbon pricing could avoid or mitigate a rebound effect induced by green recovery measures aiming at the improvement of energy efficiency. A recent empirical analysis by Schoder (2021) finds that strengthening carbon taxes within a green tax shift simultaneously decreasing personal income taxes may also have positive macroeconomic effects: for a panel of 75 high- and low-income countries and the period from 1994 to 2018, estimated personal income tax multipliers lie between 1.4 and 2.3, thus exceeding environmental tax multipliers which range from 1 to 1.8. Similarly, a number of empirical studies find that increasing environmental taxes and using revenues to cut less growth- and employment-friendly taxes (e.g., social security contributions or personal income taxes) can yield a double dividend, consisting in positive environmental and macroeconomic effects.[32])

Effective carbon pricing also requires the dismantling of environmentally harmful subsidies, which are still used extensively worldwide. According to OECD/IEA (2021) subsidies supporting fossil fuel production and consumption reached about US $ 494 billion in 2019 and US $ 345 billion in 2020 in G20 countries and emerging economies, and subsidies harming biodiversity amount to US $ 500 billion annually (OECD, 2019), thus representing a considerable volume compared to the US $ 677 in recovery measures according to the OECD Green Recovery database, which at least partially extend to several years.

Policy design in general is another success factor (Agrawala et al., 2020). One aspect in this respect is to couple additional recovery programmes with already existing programmes, which can accelerate their implementation. Tienhaara (2018) mentions the example of the energy efficiency retrofits supported by ARRA which were based on an existing programme, while the implementation of the Australian home retrofits programmes took considerably more time. In his evaluation of green elements of recovery programmes adopted during the GFC, Pollitt (2011) finds that measures that considered local conditions and requirements and addressed gaps in domestic infrastructure (e.g. investment in Estonia's water system or in Australia's rail network) were particularly successful regarding economic benefits. Moreover, green recovery

[31]) See Chen et al. (2020) for a specification of the skills needed for green jobs.

[32]) See Köppl and Schratzenstaller (2021a) for an extensive review of relevant empirical studies.

measures should be designed in a way that avoids rebound effects and ensures additionality (Agrawala et al., 2020).

Moreover, adverse policies need to be avoided. For example, Peters et al. (2012) stress that one of the reasons that emissions rebounded quickly after the GFC was the high share of brown recovery measures in recovery programmes. Therefore, green conditions should be considered also for those recovery measures not explicitly aiming at green objectives. And brown recovery measures should be avoided, as for example in the RRF, which in principle[33]) excludes investment in fossil-based activities. The green recovery trackers presented above[34]) find that green recovery measures are counteracted to a considerable degree by recovery measures with environmentally-harmful or mixed effects. For example, the OECD Green Recovery Database shows that the 21% of recovery spending with positive environmental effects are partially compensated by 10% of recovery spending associated with negative or mixed environmental effects. According to the VIVID Economics Green Stimulus Index, stimulus measures have a negative net environmental impact in 15 G20 countries and in half of the 10 further countries regarded. Also, non-fiscal adverse measures should be avoided, in particular environmentally-negative regulatory measures. The OECD Green Recovery Database, which also records regulatory measures implemented as part of countries' COVID-19 response, finds that of the total number of environmentally-relevant regulatory measures, about 75% are of an environmentally-beneficial nature, while around 25% are associated with negative or mixed effects.

OECD (2021d) mentions several facilitators supporting a successful implementation of green recovery programmes. Green budgeting tools can be an effective facilitator. In this regard the capacity building in Member States currently undertaken within the European Commission's Green Budgeting Project[35]) is very useful. Moreover, communication strategies stressing the long-run benefits of green recovery and complementary measures help to secure public acceptance. OECD (2017) points out the importance of an inclusive design of climate measures in general to avoid public resistance.

Finally, independent of their content, international coordination can enhance the effectiveness of recovery programmes. As the abovementioned studies by Freedman et al. (2009), Pollitt (2011) and Pfeiffer et al. (2021) suggest, fiscal multipliers are larger if a recovery programme involves many countries. Moreover, countries can learn and thus benefit from each others' experience (Hepburn et al., 2020).

4 Conclusions

There is a broad consensus that the next few years will determine whether a transformation process towards low-carbon structures will succeed. Related to this, there is an urgent need for large-scale investment, which raises the question how the public funds used to mitigate adverse economic effects of the pandemic can be best used to finance the necessary transition.

Our review of the empirical literature suggests that green recovery measures can be useful elements of recovery packages inducing positive growth and employment effects. Besides

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[33]) There are targeted exemptions, for example, for natural gas with specific conditions to ensure that the Do No Significant Harm Principle is respected.

[34]) See section 3.1.

[35]) Green Budgeting: a key driver to meet the environmental ambition of the European Green Deal | European Commission (europa.eu).

answering the three guiding questions motivating our survey of the literature, we have also identified several areas for future research.

As the focus of the green recovery measures actually implemented as well as of the empirical research has been on green expenditures, a first interesting question would be how these fare in comparison to green tax measures aimed at stimulating climate-friendly investment or consumption, e.g. tax exemptions for the adoption of clean vehicles.

A second issue worthy of further exploration is the quality and earning potential of green jobs, considering the ambiguous empirical findings presented above. Related to this is the question of the impact of a shift from brown to green jobs on productivity (Fankhauser et al., 2008).

A third, related aspect regards the gender-differentiated impact of green recovery programmes. The sparse empirical work differentiating between job effects for women and men focuses on direct effects, neglecting indirect and induced ones. Moreover, the quality of green jobs and the question how to secure that both women and men are equally able to benefit from the future green job potential is relevant.

Fourth, we have not explicitly and systematically explored the relationship between economic and environmental success of green recovery programmes. Some of those studies analysing the effects of green recovery measures that were actually implemented, simultaneously assess their environmental as well as their macroeconomic impact (e.g., Pollitt, 2011). However, these studies and their results are hardly comparable, and a systematic evaluation of the question whether there is a trade-off or rather a synergy between environmental and economic success is still missing.

Fifth, distributional effects of green recovery programmes are mostly neglected. One rare exception is the Oxford-UNEP Global Recovery Observatory, which not only attempts at identifying the green content of COVID-19 stimulus measures, but also aims at determining the potential social impact of policy archetypes. Wealth inequality, quality of life, and rural livelihood serve as metrics reflecting the potential social impact of policy archetypes.[36]) This assessment allows to identify those environmentally beneficial policy archetypes that simultaneously are associated with a positive (e.g., green worker retraining and job creation or disaster preparedness and capacity building investment) or a negative social impact (e.g., electric vehicle incentives). Unfortunately, the tracker does not determine the share of recovery measures with a positive social impact. As a "just transition" is key (Agrawala et al., 2020), not least regarding public acceptance of the envisaged socio-ecological transition, future empirical research should also attempt to identify the distributional impact of different green recovery measures and of whole green recovery packages.

Finally, an open field of research are comprehensive long-run analyses aimed at identifying the environmental impacts of green recovery programmes in terms of structural change. Also, studies aiming to identify the effects of green recovery measures on long-run productivity are missing.

Overall, green recovery programmes appear as a powerful lever to bring about the necessary deep socio-ecological transition. More research on their environmental, social and economic impact, the interlinkages between individual green recovery measures and in relation to other climate policies, and success factors is therefore urgently needed.

[36]) See O'Callaghan et al. (2021) for a detailed description of the methodological approach used.

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