Publizierbarer Endbericht

Gilt für Studien aus der Programmlinie Forschung

A) Projektdaten

Allgemeines zum Projekt	
Kurztitel:	GreenFin
Langtitel:	Scaling-up green finance to achieve the climate and energy targets: an assessment of macro-financial opportunities and challenges for Austria
Zitiervorschlag:	GreenFin untersucht die Bedingungen, unter denen die Komplementarität von Fiskal- und Geldpolitik, sowie Instrumente der Finanzmarktregulierung dazu beitragen, die Finanzierung einer nachhaltigen Entwicklung zu gewährleisten, die österreichische Wirtschaft an den Klimazielen auszurichten und gleichzeitig unbeabsichtigte Auswirkungen auf finanzielle Stabilität und soziale Ungleichheit zu vermeiden.
Programm inkl. Jahr:	ACRP 11th Call 2019
Dauer:	22 Monate
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Projekt- und KooperationspartnerIn (inkl. Bundesland):	International Institute for Applied Systems Analysis (IIASA), NÖ Österreichisches Institut für Wirtschaftsforschung (WIFO), Wien Universita´di Bologna (UNIBO), Italien

Allgemeines zum Projekt	
Projektgesamtkosten:	249 939,00 Euro
Fördersumme:	249 939,00 Euro
Klimafonds-Nr:	KR18AC0K14634
Zuletzt aktualisiert am:	30.12.2021

B) Projektübersicht

1 Kurzfassung

GreenFin hat untersucht, welche Rolle das Finanzwesen (über Finanzmärkte, Politik und Governance-Strukturen) bei der Ausweitung grüner Investitionen in Österreich spielen kann und unter welchen Bedingungen unbeabsichtigte Auswirkungen auf die Finanzstabilität und den sozialen Zusammenhalt entstehen könnten. Durch die Bearbeitung dieser bislang wenig erforschten Zusammenhänge hat GreenFin dazu beigetragen, die Umsetzung grüner Fiskal- und Geldpolitik zur Förderung des kohlenstoffarmen Übergangs in Österreich zu unterstützen. Österreich hat 2019 seine Agenda für grünes Finanzwesen auf den Weg gebracht und die wichtige Rolle der Finanz- und Kapitalmärkte bei der Ausrichtung von Investitionen auf Nachhaltigkeit erkannt. Die Fortschritte bei der Dekarbonisierung der Wirtschaft sind jedoch bislang zu gering. Die unzureichende Offenlegung von Klimarisiken und die unzureichende Risikobewertung bedeuten, dass österreichische Investoren immer noch stark in kohlenstoffintensive Vermögenswerte und Sektoren investieren, die bei einem ungeregelten Übergang zu "carbon stranded assets" werden können (Mercure et al. 2018, van der Ploeg und Rezai 2020), was zu finanziellen Risiken führt. Darüber hinaus wird dadurch die Ausweitung klimafreundlicher Investitionen eingeschränkt, die zur Erreichung der langfristigen Klimaschutzziele und zur Schließung der "grünen Investitionslücke" erforderlich sind. Um diese Lücke zu schließen, wird die Rolle grüner fiskalpolitischer Maßnahmen, wie der Bepreisung von Treibhausgasemissionen, betont, um ein Preissignal zu setzen (Stiglitz et al. 2017). Allerdings werden derartige Instrumente noch nicht umfassend eingesetzt. Da der Klimawandel als eine neue Art von Risiko für das Finanzwesen mit Auswirkungen auf die Finanzstabilität erkannt wurde (Battiston et al. 2017, NGFS 2019), werden grüne finanzpolitische Strategien und Regulierungen sowie Instrumente zur Bewertung von Finanzrisiken diskutiert (BIS 2021). Dennoch müssen die Risiken und Chancen, die mit der Einführung der Ansätze und Instrumente grüner Finanzpolitik verbunden sind, noch bewertet werden. Zu diesem Zweck entwickelte GreenFin in Kooperation mit ExpertInnen und Stakeholdern qualitative und quantitative Ansätze, um der österreichischen Regierung, der Zentralbank und den Finanzaufsichtsbehörden politikrelevante Informationen zur Steuerung der Transformation in Richtung Dekarbonisierung zur Verfügung zu stellen. Die Aktivitäten des Projekts lassen sich in sechs miteinander verbundene Arbeitspakete (WPs) einordnen. WP1 umfasste Interviews und eine Online-Umfrage mit internationalen Klimafinanzierungsexperten und Stakeholdern sowie einen umfangreichen Literaturüberblick. WP2 entwickelte robuste finanzökonometrische Modelle (erweitertes Marktmodell), um die Reaktion österreichischer Investoren auf klimapolitische Veränderungen wie etwa das Pariser Abkommen in Hinblick auf das Risiko-Rendite-Profil der Portfolios (alpha und beta) hin zu prüfen. WP3 erweiterte das EIRIN Stock-Flow Consistent (SFC) Verhaltensmodell (Monasterolo & Raberto 2018), um die makroökonomischen, distributiven und finanziellen Auswirkungen der Einführung der in WP1 als vielversprechendste Maßnahmen ermittelte Ansätze (d.h. CO2-Bepreisung, green supporting factor) in Österreich zu bewerten, auch unter Berücksichtigung der Auswirkungen auf Investoren (Dunz et al. 2021, Battiston et al. 2021). Darüber hinaus untersuchte das Projekt den Beitrag der Komplementarität von grüner

Steuer- und Finanzpolitik sowie die Ökologisierung der Entwicklungsfinanzierung und die Erwartungen der Investoren in Bezug auf die Transformation. WP4 untersuchte mittels eines SFC-Nord-Süd-Modells die makroökonomischen und finanziellen Auswirkungen der Einführung klimapolitischer Maßnahmen in Österreich und des De-riskings von Entwicklungsfinanzierungsprojekten in den Westbalkanstaaten. Wurden in WP5 die Projektergebnisse zusammengeführt, um politische Empfehlungen für einen klimagerechten Aufschwung nach der COVID-19 Pandemie zu entwickeln, grüne/klimagerechte Investitionen zu fördern und unbeabsichtigte Auswirkungen auf die finanzielle Stabilität und Ungleichheit zu vermeiden. WP6 befasste sich mit dem Projektmanagement und der akademischen und nicht-akademischen Öffentlichkeitsarbeit.
Die entwickelten Methoden und die Ergebnisse des GreenFin-Projekts hatten bereits während der Projektlaufzeit einen großen Einfluss auf Wissenschaft, Forschung und Politik. Einerseits brachte die Analyse der „Klimastimmung" der Investoren, d.h. die Rolle der Erwartungen der Finanzmarktakteure in Bezug auf das Klimarisiko und deren Auswirkungen auf die Risikoanpassung (z.B. Kosten und Zugang zu Kapital für Unternehmen in Abhängigkeit von ihrer Exposition gegenüber Klimarisiken), eine wesentliche Neuerung in die akademische Debatte über die Rolle der Finanzwirtschaft für die Dekarbonisierung ein. Die Modelle von GreenFin wurden in Zusammenarbeit mit internationalen Finanzmarktakteuren wie der Weltbankgruppe, der Europäischen Zentralbank und der Österreichischen Nationalbank angewandt, um die finanzpolitische Debatte zu beeinflussen. Die Ergebnisse von GreenFin wurden auf internationalen wissenschaftlichen und hochrangigen politischen Veranstaltungen vorgestellt und in renommierten Fachzeitschriften wie Science, sowie in einem co-herausgegebenen Special Issue über Klimarisiken und Finanzstabilität im Journal of Financial Stability veröffentlicht. Zur Verbreitung der Projektergebnisse wurde eine eigene Website eingerichtet (https://greenfin.at/), die auch über soziale Medien zugänglich ist.

Da die Projektlaufzeit von GreenFin mit der COVID-19-Krise zusammenfiel, wurde der Umfang des Projekts erweitert, um auch die Verknüpfung der Auswirkungen des Pandemieschocks mit den Risiken des Klimawandels in Wirtschaft und Finanzen zu analysieren. Insbesondere arbeitete ein Teil des GreenFin-Teams aktiv mit Entwicklungsfinanzierungsinstitutionen und Zentralbanken zusammen, um das im Rahmen von WP3 entwickelte EIRIN-Modell auf die Analyse der Verbindung von COVID-19- und Klimawandelrisiken und deren Auswirkungen auf die fiskal- und finanzpolitischen Reaktionen und das Risikomanagement zuzuschneiden und anzuwenden. Diese Analysen führten zu einer Fülle von Ergebnissen und Disseminationsaktivitäten, darunter die Entwicklung eines neuartigen methodischen Rahmens zur Bewertung von zusammengesetzten Risiken (Dunz et al. 2021, Monasterolo et al. 2021), wissenschaftliche Veröffentlichungen (Battiston et al. 2020), politisch relevante Veröffentlichungen über die Anpassung der COVID-19-Aufschwungstrategie an die Klimaziele der EU (Monasterolo und Volz 2020a, b) und institutionelle Blogbeiträge (Mahul et al. 2021). Darüber hinaus wurde über die Ergebnisse von GreenFin in österreichischen Medien und Zeitungen berichtet (z.B. Der Standard, Wiener Zeitung). Insgesamt lieferten die Ergebnisse von GreenFin relevante Erkenntnisse für Forschung und Politik, um den nächsten Schritt für die Forschungs- und Politikagenda zu "green finance" in Österreich zu entwickeln.

2 Executive Summary

GreenFin provided an analysis of what role finance (in the form of financial markets, policies and governance structures) can play to scale-up green investments in Austria, and under which conditions unintended effects could emerge for financial stability and social cohesion. By addressing these knowledge gaps, GreenFin contributed to inform the implementation of green fiscal and financial policies aimed to foster the low-carbon transition in Austria.

Austria launched its green finance agenda in 2019, recognizing the important role of finance and capital markets to align investments to sustainability. However, progress to decarbonize the economy have been uneven. Poor climate risk disclosure and risk assessment mean that Austrian investors are still highly exposed to high-carbon assets and sectors that can become "carbon stranded assets" in a disorderly transition (Mercure et al. 2018, van der Ploeg and Rezai 2020), giving rise to financial risk. In addition, it limits the scaling up of the low-carbon investments needed to achieve the long-term climate policy goals and fill the "green investment gap". To fill this gap, green fiscal policies, such as carbon pricing, have been advocated to signal the market (Stiglitz et al. 2017), but are not implemented comprehensively. Since climate change has been recognized as a new type of risk for finance, with implications for financial stability (Battiston et al. 2017, NGFS 2019), green financial policies and regulations, and tools for financial risk assessment, are being discussed by financial authorities (BIS 2021). Nevertheless, the risks and opportunities associated with the introduction of the most debated green finance policies and instruments have still to be assessed. To this aim, GreenFin developed fit for purpose qualitative and quantitative approaches, and developed networks of collaborations with climate finance stakeholders, to provide policy-relevant information to the Austrian government, central bank and financial regulators to navigate the low-carbon transition. The project's activities are organized into 6 interconnected Work-Packages (WPs). WP1 involved interviews and an online survey with international climate finance experts and stakeholders as well as extensive desk research. WP2 developed robust financial econometric models (extended market model) to test Austrian investors' reaction to climate news and the Paris Agreement, in terms of risk-return profile of the portfolios (alpha and beta). WP3 extended the EIRIN Stock-Flow Consistent (SFC) behavioral model (Monasterolo & Raberto 2018) to assess the macroeconomic, distributive and financial impacts of the introduction of the most debated green policies (i.e. a carbon tax and green supporting factor) in Austria. In addition, it also considered the impact of investors' climate sentiments (Dunz et al. 2021, Battiston et al. 2021) on policy effectiveness, and the contribution of green fiscal and financial policy complementarity. WP4 considered the role of greening of Austrian development finance to de-risking of green investments in the beneficiary countries in the Western Balkans, and to the low-carbon transition. To achieve this goal, WP4 developed a SFC North-South model calibrated on Austria and the Western Balkans, the latter being tightly connected via trade to Austria. WP5 took stock of the project results to develop actionable policy recommendations about the role of fiscal and financial policies, and governance, to inform a climate-aligned COVID-19 recovery, avoiding unintended effects on financial stability and inequality. WP6 dealt with project management, academic and non-academic dissemination.

The methodologies developed and the results of the GreenFin project had a major academic, research and policy impact, already during the project's duration. On the one hand, the analysis of investors' climate sentiments, i.e. the role of financial actors' expectations on climate risk, and their implications on risk adjustment (e.g. cost of and access to capital for firms, depending on their exposure to climate risks), introduced a main novelty in the academic debate about the role of finance in the low-carbon transition. GreenFin's models have been applied in collaboration with international financial actors, such as the World Bank Group (WBG), the European Central Bank (ECB), and the Austrian National Bank (OeNB), to inform finance policy debate. GreenFin's results have been presented in international scientific and high-level policy events (e.g. the International Monetary Fund, the San Francisco FED, the Bundesbank, the ECB) and published in top journals such as Science, in Nature's Scientific Reports, and in a co-edited special issue on climate risks and financial stability on Journal of Financial Stability. A dedicated website was launched (https://greenfin.at/) to inform the broader public about the project results, which were disseminated also via social media accounts.

On the other hand, since GreenFin was implemented during the COVID-19 crisis, the scope of the project has been extended to consider the compounding of the impact of the pandemic shock with climate change risk in the economy and finance. In particular, part of the GreenFin's team actively collaborated with development finance institutions and central banks (the G20 T20, the WBG and the ECB) to tailor and apply the EIRIN model developed within WP3 to the analysis of compounding COVID-19 and climate change risks, and their implications for the fiscal and financial policy responses and risk management. These analyses gave rise to a rich body of results and dissemination outputs, including the development of a novel methodological framework to assess compound risk (Dunz et al. 2021, Monasterolo et al. 2021), academic publications (Battiston et al. 2020), policy relevant publications about the alignment of COVID-19 recovery policies with the climate ambitions of the EU (Monasterolo and Volz 2021a, b), and institutional blog posts (Mahul et al. 2021). In addition, GreenFin's results have been covered by Austrian media and newspapers (e.g. Der Standard, Wiener Zeitung).

Overall, GreenFin's results provided relevant research and policy insights to build the next step for the research and policy agenda on "green finance" in Austria.

3 Hintergrund und Zielsetzung

Project motivation: Austria launched its green finance agenda in 2019, recognizing the important role of finance and capital markets to align investments to sustainability. However, on the one hand, progress to decarbonize the economy are uneven and, on the other hand, Austrian investors are still highly exposed to high-carbon assets and sectors. In this regard, a main obstacle is represented by poor climate risk disclosure and risk assessment. Climate change represents a new source of risk for financial stability (Battiston et al. 2017, NGFS 2019). Investors who are exposed to high-carbon activities, which could incur losses induced by the so-called "carbon stranded assets" in a disorderly transition (Mercure et al. 2018, van der Ploeg and Rezai 2020). Thus, a green finance transition in Austria is urgently needed to tame the risk of carbon stranded assets and to scale up the investments needed to achieve the country's climate and energy targets. In this regard, green fiscal and financial policies (e.g. a carbon tax, green macroprudential policies) could contribute to address existing green market failure. Nevertheless, the risks and opportunities associated to the introduction of most debated green finance policies and instruments have still to be assessed. This is an urgent gap to fill. Furthermore, the COVID-19 pandemic has introduced new challenges for socio-economic and financial stability also in Austria. In this regard, it is crucial to understand how pandemics interact with climate risks and their macroeconomic and financial implications, in order to inform the alignment of COVID-19 recovery policies to the EU Green Deal.

Project objectives: GreenFin aimed to analyse the role of finance (markets, instruments, policies) and development finance in the low-carbon transition in Austria and neighboring countries, and the **conditions of the successful introduction of green finance policies**, to inform evidence-based policy recommendations. In particular, GreenFin aimed to contribute to five research objectives (O):

O1: understand what role green finance can play in driving/hindering the low-carbon transition;

O2: assess Austrian investors' reaction to the Paris Agreement and their portfolio decisions;

O3: analyse the role of green fiscal and financial policies, their complementarity, and the potential unintended effects for financial stability and inequality in the low-carbon transition in Austria;

O4: assess the impact of the introduction of climate policies in Austria on the Western Balkans (WB);

O5: inform the integration of climate mitigation risks, and the compounding between pandemic and climate shocks, into the country's fiscal and financial risk management, and provide recommendations to the alignment of the COVID-19 recovery policies to the Green Deal agenda. *This last objective has been updated with regard to the original one (which focused only on climate change mitigation) as a consequence of the outbreak of the COVID-19 pandemic.*

Project methodology: the project integrates scientifically robust quantitative and qualitative methodologies and is organized in five interconnected and logical steps, each represented by a work-package (WP). **Step 1** involves interviews and an online survey with international climate finance experts and stakeholders as well as extensive desk research. **Step 2** develops robust financial econometric models (extended market model) to test Austrian investors' reaction to climate news and the Paris Agreement, in terms of risk-return profile of the portfolios (alpha and beta). **Step 3** extends the EIRIN Stock-Flow Consistent (SFC) behavioral model (Monasterolo & Raberto 2018) to assess the macroeconomic, distributive and financial impacts of the introduction of most debated green finance policies (i.e. a carbon tax and green supporting factor) in Austria, also considering the impact of investors' climate sentiments (Dunz et al. 2021, Battiston et al. 2021). **Step 4** develops a North-South model to assess the macroeconomic and financial impacts of the introduction of climate policies in Austria, and derisking of development finance projects, on the beneficiary countries in the WB. **Step 5** takes stock of the project results to develop actionable policy recommendations to inform a climate-aligned COVID-19 recovery.

Project implementation: GreenFin's results were delivered through the implementation of **six interconnected work packages (WP)**:

- **WP1** (lead: WIFO) provided an extensive desk research on the green finance landscape, political and regulatory initiatives regarding green finance, to deliver insights on the framework conditions and actors for green finance in Austria.
- **WP2** (lead: UNIBO) analysed the Austrian stock market's reaction to the Paris Agreement announcement (PA) in terms of risk and performance of low/high-carbon portfolios, classified in shades of green and brown, as well as the reaction to, and pricing of, the COVID-19 outbreak.
- **WP3** (lead: WU) further developed the EIRIN SFC behavioral model, tailored and calibrated it on Austria to assess and compare the impacts of (i) a carbon tax aligned to the NGFS climate mitigation scenarios, (ii) a green supporting factor for Austrian banks, and (iii) the role of investors' expectations of climate risk, i.e. their climate sentiments, on the decarbonization of the economy, on macroeconomic and financial performance, on social cohesion.
- **WP4** (lead: IIASA) developed a Stock-Flow Consistent (SFC) model to explore the impact of Austrian climate policies (a carbon tax, a border adjustment tariff and a de-risk green investment) on emission reductions of Austria and the Western Balkans interacting through traded intermediate goods and finance.
- **WP5** (lead: WU) developed actionable recommendations for European Union member states to (i) embed the compounding of pandemics and climate shocks in their fiscal and financial risk management, and (ii) inform the alignment of COVID-19 recovery policies with the Green Deal and Sustainable Finance agenda, to avoid unnecessary trade off in public spending.
- **WP6** (lead: WU) dealt with project management and dissemination.

Results obtained so far have been presented in international scientific and high-level policy events and published on top journals (e.g. Science). Relevant research collaborations with national and international financial institutions have been developed. A dedicated website was launched to disseminate the project results (https://greenfin.at/), also via social media accounts.

4 Projektinhalt und Ergebnis(se)

A concise overview of the activities performed in each WP, including the methods employed, and the results obtained, is provided below.

WP1's objectives included a comprehensive overview of sustainable finance instruments and initiatives and the development of empirical evidence on the relevant framework conditions and actors for supporting the development of a green finance agenda in Austria. As a *first task*, an extensive desk research was carried out in order to summarise the evolvement of green finance over the past years, taking into account relevant policy and governance initiatives on various levels (e.g. the European Union (EU), the Network for Greening the Financial System (NGFS), etc.) as well as the quantitative development of sustainable/green investments on the financial markets.

The dynamic development of the green finance agenda is closely linked to the investment gap that has to be bridged for reaching the climate mitigation objectives and the low-carbon transition transformation requirements. The regulatory framework for the finance sector can play a crucial role in mobilising and redirecting private capital flows towards sustainable investment and climate finance. This also requires that financial institutions integrate climate-risk assessment into their decision making in order to align their business operations with the Paris Agreement targets.

Nevertheless, the lack of common standards and taxonomies for green finance hampers green finance market development and integration, raises concerns about greenwashing and increases information costs for investors.

An ambitious approach to a definition of green finance is provided by the EU Taxonomy of sustainable investments, with the aim to (i) decrease information asymmetries about sustainable activities, and thus foster financial flows into sustainable economic activities, and (ii) to provide more investment security regarding the climate mitigation and adaptation impacts of an economic activity, as well as impacts on the climate or other dimensions of sustainability (double materiality).

The multitude of instruments available in the market complicate the comparison of different data sources. Depending on the delimitation used (e.g. Environmental Social Governance (ESG) vs. green vs. climate finance) volumes will differ significantly. The most comprehensive overview of global climate finance is provided by the Climate Policy Initiative (2021) that confirms results of In other sources (Climate Bonds Initiative, 2021, Aramonte and Zabai, 2021, UNCTAD, 2021) Climate Policy Initative (2021) finding high growth rates for sustainable and green finance in recent years. According to Climate Policy Initiiative (2021), global climate finance funds amounted to 632 bn USD $ (average 2019/2020), which corresponds to an increase of 10% compared to 2017/2018. 90% of the funds (571 bn $) are directed towards climate mitigation measures. Although funds for adaptation have increased substantially (+53%) reaching 46 bn $, they still fall well short of the volumes needed for building resilience and adaptative capacity in developing countries. This is also illustrated by the fact that around 75% of climate funds are raised and invested in the same country and these funds are concentrated in a rather small number of countries (mainly Western Europe, North America, East Asia and Pacific).

Similar developments are stated for other delimitations of green or sustainable finance markets. For instance, Green Bond Initiative (2021) include Green, Social and Sustainability bonds, Sustainability-linked bonds (SLB) and Transition bonds in their analysis and report a volume of 735 bn $ for 2020 and 779 bn $ for the first three quarters of 2021. Green bonds alone reached a total issuance of 290 bn $ in 2020.

In addition to the summary of the current green finance landscape and political and regulatory developments, an evaluation approach for categorizing green finance instruments was developed. This fact sheet summarizes all relevant information on the respective instrument like type of instrument, issuer, geographic scope and time horizon, focus area or special use, volume, additional information (e.g. rating, monitoring, verification and transparency requirements). This evaluation sheet can be used to systematically compile information on green finance products and inform investors, researchers and practitioners.

The second task was to investigate supporting and inhibiting factors for a broader implementation of green finance mechanisms as well as appropriate framework conditions for greening the finance sector in Austria. Therefore, an online survey was carried out among national and international experts and stakeholders for identifying the main drivers and barriers for successful implementation.

For the design of the questionnaire, in order to ensure that all relevant aspects related to the topic were included, we led a series of guided interviews with experts from the Austrian National Bank (OeNB), a rating agency and research institutions. With the online questionnaire we addressed national and international experts and stakeholders from administration/regulatory bodies, the financial market, (institutional) investors, Non-Governmental Organizations (NGOs) and interest representations as well as research and consulting. The list of addressees for the questionnaire was compiled using snowball sampling. This non-probabilistic method involves primary data sources nominating other potential data sources to be used in the research. The primary sources in our sample were the members of the project team that personal contacts from various areas of their work who in turn provided further contacts. The results give an insight on key strategies, policies and actors that can support the growth of green finance. In particular, the results also provide conclusions regarding key policies that should be integrated in post-COVID-19 stimulus packages to ensure that the recovery is Paris-aligned. The online survey was sent to a total of 185 experts and stakeholders. With 84 questionnaires completed we achieved a response rate of 46%. The largest group among respondents are researchers (31%) followed by people active in policy making or regulating authorities (26%). The financial sector (banks, investment companies, etc.) supplied the third largest group (14%), institutional and private investors account for 12%. Another 11% of respondents are consultants, 7% pertain to other institutions like interest representations or NGOs.

A high share of respondents (85%) note a strong increase in the relevance of green finance on the financial market in the last three years. This also applies to climate policy but to a lesser extent. The majority of respondents do not yet consider integration into climate policy to be sufficient. The main drivers for the increase in importance are new regulations (e.g. the EU Taxonomy), increasing public awareness of the climate crisis, increased consideration of climate risks on the financial market and rising investor demand for green investment products. In contrast, insufficient national regulation, inadequate consideration of climate risks, and lobbying by "brown" sectors are cited as the main obstacles to green finance. In addition, the lack of transparency or the risk of greenwashing are regarded as significant barriers. Aspects that are often put forward as being problematic with regard to green or sustainable in-vestments like low acceptance, high information costs, a pessimistic view of the investments' profitability are not perceived as being very obstructive by our respondents.

Another aspect included in the questionnaire was which actors are perceived as being supportive or interfering with green finance. Our survey finds that it is mainly EU policy makers, research and civil society that are perceived as promoting green finance (80% to 90% of respondents ranking these actors as supportive or very supportive). Also, institutional investors (e.g. pension funds, churches etc.) are largely perceived as supportive. At the other end we find real economy actors (21% seeing them as obstructive or very obstructive), financial market actors (11%) and the media (12%).

Regarding the impact of the COVID-19 crisis on Green Finance, the results show a rather positive trend. About 40% of responses indicate that the relevance of Green Finance has increased in politics, on the financial market and in public perception. Between 40% and 50% indicate unchanged relevance. When asked which instruments should be integrated into economic stimulus packages to foster the growth of green finance, measures related to an ecological fiscal reform (CO2 pricing, subsidy reform, introduction of specific green subsidies) were given priority. Furthermore, measures and instruments for risk management and regulation of the financial sector as well as public investment and procurement were considered relevant.

Our survey results complement the existing body of empirical literature and the results are in line with other similar assessments (CRIC, 2021, Glas et al., 2020, Hafner et al., 2020, Ilhan et al., 2019, Siri and Zhu, 2019). WP1's results are reported in a working paper by Kletzan-Slamanig and Koeppl (2021) "The Evolution of the Green Finance Agenda – Institutional Anchoring and a Survey-based Assessment for Austria".

WP2 aimed to analyze the reaction of the Austrian financial market to the Paris Agreement in terms of risk and performance of low and high-carbon portfolios, and to analyze the Austrian stock market's reaction to, and pricing of, the COVID-19 pandemic. WP2 first classified stocks into value-weighted portfolios defined according to their shades of green (defined according to the EU Taxonomy alignment) and their exposure to climate transition risk, defined following the Climate Policy Relevant Sectors (CPRS) methodology (Battiston et al. 2017).

First, (shades of) "green" and "brown" portfolios were defined by using the EU Taxonomy for sustainable activities (Regulation EU 2020/852) and CPRS, respectively. As a starting point for the construction of the portfolios from the Wiener Börse Index (WBI) constituents, we utilized the CPRS Main sector, which includes all activities related to fossil fuels extraction, production and commercialization. The CPRS classification allows us to classify economic activities according to their climate transition risk in a disorderly low-carbon transition. CPRS contributes to overcome the limits of classification of exposures based on GHG emissions solely, by adding information about the energy technology profile of the economic activity and its value chain, the business and revenue models (in terms of input substitutability) as well as the cost sensitivity to climate policy change. By mapping economic activities at a highly granular level (e.g. NACE 4 digit) into CPRS, and by classifying portfolios of financial contracts (e.g. stocks, bonds) into CPRS depending on the characteristics of the issuers, the CPRS help to quantify carbon stranded assets in the economy (Monasterolo 2020a). As a proxy for the level of greenness of firms classified in CPRS2-utility sector, we utilize the data on capacity ownership in power plant units that generate electricity from various fuel types. The EU Taxonomy is applied with the aim of identifying all the companies' activities categorized as "taxonomy-eligible" (Alessi et al. 2021). Taxonomy-eligible activities include all the activities that have been explicitly mentioned in the Taxonomy Regulation (e.g., electricity generation from wind power, but also the manufacture of aluminium, cement, etc.).

After having identified the following classes - Very Green, Green, Light Brown, Brown, Dark Brown, Very Dark Brown – we develop an extended market model (Sharpe 1964). We use the model to analyse the financial performance of portfolios during the COVID-19 crisis, by comparing the resilience of green and brown portfolios. We apply the methodology to the Austrian stock market, analyzing the Wiener Boerse Index.

Results of WP2's analysis are reported in the working paper by De Angelis, Duranovic, Monasterolo (2021) "Portfolios' greenness and resilience to the COVID-19 crisis: the case of the Austrian stock market".

WP3's objectives included the analysis of the impact of green fiscal and financial policies in the economy and finance in Austria. As a first step, we further extended the EIRIN Stock-Flow Consistent (SFC) behavioural model (Monasterolo and Raberto, 2018) tailoring it on Austria, and we calibrated it on Austrian national accounting data through the statistical office of the EU, i.e. Eurostat. In this regard, an existing tool[1] was adapted to the needs of EIRIN to provide an automatic downloading tool aimed to facilitate the mutual interaction between the calibration procedure of EIRIN, which targets key macroeconomic statistics regarding long-term growth and business cycles, and the wide range of data available from national accounting data sources. The adaptation involved overcoming the limitation of this tool in downloading complex data sources. With this adapted and extended tool, a wide range of data sources became available (including the possibility of automatic updates) to calibrate EIRIN, including input-output tables[2] and a wide range of datasets from the national accounts[3]. With this wide range of data availability, the calibration and tailoring process of EIRIN has become more efficient and also replicable due to the documentation of data downloads directly in Matlab code. In this process, it is important to acknowledge for the endogenous characteristics of the model dynamics – i.e. mutual interdependencies of parameters and variables amongst each other within the logic of the model – and the corresponding empirical information available from our data sources. This general difficulty in macroeconomic model building is normally either tackled by (1) the choice of free parameters to tailor SFC behavioral models (SFC) such as EIRIN to main business cycle facts, or (2) by calibration of models with very rigid dynamics (time series models, computable general equilibrium or dynamic stochastic general equilibrium models) to a wide variety of data sources. Our approach is novel with regards to its hybrid nature, and thus an innovation in

[1] See https://de.mathworks.com/matlabcentral/fileexchange/68812-eurostat-data-downloading-facility for further information.
[2] https://ec.europa.eu/eurostat/web/esa-supply-use-input-tables/overview
[3] https://ec.europa.eu/eurostat/web/national-accounts

macroeconomic modelling per se, which brings challenges, but also potential for successful scientific innovation.

The next step was to select the relevant climate mitigation scenarios for Austria. In this regard, since no country-specific scenarios are available, we opted for the second vintage of the NGFS climate scenarios published in 2021 (NGFS 2021), which comprises six scenarios of climate transition and physical risks (see Figure 1). The NGFS scenarios are provided by three IAMs: GCAM[6], MESSAGE-GLOBIOM[7] and REMIND-MagPIE[8]. The scenarios are characterised by output trajectories of economic activities (e.g. electricity production out of coal or wind), following a model-specific geographic disaggregation. This feature allows us to downscale model inputs and outputs at country level and to integrated them in the EIRIN model. The six NGFS scenarios differ with regard to global temperature targets (e.g. 1.5°C, 2°C), GHG emissions targets by 2050 (e.g. net zero), climate policy ambition, timeliness of policy implementation (e.g. early or delayed implementation), and availability of carbon dioxide removal technologies.

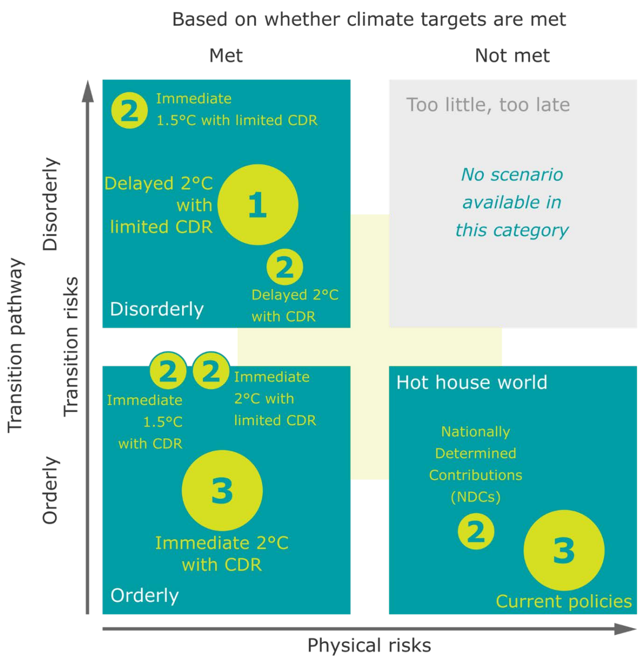

Figure 1: NGFS climate mitigation scenarios. Source: NGFS 2021.

In this analysis, we considered only transition scenarios, including orderly transition (i.e. early introduction of carbon pricing) and disorderly transition (i.e. late and sudden introduction of carbon pricing), and are widely used now by investors, central banks and financial regulators to assess climate-related financial risks. We downscaled the scenarios to Austria, and then we modelled the macroeconomic, financial and distributive effects of green fiscal policies, i.e. a carbon tax aligned to the NGFS climate mitigation scenarios, green macroprudential policies, i.e. a green supporting factor for Austrian banks. In addition, by means of a sensitivity analysis, we considered the role of banks' climate sentiments on the effectiveness of the policies' implementation. Consistently with the definition of investors' climate sentiments developed by Dunz et al. (2021a), we considered Austrian banks' expectations towards climate mitigation scenarios, which can lead them to revise the cost of capital for high and low-carbon firms, based on their GHG emissions intensity of earnings[4]. As such, banks' climate sentiments allow us to capture the reaction of the financial sector to the low-carbon transition (Gourdel et al., 2021).

Finally, we analysed under which conditions synergies between the carbon tax and the green macroprudential regulation and could emerge and inform the development of green fiscal and finance policies that may be introduced by governments, central banks and financial regulators. A working paper titled "Green finance policies for the low-carbon transition in Austria: challenges and on opportunities for complementarity" by Vismara, Mazzocchetti and Monasterolo (2021) provides a description of the model setting and the results of the analysis.

We opted for the EIRIN model for its structural and behavioural characteristics, which facilitate a dynamic analysis of climate-related financial risks and opportunities. EIRIN is composed of agents and sectors of the real economy and finance (thus including banks, a central bank and investors), which are heterogeneous with regard to their characteristics (e.g. income, wealth) and preferences. EIRIN's agents and sectors interact with each other and with the foreign sector through a set of markets. In addition, they are endowed with adaptive expectations about the future of the economy[1]. EIRIN allows us to consider the heuristics and behavioural patterns of sectors that con-tribute to the generation of emerging phenomena and out-of-equilibrium states of the economy. Thus, with EIRIN we can relax strong assumptions on agents' perfect foresight and efficient markets hypothesis that may not hold in the context of deep uncertainty, non-linearity and endogeneity of climate risks (Monasterolo 2020b). EIRIN's agents and sectors are represented as a network of balance sheet items in SFC framework, making it possible to trace a direct correspondence between stocks and flows, and analysing how they change as a result of exogenous or endogenous shocks. The stock-flow consistency provides a rigorous accounting framework where equilibrium conditions are substituted by accounting identities that hold irrespective of any behavioural assumptions. EIRIN's accounting identities represent structural specifications that have to be fulfilled at any time step in the model simulation, thus providing relevant binding constraints for the model dynamics. Therefore, the SFC constraints contribute to strengthen both the model and code validation, and the transparency and accountability of results, overcoming a main limitation of simulation models (e.g. ABM). Figure 2 shows the interactions among the agents and sectors of the EIRIN model, while Figure 3 shows the main current and capital accounts flows of its economy.

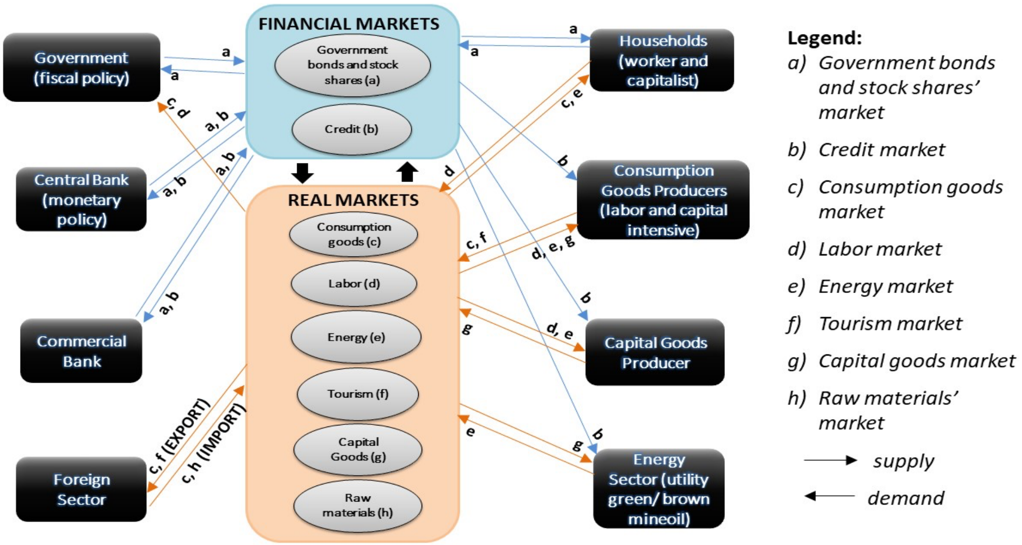

Figure 2: Agents and sector of the EIRIN economy that interact through real and financial markets Black boxes: heterogenous agents and sectors. Light blue box: financial markets. Orange box: real markets. Outgoing arrows: supply. Incoming arrows: demand.

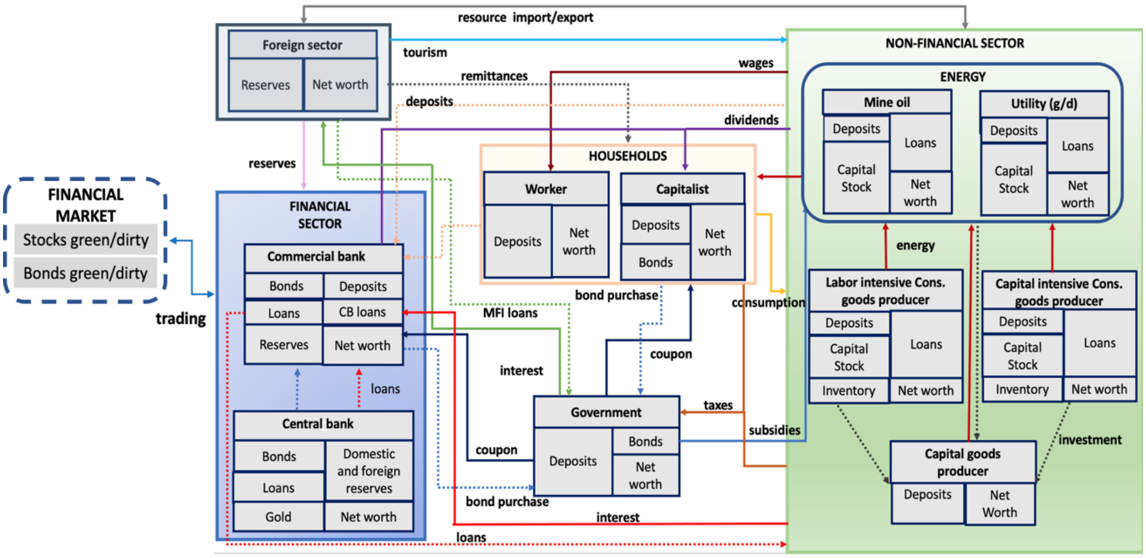

Figure 3: Main capital (dotted) and current (solid) of the EIRIN economy.

WP4's objectives included the development of a SFC model to explore the impact of climate policies on emission reductions on two highly inter-connected regions, i.e. Austria and the Western Balkans, that interact through traded intermediate goods (Figure 4). This North-South model also incorporates a banking sector, households, a public sector, and a development finance institution. We show that a unilateral climate tax in Austria, to achieve emission reduction targets, will result in carbon leakages to the Western Balkans. Austria can counter this by introducing a Border Adjustment Tariff (BATs) on brown imports. Yet, the bulk of the adjustment burden of the low-carbon transition is shifted to the Western Balkans, which lose market share with Austrian imports. A combination of three climate policy instruments, including green investment de-risking in the Western Balkans, is preferable, as it allows to achieve emission targets in Austria without compromising on economic progress in other regions or inducing carbon leakage. The model development took a year to setup and calibrate it. This involved reading the literature to explore Austria and its relationship with the West Balkans. Several institute in Vienna also provided support on this topic including the OeNB, wiiw, and WIFO. In addition to this several experts who work on the Balkan region, and transition economies were also contacted for insights.

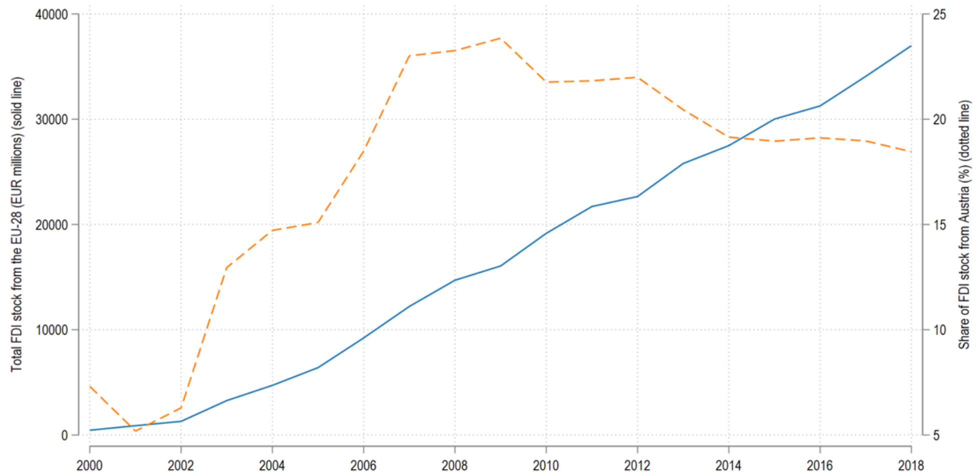

Figure 4: Stock of Foreign Direct Investment from Austria to the West Balkans.

The model was structured on a two-region model that captures EU countries' interactions with another region in the rest of the world (Figure 5). This model was developed to explore cross-border impacts of climate policies, which also accounting for financial and trade interactions.

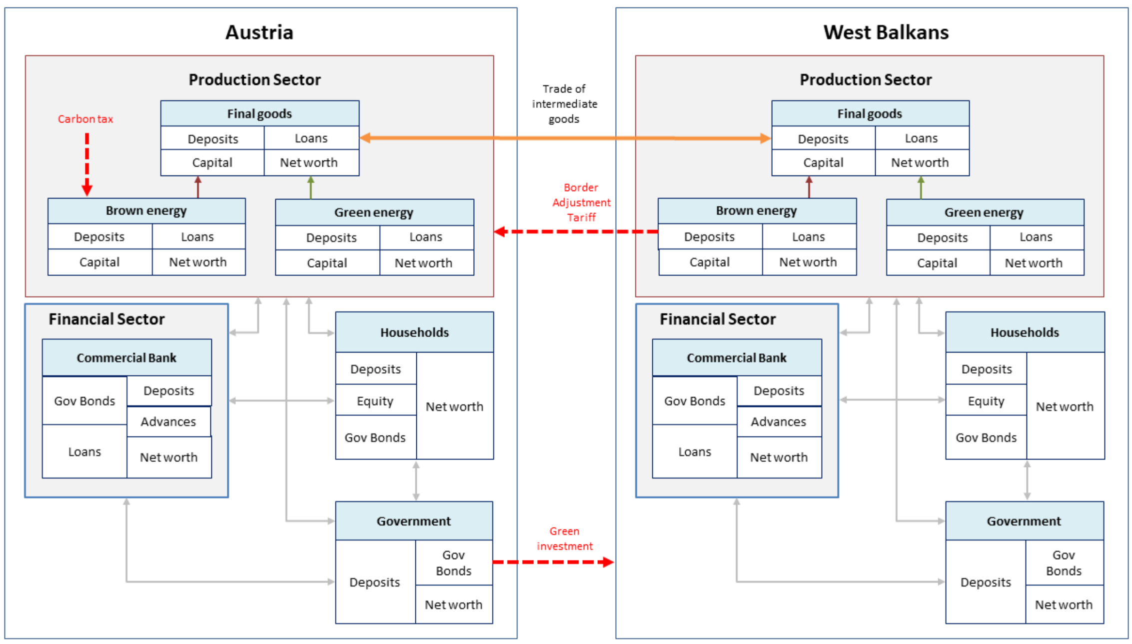

Figure 5: North South SFC model framework applied to Austria and the Western Balkans.

The economy of each region comprises of a goods firm that produces final goods demand in the economy. It also produces intermediate inputs that are traded since demand for these inputs exist in both regions. Hence firms make a portfolio choice decision across domestic and foreign intermediate goods based on price signals and elasticities. The firms are also supplemented by a green (low-carbon) and brown (high-carbon) energy producers. Firms also make a decision on the energy input portfolio based on the price of energy. Here we assume that brown energy, due to economies of scale, is cheaper. The energy sectors grow based on the level of investment. Accelerating investment in green sector, can make it more productive and allow it to catch to the brown sector.

The SFC nature of the model also implies that all flows are zero sum. The outflow of a sector equals another sector's inflow. This accounting convention, which is also used in the national system of accounts, implies that any policy-led changes to one sector (e.g. a carbon tax) will transmit through all the sectors. These features allow us to capture the drivers of the transitions to new equilibria, via adjustments in balance sheets entries, while also keeping the model's results statistically tractable.

The scenario developments also went through several phases since in 2020 and 2021. In particular, the debate around climate policies in the EU leading up to the COP26 conference in 2021 played an important role (e.g. with regard to carbon pricing and border tariffs). Most of the policies that we implemented in the model were extracted from discussions around carbon taxes to reduce emissions, and the push for border adjustment tariffs at the EU level. We also introduced a development bank agent, whose structure resembles institutions like the European Investment Bank (EIB), as a potential enabler of green investments. Indeed, development finance institutions can contribute to reduce the green investment risk, signalled via interest rates, and to de-risk investments. The preliminary results of the model are included in a working paper titled "Analyzing the spillover effects of climate policies in a Stock-Flow Consistent North-South model: The case of Austria and the Western Balkans" by Naqvi, Dunz and Monasterolo (2021).

WP5 aimed to support the policy makers and financial supervisors' green finance agenda. On 19th May 2021, the GreenFin team presented the project's research results (focusing on WP1, WP2 and WP3) to climate finance stakeholders, and discussed them in a knowledge co-production approach, in order to inform actionable policy recommendations. In this regard, we organized an online stakeholders' workshop titled "*What role for green fiscal and financial policy complementarities in the COVID-19 recovery? Issues at stake and opportunities ahead*", including nineteen stakeholders and seven project team members from twenty-one different institutions, including representatives from academia, business, finance, central banks, financial supervisors and development finance. The workshop was organized in two sessions, covering the following **topics:**

- Role of green fiscal, monetary and macroprudential policy complementarity to green COVID-19 recovery: investors' expectations and how to provide coherent signals?
- Challenges and opportunities for green finance policy implementation: role of metrics and methods, and governance structures.

The workshop was opened by a high-level keynote presentation by Dr. Andrea Beltramello, Member of Cabinet of the Executive Vice-President of the European Commission, V. Dombrovskis. He highlighted that the EU was among the first to focus on sustainable finance, which plays a key role for the low-carbon transition, and the importance of a strong and sustainable, fair and inclusive EU COVID-19 recovery. In this context, investment challenges are large and public finance alone cannot address them. That is why the EU is working on stimulating the flow of private capital into green activities and support investors in identifying what it green (e.g., EU Taxonomy).

The preliminary results of the project were presented by the four work package leaders. The first part of the workshop was followed by the two interactive sessions in which the participants were split into two groups and discussed specific topics:

- **Interactive session I:** What are the most relevant policies and conditions for implementation (e.g., market, governance) that help to align finance to climate objectives in the COVID-19 recovery?
- **Interactive session II**: Who will be the winners and losers in the economy and finance? Risk transmission channels?

Concluding remarks were provided by I. Monasterolo. Overall, the workshop had an enthusiastic participation. Annex 3 includes the workshop's agenda, and the list of institutions of the workshop participants, respectively.

WP6 aimed to support all the management (including financial management) and dissemination activities of the project, including:

- Day-by-day project management, including: i) communication with the funder, ii) regular monthly meetings (online), iii) contracts and financial resources management, iv) organization of the kick-off meeting in December 2019 and of the stakeholders' workshop held in May 2021.
- Dissemination:
  - i) launch of the GreenFin website (https://greenfin.at/);
  - ii) dissemination the project on the PI and project partners' social media (Twitter, LinkedIn);
  - iii) presentation the project and the results obtained so far in several international academic

  (e.g. UZH Sustainable Finance conference 2020, Computational and Financial Econometrics conference 2020, EAEPE Conference 2020, 221, CREDIT conference 2020, 2021), Austrian Climate Days, and several high-level policy events, including those organized by the members of the NGFS).

5 Schlussfolgerungen und Empfehlungen

The GreenFin's results provided relevant research and policy insights to build the next step for the research and policy agenda on "green finance" in Austria. The project's research activities attracted a lot of interest from academic and non-academic stakeholders (see e.g. the participation and richness of discussion at the stakeholders' workshop, with participation of international experts from climate economics, finance, policy and business). In this regard, GreenFin's members have collaborated extensively with both national and international financial institutions (e.g. the G20 T20, WBG, the OeNB, the ECB), as well as with leading academic and research institutions (University of Zurich, SOAS University of London, the International Institute for Applied Systems Analysis, University of Venice, Boston University, etc) on the analysis of the impact of green fiscal and financial policies on the low-carbon transition, as well as on the interplay between climate and pandemic risk. The project contributed to fill policy-relevant knowledge gaps (e.g. about the role and implications of green finance instruments and policies) in a research area that still has development potential in Austria. In addition, it provided methodological developments to address the novel risk represented by the compounding of climate change and COVID-19 risk, and results and recommendations to introduce compound risk considerations into fiscal and financial risk management.

Below we provide an overview of main insights from each WP.

WP1's results show that green finance is an area that has massively evolved over the past few years, both with regard to the financial volumes flowing into green investments, and in terms of the political and regulatory landscape. The latter – especially at EU level – is considered by climate finance stakeholders as the main driver for fostering the growth of green finance, by (i) providing comprehensive and robust regulation for ensuring transparency and credibility, and (ii) enhancing the consideration of climate related risks in financial markets. The alignment of financial markets and investment decisions with the Paris Agreement temperature targets is a prerequisite for closing the pertaining investment gap for the transformation.

The survey conducted in WP1 provided stakeholders and experts' views on the relevant conditions for greening the financial system (in Austria), on barriers that will have to be reduced or removed as well as on the key actors for green finance.

The empirical results obtained from the survey are also of interest for policy makers, regulators and researchers as an information source for decision making and further research. The lively discussion of the large group of participants in the GreenFin stakeholders' workshop that took place in May 2021 showed the interest in our research results by various potential user groups.

WP2's results show that the overall performance of the Very Green portfolio and the Green Class improves after the PA and even after the COVID-19 outbreak. Such a positive trend is not observed for the other portfolios and the overall market (WBI index). In particular, considering the post-COVID-19 period, WP2 found that the performance is negative (in terms of Sharpe ratio) for the Light Brown, Brown, Very Dark Brown (but not Dark Brown) as well as the Dark Brown Class and the WBI, thus implying negative mean returns as well as a substantial increase in the standard deviations. This evidence provides support of resilience of the green class and portfolios to the pandemic. After the PA and during the COVID-19 pandemic, according to the Sharpe ratios, the Green Class outperforms both the Dark Brown Class and the market index, but not for all the sample period considered in the analysis. This evidence suggests that the recent performance of the low-carbon stocks is superior to the one of the carbon-intensive stocks. Interestingly, Very Green is the portfolio which provides the best performance in terms of the risk-adjusted mean returns.

The results from model (1) estimation show that the low-carbon Very Green portfolio is characterized by a risk-return profile significantly smaller than the market before the PA, but the same feature is observed also for the carbon-intensive Dark Brown portfolio. However, focusing on the estimates for the dummy interaction variable that measure the impact of the PA announcement, we found that the level of systematic risk associated to the Dark Brown portfolio has significantly increased after the PA, albeit only at the 10% significance level. The rejection of the null hypothesis in favor of the alternative one is more evident for the Very Dark Brown portfolio and the Dark Brown Class, which after the PA experienced an increase of their levels of systematic risk significantly different from 0 even at the 1% level.

Moreover, after the PA, the aggregate level of systematic risk for the Very Dark Brown portfolio and the Dark Brown class becomes *larger* than the overall market. In contrast, even though we do not reject the null hypothesis for the Green Class portfolio, we do find evidence of a significant *decrease* in the aggregate level of systematic risk with respect to the market, i.e. we reject the null hypothesis in favor of the alternative one.

Interestingly, WP2 found a significant decrease in the level of systematic risk for the Light Brown portfolio after the PA, but this portfolio is mainly constituted by financial and insurance companies and, therefore, despite not being in the frontline of sustainability, the majority of the stocks classified into the Light Brown portfolio are not directly associated to carbon-intensive industry. Finally, even if we did not observe a significant reduction of its level of systematic risk (which remains strictly smaller than the market), we found evidence of a significant structural break in the intercept after the PA for the Very Green portfolio, i.e. a strong rejection of the null hypothesis in favor of the alternative hypothesis. Therefore, we found evidence of *abnormal* (excess) returns for the Very Green portfolio and the Green Class after the PA. This means that overall the low-carbon class has both sensibly reduced the level of systematic risk and provides extra returns, thus representing an appealing investment opportunity.

With regard to the impact of the COVID-19 pandemic outbreak, we can conclude that the Green Class is resilient to the COVID-19 outbreak, as no structural break is detected. In contrast, the Dark Brown Class portfolio is not resilient to the COVID-19 pandemic as we find evidence of a structural break in the slope, which implies that the systematic risk (beta) of this portfolio significantly increased after the pandemic outbreak. Interestingly, the greenest portfolio shows abnormal positive returns (significantly positive Jensen's alpha) also after the COVID-19 pandemic shock. The resilience and the superior performance of the greenest assets on the Austrian stock market is further confirmed by the definition à la Fama-French of a Green Factor, which basically corresponds to an investment strategy that simultaneously go long on green assets and short on brown assets, that shows a positive cumulative return of around 41% after 2020.

WP3's results show that an early adoption of low-carbon transition policies has important co-benefits in the mid- and long-run, in terms of GHG emissions abatement, government' fiscal stability, employment and income distribution. In contrast, a late implementation of the transition policies brings to lower GHG emissions abatement and creates higher economic instability by imposing stronger constraints on firms' investments. In addition, we tested the effects of the introduction of green macroprudential policy in the form of a Green Supporting Factor (GSF), showing how it influences interest rate levels both directly and indirectly (e.g. fossil fuel-based energy producers face an increase in interest rates caused not by the GSF directly, but by a loss of competitiveness vis `a vis renewable energy producers). This mechanism leads to an increase in low-carbon investments, which bring to a reduction in GHG emissions. In addition, coupling policy measures with a GSF has substantial co-benefits in GHG emissions abatement and economic stability. Furthermore, we introduced banks' "climate sentiments", i.e. the possibility for commercial banks to introduce a penalty based on the borrowers' GHG emissions intensity of earnings. We showed that when sentiments emerge, most sectors have high GHG intensities of earnings and thus get penalised on interest rates. This results in a reduced opportunity to take up low-carbon investment, which are structurally costlier, and thus lower overall emissions reductions. Finally, we analysed the complementarity of the introduction of a GSF and banks' climate sentiments. We found that a high GSF discount parameter and a moderate target for the banks' climate sentiments produce the most favourable effect both in terms of decarbonizing the economy and maintaining high GDP levels and low unemployment rates. Indeed, a more abrupt reaction in the financial system to the green transition has worst consequences than a moderate response.

WP4's results show that Austria can implement various policies to reduce emissions. In the paper we introduce three "unilateral" climate policies in Austria: (a) a carbon tax on brown energy, (b) a border adjustment tariff (BAT) on intermediate imports, and (c), a de-risk green FDI, where a development-bank like institution (subsumed within the Austrian government) invested in the West Balkans while also reducing interest costs. Model results show that a carbon tax results in carbon leakages, where domestic products are substituted with foreign inputs. As a result, GHG emissions go down in Austria but go up in the West Balkans. The Austrian economy also performs much worse. The second policy of a BAT together with a carbon tax, prevents the leakages but also hurts the economies of both the regions. The two policies combined with a de-risking green FDI in the South, allows the green sector to develop in the South, improving its productivity, and allowing it to catch up to the South brown sector, and the green sector in the North. As a consequence, GHG emission reductions have a minimal impact on the economic trajectories. WP4's results are also coherent with European climate targets that aim to bolster growth which tackling climate change not only domestically but also in other key regions of the world.

WP5 discussed first the most relevant policies and the conditions for their implementation, in order to align finance with the climate objectives in the COVID-19 recovery. Here the main results:

- *Central banks*: the role of central banks emerged clearly from the discussion, with lights and shadows. Participants highlighted that central banks' policies are not the only game in town and are however characterised by challenges both with regards to greening collaterals, and with the 2°C - aligned balance sheet targets of central banks. Since progress in decarbonizing the economy is uneven, unexpected and unintended effects on prices could emerge from central banks' greening collaterals. Thus, a structural change of the economy is still a priority to allow central banks' policies to be effective in signalling the market. The first signal should come from the fiscal policy, while central banks could contribute by awarding the companies that reduce their emissions and penalizing the others. Among the most important conditions, participants included the need to: (i) enforce the EU Taxonomy to inform the policy response, and (ii) introduce a clear definition of 'green' for public spending because the way the public expenditure is classified and the way the public projects are evaluated is not aligned with the EU Taxonomy.

- *Governments:* credible and coherent green fiscal policies have been delayed so far but play a main role to create the conditions for a smooth low-carbon transition, and for the implementation of green central banks' policies. First, fiscal policy's response should provide a buffer to support SME businesses' alignment to the EU Taxonomy. Second, fiscal policy should not only consider mitigation but also adaptation investments because the latter can mitigate climate physical risk and reduce vulnerability.
- *Greening the COVID-19 recovery*: green recovery plans should include both the *reforming* and *repurposing* policies. In order to be effective, governments need to target sustainable investing in their spending decisions. Clear exclusion criteria for the public money being spent in the economy are needed – no activities in the fossil sector should be subsidized any more.
- *Governance: the enforcing and monitoring regulations* already discussed are important: (i) corporate reporting should be harmonized and applied on a global level; (ii) rating agencies should consider climate risk as part of the credit risk assessment; (iii) public initiatives and public-private partnerships could foster the role of the government in private de-risking green innovation investments.

The second part of the workshop focused on distributive effects of green fiscal and central banks' policies, and their risk transmission channels. Participants highlighted that while the discussion about the distributive effects of the low-carbon transition and green policies has been on the agenda of researchers for long, policy reaction is still to come. The creation of losers depends from how and when we make the transition. In the short run, there will be losers (e.g. SME that could face high costs to align to the EU Taxonomy, lower-income households that could be more negatively affected by adjustments in relative prices, convergence regions in the EU). Thus, *compensation measures* for the most affected groups are crucial in order to achieve a just transition and a broad acceptability of green policies. The *time dimension* is also very important with regards to distributive effects: the more we wait to make the transition, the costlier it will be for the economy and finance, and the riskier. In particular, lock-in of investments in electricity production technologies (e.g., water) in some regions (e.g., Africa) that would imply a trade-off in resources use and create new challenges, instead of mitigating of and adapting to climate risk. Also, the *global perspective* should be taken into account – the effects of investment decisions in the "Global North" on climate adaptation in the "Global South" and, thus, further on climate physical risk should be considered.

Furthermore, *market imperfections* can hinder the low-carbon transition. Nevertheless, they are difficult to identify, it is not clear who has the mandate to address them, and which tools should be applied. For instance, the implementation of a carbon tax is an important step in mitigating climate change and foster a low-carbon transition, but it should be implemented in a socially acceptable way. With this regard, it is important not only to take the carbon risk into consideration (e.g., the pricing of CO2 emissions), but also to consider some market imperfections in the Emission Trading Scheme (ETS) markets (e.g., hoarding of CO2 licenses with the expectation that a more stringent regulation would put even more pressure on certain companies). Also, in *credit markets*, market imperfections exist, linked to the lack of internalization of climate change into credit risk models (e.g., the fact that the cost of capital does not take climate risk into consideration).

Finally, a sound governance of the low-carbon transition is needed to avoid systemic financial risks. Indeed, the FED draw some parallels between the 2008 financial crisis and the COVID-19 recovery. Thus, it is crucial that increased investments in the green sector do not have similar consequences to those that excess provision of social housing in the US had. However, it should be noted that these considerations do not take into account the counterfactual – how the world would be without the green investments (i.e., physical risks).

The project's results provided food for thought for next research steps in the following directions:

- The analysis of the alignment of EU member states' COVID-19 Recovery programs to the EU Taxonomy and their effects on financial markets, with a focus on sovereign debt
- The assessment of the optimal design of green fiscal and financial policy complementarity in the economy and finance
- Metrics and methods to embed compound risk assessment into fiscal and financial risk management of public financial institutions
- Improving the understanding of the characteristics and role of climate mitigation scenarios for better climate financial risk assessment of low carbon transition policies.

GreenFin involved a broad target group of stakeholders, from academia, business, finance, and policy. The interest showed by several stakeholders in the GreenFin's activities contributed to open new collaborations:

- With the European Commission's Joint research Center (new project about the greenness of EU sovereign debts)
- With the World Bank (new project about the role of Green Financial Sector Interventions for climate mitigation)
- With representatives of Banco de Espana and of the Bank of England for a joint working paper about the use of climate scenarios and climate economic models in climate financial risk assessment, to be published within Banco de Espana's Financial Stability Report
- The submission of the Marie Curie Horizon Doctoral Network program (HORIZON-MSCA-2021-DN-01) ClimaX, in collaboration with international academic and financial institutions (e.g. Banque de France, Amundi, Swiss re, etc)
- The preparation of a follow up ACRP project (Umweltbundesamt, WU)

- The preparation of an Austrian Research Promotion Agency (FFG) stand-alone project (WU)

These collaborations aim to mainstream GreenFin's research tools and results to inform i) the development and application of climate macroeconomic and financial models by academia and practitioners, ii) the further development of the green finance agenda in Austria as well as the greening of the COVID-19 Recovery Fund in Austria and in the EU.

C) Projektdetails

6 Methodik

GreenFin develops and implements an interdisciplinary approach to analyse the role of green finance policies, instruments and governance, in the low-carbon transition.
The project is interdisciplinary both with regard to the skills and competencies of its team that stem from energy and climate economics (WIFO), financial econometrics (UNIBO), SFC macroeconomic models (WU, IIASA), sustainable finance (WU), climate policy (WIFO, WU, IIASA), and the qualitative and quantitative methodologies applied.

WP1 develops a qualitative approach to the analysis of green finance policies and instruments, to inform the development of scenario analysis and macroeconomic modelling of the other WPs. WP1's methodologies include:

- An extensive desk research to sum up the evolution of green finance over the past years, taking into account relevant policy and governance initiatives (e.g. the European Union (EU), the Network for Greening the Financial System (NGFS), etc.), and the development of sustainable/green investments on the financial markets.
- An online semi-structured survey was carried out among national and international experts and stakeholders. The survey aimed to investigate the supporting and inhibiting factors for a broader implementation of green finance, framework conditions for greening, and the main drivers and barriers for successful implementation in Austria.
- Experts' guided interviews to inform the design of the questionnaire, in order to ensure that all relevant aspects related to the topic were included.

WP1 results contributed to develop an evaluation sheet for categorizing green finance instruments that summarizes all relevant information on the respective instrument like type of instrument, issuer, geographic scope and time horizon, focus area or special use, volume, additional information (e.g. rating, monitoring, verification and transparency requirements). It can be used to systematically compile information on green finance products and inform investors, researchers and practitioners.

WP2's methodological approach builds on financial econometrics and sustainable finance. It extends traditional market models to account for the greeness characteristics of portfolios, and to explore the role of greenesss in portfolio's resilience during the COVID-19 crisis.

First, in order to analyse Austrian stock market (Wiener Boerse Index, WBI)'s reaction to, and pricing of, the announcement of the PA and the COVID-19 outbreak, WP2 defines (shades of) "green" and "brown" portfolios by using the criteria of EU Taxonomy for sustainable activities and the Climate Policy Relevant Sectors (CPRS) classification (Battiston et al. 2017). The CPRS methodology allows to classify economic activities according to their climate transition risk, considering economic activities that could be affected positively or negatively (thus becoming stranded assets) in a disorderly low-carbon transition. The economic activities belonging to CPRS are identified considering not only the direct/indirect/induced contribution to GHG emissions but also the relevance for climate policy implementation (i.e., their costs sensitivity to climate policy change, based e.g., on the EU carbon leakage directive 2003/87/EC, and on the business model and revenues structure of the firm), and the role of the firms' activity in the energy value chain. Starting with the NACE classification (4 digit), these criteria yield six traditional CPRS Main sectors - fossil fuel, utility, energy-intensive, housing, transportation, agriculture - that can be further disaggregated considering the energy technologies that are relevant for the transition (e.g., fossil fuel/coal, fossil fuel/oil, fossil fuel/gas, electricity/renewable wind, electricity/renewable solar, etc.). CPRS overcomes the limits of classification of exposures based on GHG emissions; it adds information on the climate risk exposure to the NACE 4-digit sector classification, which by itself does not provide any proxy of climate risk; it provides information on the energy technology mix of the economic activity and its relevance for climate policy implementation.

The NACE Rev.2 classification of the primary activities of the issuers of WBI stocks is extracted from the Refinitiv Eikon. Based on their NACE classes, the companies are assigned to CPRS Main sectors. As a proxy for the level of greenness of firms classified in CPRS Main 2-utility sector, we utilize the data on capacity ownership in power plant units that generate electricity from various fuel types. This dataset is obtained from the S&P Capital IQ Pro platform and contains power plant units' information and their respective nameplate capacities, together with the ownership percentage of companies considered.

The EU Taxonomy is applied with the aim of identifying all the companies' activities categorized as "taxonomy-eligible". Taxonomy-eligible activities include all the activities that have been explicitly mentioned in the Taxonomy Regulation (e.g., electricity generation from wind power, but also the manufacture of aluminium, cement, etc.). However, the fact that an activity is taxonomy-eligible does not necessarily mean that it is taxonomy-aligned. For instance, some manufacturing activities can be classified as taxonomy-aligned only if their emissions do not exceed a particular CO2 threshold. This means that a taxonomy-eligible activity can also be an activity that is not green or may even be harmful. Furthermore, power generation from fossil fuels is explicitly excluded from being taxonomy-eligible, and this activity can never become green, while, on the other hand, power generation from renewables is classified as a taxonomy-aligned activity.

Based on this approach, we classify the issuers of WBI stocks into six portfolios by applying the following criteria:

1. **Very Green**: All the companies from the CPRS 2-utility sector that are primarily engaged in renewable activities are assigned to this portfolio. Those are the companies classified in CPRS 2-utility sector that have more than 85% of their electricity generation capacity in renewable technologies. At this point, it is important to mention that green utility companies are companies that can usually be easily recognized as being green by investors in the market.
   2. **Green**: This portfolio consists of all the companies that fulfil the following two criteria: (i) they are primarily engaged in the taxonomy-eligible activities; (ii) based on companies' information from various sources, they have already made some effort towards greening their activities. If a

company fulfils the second criterion, it does not necessarily mean that its activities are fully taxonomy-aligned; it means that the companies' activities cannot be classified as being brown. Those companies that fulfil the first but not the second criterion are assigned to the brown-shaded portfolios by considering their CPRS classification as elaborated below. An alternative approach for assessing the sustainability of companies identified as being taxonomy-eligible would be to use the Taxonomy Alignment Coefficient (TAC) defined by Alessi et al., 2021. This approach consists of assigning the TACs to all the taxonomy-eligible activities, and, based on a certain pre-defined threshold, classifying the activities to the 'Green' portfolio[4]. However, in this way, we would directly assign all the companies classified in the same NACE class to the same portfolio, irrespective of their individual characteristics and technologies used. For instance, the TAC for all the companies in NACE Rev.2 35.11 – Production of electricity is 0.35; however, this TAC is defined by the share of the production of electricity and derived heat from renewable sources in the EU[5] (Alessi et al., 2021), and represents the taxonomy alignment of an average company that produces electricity in the EU. However, whether a specific company that produces electric power is sustainable or not depends on the fuel mix used in its power plant units. This is the reason why we utilize the information about the companies obtained from various sources (e.g., companies' filings and websites, different data providers, etc.) in order to estimate sustainability of the taxonomy-eligible companies' activities.

3. **Light Brown**: These are the companies classified either in CPRS 7-finance or 9-other sectors. The WBI Index does not include any constituents from the CPRS1 8-scientific R&D sector. We call these companies "Light brown" because their activities are not explicitly listed in the EU Taxonomy Regulation and they are also not part of the first six traditional CPRS sectors, so the level of their exposure to climate transition risk is relatively low.
4. **Brown**: Following the CPRS classification further, companies assigned to this portfolio have the majority of their activities in either CPRS 5-transportation, 4-buildings or 3-energy-intensive sectors. These sectors are highly exposed to transition risk and their activities can be classified as 'brown'. The WBI Index does not have any constituents in the CPRS 6-agriculture sector.
5. **Dark Brown**: Companies classified in CPRS 2-utility that generate the major share of their revenues from non-renewable energy sources are part of this portfolio. In our case, only the EVN AG is classified here because, although its NACE class is "Taxonomy eligible", the majority of its activities are directly related to fossil-fuels.
6. **Very Brown**: These companies are classified in the CPRS 1-fossil-fuel sector. Their revenues are generated from the dirtiest activities related to the fossil-fuels production and manufacturing.

Then, we consider the following extended market model to test for the structural change in both alpha and the beta of the portfolio:

[4] We could, for instance, classify an activity to the 'Green' portfolios if its TAC is larger than 0.5.

[5] 2019 data, source: Eurostat, https://ec.europa.eu/eurostat/databrowser/view/NRG_BAL_PEH__custom_1160933/default/table?lang=en (Alessi et al., 2021).

$$r_{i,t} = \alpha_i + \beta_i r_{m,t} + \gamma_i d_t + \delta_i (d_t \cdot r_{m,t}) + \varepsilon_{i,t} \quad (1)$$

where $r_{i,t}$ is the return on the (value-weighted) portfolio *i* at time *t*, $r_{m,t}$ is the return on the market index (Wiener Börse Index, WBI) at time t, d_t is a dummy variable which denotes an event, i.e. $d_t = 1$ after the event occurred and $d_t = 0$ before, and $\varepsilon_{i,t}$ is an i.i.d. error term with $E(\varepsilon_{i,t}) = 0$ and $E(\varepsilon_{i,t} \cdot r_{m,t}) = 0$.

The model in (1) is akin to the market model within the CAPM framework (Sharpe, 1964) as it derives the linear relationship between the asset's expected return and its beta, which is a standard measure of the asset's systematic risk. This means that, similarly to the market model, our model identifies the risk-return profile of asset *i* in a simple and straightforward way.

There are several well-known statistical limitations of the market model and of the CAPM framework, including the assumptions of absence of autocorrelation, of homoskedasticity and Gaussianity, and of independence between the market index used as regressor and the stochastic component. Nevertheless, despite these limitations, the market model is still considered as one of the main benchmarks in financial studies for its simplicity and interpretability[6]. In our analysis, we address these potential limitations by using Heteroskedasticity and Autocorrelation Consistent (HAC) standard errors to account for possible autocorrelation, heteroskedasticity and, to some extent, the deviation from the normal distribution; considering a relatively high number of portfolios with the intent to limit the weight of a single portfolio with respect to the overall market and hence to weaken the possible correlation between the regressor and the model's stochastic component.

Using the extended market model in (1) we test for a change in the portfolio's performance and risk-return profile by considering the null hypotheses (H_0) of no change in the value of *alphas* and *betas* before/after the event captured by the dummy variable d_t. In particular, a (heteroskedasticity and autocorrelation) robust test on coefficients γ_i and δ_i is carried out to evaluate whether the climate announcement under investigation (e.g. the PA) has a significant effect on the portfolio's performance, i.e. possible excess (abnormal) returns ($\gamma_i > 0$), and a change in the portfolio's systematic risk ($\delta_i \neq 0$), respectively. Therefore, we test for the presence of significant differences in systematic risk (beta) across low-carbon and high-carbon portfolios to understand if the Austrian market is pricing them in a different (and statistically significant) way in terms of the systematic risk profile (beta), and if the market is, on average, rewarding with larger returns (positive alpha) or penalizing (negative alpha) the two classes of assets. More precisely, rejecting the null hypothesis $H_0: \delta_i = 0$ in favor of the alternative $H_{1A}: \delta_i < 0$, implies that the portfolio has reduced its level of systematic risk. In contrast, rejecting the null hypothesis in favor of the alternative $H_{1B}: \delta_i > 0$ implies an increase in the portfolio's systematic risk. Moreover, rejecting the null hypothesis $H_0: \gamma_i = 0$ in favor of the alternative $H_{1A}: \gamma_i < 0$, implies negative mean returns after the event for the portfolio, while rejecting the null hypothesis in favor of the alternative $H_{1B}: \gamma_i > 0$ implies evidence of positive abnormal returns, on average.

[6] In addition, we are well aware of the fact that future climate impacts are characterized by large uncertainty and non-linearity, thus implying the need to consider stochasticity. For a discussion of the challenges for pricing climate policy risks in financial contracts see Battiston and Monasterolo (2020).

Our testing approach is in the spirit of the Chow test to assess the presence of a structural break at a given date in time (Chow, 1960). In particular, here we focus on both the break of the intercept and of the slope parameters, i.e. an abrupt change in the (excess) mean return and the level of systematic risk related to the climate announcement, respectively.

The same analysis is repeated to analyze the impact of the COVID-19 outbreak on the performance of the portfolios. To do so, we re-define accordingly the dummy variable d_t in (1), i.e. $d_t = 1$ after the COVID-19 outbreak in Austria (end of February 2020) and $d_t = 0$ before. Therefore, the tests on the coefficients γ_i and δ_i allow to investigate whether the pandemic shock has a significant effect on the risk-return profile of the portfolios, e.g. in terms of resilience to such shock in the case of an insignificant impact on both *alpha* and *beta*.

WP3 is a macroeconomic and financial WP. It further develops the EIRIN SFC behavioral model (Monasterolo and Raberto 2018) and calibrates it to Austrian national accounts and emissions.

In the last decade, research in macroeconomics and finance has extended to consider climate change and systemic financial risks, as well as their transmission channels and impact on the real economy. It is well recognized that the transition to a low-carbon economy is characterized by deep uncertainty and endogeneity (Battiston et al. 2021). Deep uncertainty about the outcomes makes decision making more difficult, thus contributing to increase uncertainty for firms and investors. When agents are uncertain about the magnitude and potential impacts of the climate policies, and about the outcomes that will prevail, they cannot have perfect foresight.

Risk averse firms will consequently delay the investment decisions, whereas risk averse banks will tighten firms' access to credit, by revising the cost of debt upward. This means that public policies aimed at restoring economic and financial stability will be less effective because their economic signaling might be weaker in the face of the uncertainty. Considering these dynamics is important because they can lead to long-lasting effects and slow recovery (hysteresis).

Recent research (e.g. Farmer et al. 2015, Balint et al. 2017, Monasterolo 2020, Stern 2021) highlighted the limitations of traditional macroeconomic and financial risk approaches to analyze the non-linearity and complexity of climate-related risks, and the implications of using traditional approaches for policy recommendations.

For instance, macroeconomic models commonly used by Ministries of Finance and Central Banks, such as the Dynamic Stochastic General Equilibrium (DSGE) models, typically assume that agents have rational expectations, that hysteresis plays no role, and that the evolution of the economy is driven primarily by exogenous shocks. Although some DSGEs have started to incorporate individual actors and more endogenous factors (e.g., money creation by banks), they mostly relegate it to short-term "financial frictions," without considering the potential for long-term build-up of economic and financial fragility.

Dunz et al. (2021) and Battiston et al. (2021) showed that embedding investors' expectations and risk perception is crucial to avoiding underestimating risk. This is highly relevant in the context of the low-carbon transition, for which we need models that are flexible enough to consider different high-end climate policy scenarios, endogenously generated demand and supply side reactions, and a realistic representation of financial markets. In this regard, stock-flow consistent (SFC) models have emerged as one important class of models for this type of problem, in that they can endogenize the climate-economy-finance feedback.

SFC model structure

The EIRIN model contributes to address these issues. EIRIN is composed of heterogeneous agents and sectors of the real economy and finance (see Figure 2). In particular, we can distinguish a working class household (H_w), a capitalist household (H_k), a labour intensive consumption good producer (CGPl, or F_L), a capital intensive consumption goods producer (CGPk, or F_K), a capital goods producer (K), an energy company (EN), a commercial bank (BA), a central bank (CB), a government (G) and a foreign sector (ROW).

Agents and sectors interact with each other and with the foreign sector through a set of markets: a) Government bonds and stock shares market, b) Credit market, c) Consumption goods market, d) Labor market, e) Energy market, f) Tourism market, g) Capital goods market, h) Raw materials market. The formation of demand, supply and prices in each market is independent from each other at any simulation step.

Agents are modelled as a network of interconnected balance sheet items (see Figure 3) in a SFC modelling approach, which makes it possible to trace a direct correspondence between stocks and flows, and how they change as a result of exogenous or endogenous shocks.

In addition, the SFC approach provides a rigorous accounting framework where equilibrium conditions are substituted by accounting identities that hold irrespective of any behavioral assumptions. In this context, EIRIN's accounting identities represent structural specifications that have to be fulfilled at any time step in the model simulation, thus providing relevant binding constraints for the model dynamics. It is worth noting that the constraints linked to the stock-flows consistency of the model contribute to strengthen both the model and code validation, and the transparency and accountability of results, overcoming a main limitation of simulation models (e.g. Agent Based models).

EIRIN's agents and sectors are heterogeneous with regard to their characteristics (e.g. income, wealth) and preferences, and are characterized by behavioral rules and adaptive expectations about the future of the economy. EIRIN allows us to consider the heuristics and behavioral patterns of sectors that contribute to the generation of emerging phenomena and out-of-equilibrium states of the economy. Thus, EIRIN allows us to relax strong assumptions on agents' perfect foresight and efficient markets hypothesis that may not hold in the context of deep uncertainty, non-linearity and endogeneity of climate risks.

Scenarios

We follow the scenario design by NGFS (2021) and the trajectories provided by REMIND-MagPie model because it provides very rich input and output data, including an EU level breakdown, which we downscale to extrapolate information specific to Austria. We produce four transition scenarios that differ in terms of policy ambition, measures, readiness of innovation (Gourdel et al. 2021):

- "Net Zero" (NZ) scenario

- Below 2°C"(B2C) scenario. Here, the climate policies are introduced early and smoothly, but are compatible with a 67% chance of achieving a less than 2°C temperature increase.
- Delayed Transition" (DT) scenario in which climate policies are introduced late in 2030, rather than in 2021.
- Current Policy" (CP) scenario. This assumes no transition to happen and the continuation of the current policies.

With EIRIN, we model the impact of the NGFS scenarios in Austria, as from Figure 6. We consider the carbon prices trajectories of each NGFS scenario, provided by REMIND-MagPie. We use linear interpolation to obtain values by semester. The NGFS carbon price inputs are expressed in terms of price per tonne of CO2, while GHG taxes in EIRIN are levied as a percentage of sectoral GHG emissions. Thus, we introduce a conversion factor to transform NGFS carbon price values into carbon taxes applicable into the EIRIN model. The conversion factor is calibrated so that the baseline model in EIRIN matches the current carbon tax revenues in Austria. We couple the increase in carbon prices with an increased flexibility in fiscal policy for which the government -after the transition - can modify other components of their fiscal policy. The decision depends on the government's current fiscal performance regarding debt to GDP levels and deficit to GDP levels. This allows for partially smoothing the impacts of an increase in carbon prices in our implementation of the NGFS scenarios.

Based on these scenarios, we simulate the following green finance policies:

- Carbon pricing, coherent with the above described scenarios
- Green Supporting Factor (GSF), i.e. a reduction in risk parameters assigned to low-carbon assets in the calculation of commercial banks' capitalization mandated by the country's central bank (Krogstrup and Oman, 2019).

We also consider banks' "climate sentiments" by adding a penalty, based on the GHG emissions intensity of production by sector, in the interest rate required by banks on the loans to the production sectors.

We analyse these policies and sentiments both individually and in combination. In particular, we analyse potential complementarities between banks' climate sentiments and GSF, by performing a sensitivity analysis.

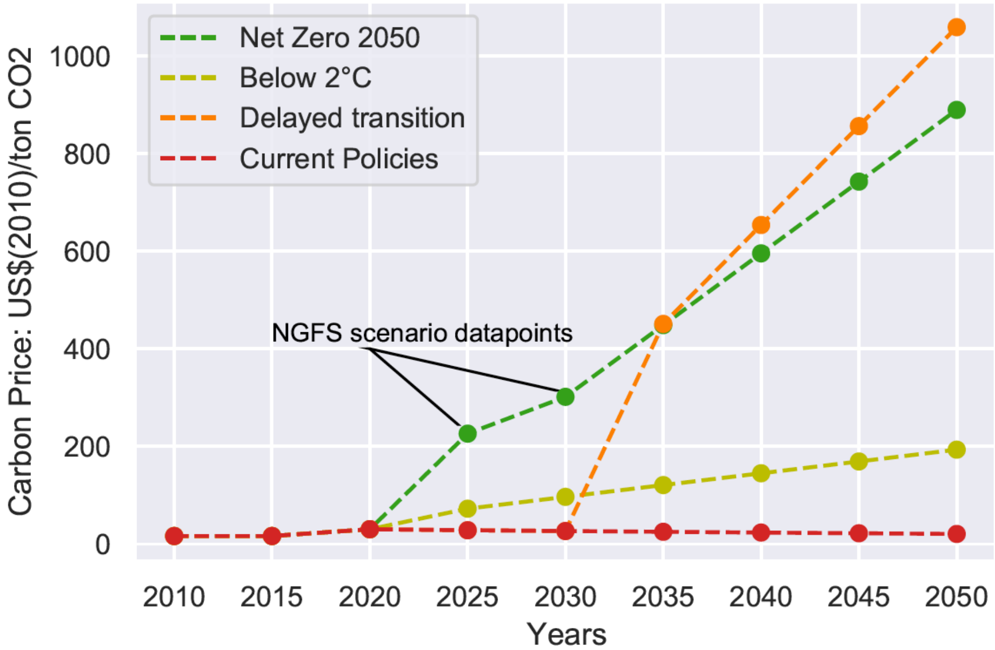

Figure 6: carbon price trajectories by NGFS scenarios. The x axis displays the years, the y axis reports the carbon price in units of 2010 US$ per ton of CO2 emitted. The dots represent the values outputted by the NGFS (2021) scenarios application in REMIND-MAgPIE (available at https://data.ene.iiasa.ac.at/ngfs). The linear interpolation lines are the result of the authors' work.

WP4 develops an SFC North-South model defined by two regions, a North (Austria) and a South (Western Balkans) economy, which are symmetric in their behavior except for lower wages and labor productivity in the South (Figure 5).

SFC model structure:
Each economy is composed of six sectors - Households, Government, Commercial banks, a Firm sector consisting of a final good producer (capital, intermediate, and consumption goods) and energy firms that can choose between fossil fuel (Brown) and renewable (Green) energy. The economies engage in the trade of intermediate goods required for producing the final good. Trade volume is determined by demand, relative prices, and the elasticity of substitution across the different goods. Households and the government consume the final good, whereas all firms, including the energy good producers, must build up and maintain capital stock through investment.
All producers require three key inputs in production, i.e. labor (l) and capital (k) and energy (e), while final good forms also require intermediate goods (int). Profit-maximizing final good firms can decide between domestic green or brown energy, and domestic and foreign intermediate goods, depending on their relative prices. For the sake of simplicity, green energy is assumed to have zero emissions. Therefore, the share of brown energy in total North and South output output determines the level of emissions.
Firms also face an investment decision about the target capital stock, which is determined by market conditions and depreciation rates (Lavoie, 2014). We assume that investments can be financed either via retained profits or through new loans from commercial banks (McLeay et al., 2014). In addition, banks fulfill all the

credit requirements, but lending interest rates vary by green or brown loan type and by region. In line with empirical literature (Ongina et al. 2021), brown loans are cheaper than green loans, and are also assumed more expensive in the South. This reflects the current situation that green technologies are still considered financially riskier (Dhruba, 2018). Similarly, the weighted average cost of capital is generally higher in low-income countries (Ameli et al., 2021). Different interest rates, along with different energy productivity, contribute to the differences in unit costs of green and brown energy producers in Austria and the Western Balkans.
The banking sector pays interest on deposits and pays out dividends to the household sector. In addition to income from banks, households also receive wage income from firms. The government purchases consumption goods and covers its expenses with its tax revenues as well as from issuing government bonds in the case of a de cit. Government bonds are bought by the banking sector.
The end period stocks are captured in a Balance Sheet (see Table 1), and all flows between sectors and regions in between time periods in a Transaction Flow Matrix (TFM) (see Table 2). TFMs are another way of representing Structural Accounting Matrices (SAMs), under which national accounting are done.

	North/South Region						$\sum$
	Households^i	Firms^i	Brown Energy Producer^i	Green Energy Producer^i	Government	Bank^i	
Fixed Capital		$+K_t^F$	$+K_t^B$	$+K_t^G$			$+K_t^n$
Deposits	$+D_t^H$	$+D_t^F$	$+D_t^B$	$+D_t^G$		$-D_t^i$	0
Bonds					$-Bond_t^{Gov}$	$+Bond_t^{Gov}$	0
Loans		$-L_t^F$	$-L_t^B$	$-L_t^G$		$+L_t^q$	0
Balance Net Worth	$-NW_t^H$	$-NW_t^F$	$-NW_t^B$	$-NW_t^G$	$+NW_t^{Gov}$		$-NW_t^i$
$\sum$	0	0	0	0	0	0	0

Table 1: Balance sheet of the economy

	Households^i	Firms^i		Brown Energy Producer^i		Green Energy Producer^i		Govt.^{i}	Bank^i	$\sum$
		Cur	Cap	Cur	Cap	Cur	Cap			
Consumption	$-C_t^i$	$+C_t^i$								0
Govt. Exp.		$+G_t^i$						$-G_t^i$		0
Investment		$+I_t^i$	$-I_t^{iF}$		$-I_t^{iB}$		$-I_t^{iG}$			0
Intermediate Import		$-Q_t^N$								0
Intermediate Export		$+Q_t^S$								0
Energy		$-\sum_i E_t^i$		$+E_t^{iB}$		$+E_t^{iG}$				0
Wages	$+WB_t^i$	$-WB_t^{iF}$		$-WB_t^{iB}$		$-WB_t^{iG}$				0
Profits	$+\Pi_t^i$	$-\Pi_t^{iF}$	$+\gamma\Pi_t^{iF}$	$-\Pi_t^{iB}$	$+\gamma\Pi_t^{iB}$	$-\Pi_t^{iG}$	$+\gamma\Pi_t^{iG}$		$-\Pi_t^{iBk}$	0
Loan Repay		$-\rho L_{t-1}^{iF}$	$+\rho L_{t-1}^{iF}$	$-\rho L_{t-1}^{iB}$	$+\rho L_{t-1}^{iB}$	$-\rho L_{t-1}^{iG}$	$+\rho L_{t-1}^{iG}$			0
Taxes	$-T_t^{iH}$	$-T_t^{iF}$		$-T_t^{iB}$		$-T_t^{iG}$		$+T_t^i$		0
i Loans		$-rL_{t-1}^{iF}$		$-rL_{t-1}^{iB}$		$-rL_{t-1}^{iG}$			$+rL_{t-1}^i$	0
i Deposits	$+r^M D^H Hi_{t-1}$	$+r^M D^F i_{t-1}$		$+r^M D^B i_{t-1}$		$+r^M D^G i_{t-1}$			$-r^M D_{t-1}^i$	0
i Gov Bonds								$-r^{Gov} B_{t-1}^i$	$+r^{Gov} B_{t-1}^i$	0
ΔLoans			$+\Delta L_t^{iF}$		$+\Delta L_t^{iB}$		$+\Delta L_t^{iG}$		$-\Delta L_t^i$	0
ΔDeposits	$-\Delta D^H i_t$		$-\Delta D^F i_t$		$-\Delta D^B i_t$		$-\Delta D^G i_t$		$+\Delta D_t^i$	0
ΔGov Bonds								$+\Delta B_t^i$	$-\Delta B_t^i$	0
$\sum$	0	0	0	0	0	0	0	0	0	0

Note: $i = \{N, S\}$ is the index of north and south regions. Both regions trade intermediate goods.

Table 2: Transaction Flow Matrix of the economy

Notation to read the figures: superscripts represent the firm sectors in the economy, where F is the final goods Firm sector, while B and G represent brown and green energy sectors respectively. The firm sector is collectively represented by the superscript j = fF; B; Gg. Further, Gov represents the government sector, while H is the household sector. The regions are indexed by superscript i = fN; Sg for either Austria in the North (N) or the Western Balkans in the South (S). Subscript t indicates the respective time period and first order time differences. Exogenous parameters are expressed using Greek symbols, where endogenous parameters are explicitly pointed out and carry a time t subscript. Lowercase letters depict real values or stocks, while uppercase letters stand for nominal values in current price levels.

While the financial flows are more mechanical identities, the interactions across di different sectors are represented by behavioral equations. The SFC logic requires that all entities must stick to their respective budget constraints and all transactions within the economy add up to zero. In this regard, a decision for a particular good or investment automatically implies a non-decision for its counterpart as a consequence of limited financial resources.

Scenarios:
The EU recently updated its climate targets, aiming for 55% of emissions reductions by 2030 compared to 1990 levels. As the EU already achieved 23% by 2019, this would imply about 40% of additional emission reductions compared to 2019 levels. We assume that Austria would directly apply the EU emission targets. In line with this target, our policy simulation scenarios aim for 40% global emissions cut in Austria until 2030 by relying on different unilaterally introduced climate policy instruments and their combinations. In particular we look at the combination of the following three policies:

1. A unilateral carbon tax (CT), on carbon-intensive intermediate goods in Austria.
2. A border adjustment tariff (BAT), on carbon-intensive intermediate goods' imports from the Western Balkans.
3. A reduction in the green risk premium on interest rates in the Western Balkans (DERISK). In this scenario, blended finance options to Western Balkans contribute to de-risk green investments, thus reducing their capital costs. The spread between the interest rate that commercial banks would charge for loans for green investment projects, and the interest rate that green firms would need to pay in the Western Balkans is financed by an Austrian development bank, which ultimately refinances itself at international capital markets at Austria's preferential financing conditions.

The scenario combinations are summarized in Table 3.

No.	Name	Description
S1	CT	Unilateral carbon tax
S2	CT+BAT	Unilateral carbon tax plus a Border Adjustment Tariff (BAT)
S3	CT+DERISK	Unilateral carbon tax plus lower green risk premium in the Western Balkans
S4	CT+BAT+DERISK	Unilateral carbon tax plus BAT plus lower the green risk premium in the Western Balkans

Table 3: Model scenarios

WP5 develops a knowledge co-production approach that culminated in the organization of an interactive online workshop, involving stakeholders from academia, business, finance, policy, on 19th May 2021.

7 Arbeits- und Zeitplan

Table 4's Gantt chart shows the original time schedule of GreenFin activities. The outbreak of the COVID-19 crisis led to the changes reported in Table 5.

		2019	2020												2021				
WP	Task	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
6	**Management and dissemination**																		
	Kick off/Final dissemination		M6.1																
	Closing of the project																		
	Interim and final reports																		M6.4
	Quality assurance	M6.2																	M6.3
	Scientific papers																		
	Conferences and focus groups																		
1	**Supporting/limiting factors for green finance**																		
	Identification of relevant examples	M1.1																	
	Development of the assessment framework			M1.2															
	Analysis of interviews					M1.3													
	Reporting and development of recommendations							M1.4											
2	**Austrian green/brown portfolio performance**																		
	Definition of the variables of interest and database						M2.1												
	Definition of 'green' and 'brown' portfolios							M2.2											
	Definition of sustainability factor									M2.3									
	Austrian market's reaction to climate announcements											M2.4							
3	**Green finance's economic and financial impacts**																		
	EIRIN extension and tailoring to Austria											M3.1							
	EIRIN model calibration on Austrian data													M3.2					
	Simulation of green finance pathways																M3.3		
4	**Implications fo greening Austrian development finance**																		
	North-South model extension									M4.1									
	North-South model calibration											M4.2							
	Simulation of greening development finance impacts													M4.3					
5	**Toolkit and recommendations**																		
	Toolbox prototype development															M5.1			
	Focus group																M5.2		
	Recommendations for Austria																		M5.3

Table 4: Gantt chart of the GreenFin project (original schedule)

		2019	2020												2021								
WP	Task	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9
6	**Management and dissemination**																						
	Kick off/Final dissemination		M6.1																				
	Closing of the project																						
	Interim and final reports																						M6.4
	Quality assurance	M6.2																					M6.3
	Scientific papers																						
	Conferences and focus groups																						
1	**Supporting/limiting factors for green finance**																						
	Identification of relevant examples	M1.1																					
	Development of the assessment framework					M1.2																	
	Analysis of interviews														M1.3								
	Reporting and development of recommendations																	M1.4					
2	**Austrian green/brown portfolio performance**																						
	Definition of the variables of interest and database						M2.1																
	Definition of 'green' and 'brown' portfolios									M2.2													
	Definition of sustainability factor														M2.3								
	Austrian market's reaction to climate announcements																	M2.4					
3	**Green finance's economic and financial impacts**																						
	EIRIN extension and tailoring to Austria											M3.1											
	EIRIN model calibration on Austrian data														M3.2								
	Simulation of green finance pathways																				M3.3		
4	**Implications fo greening Austrian development finance**																						
	North-South model extension												M4.1										
	North-South model calibration															M4.2							
	Simulation of greening development finance impacts																				M4.3		
5	**Toolkit and recommendations**																						
	Toolbox prototype development																		M5.1				
	Focus group																M5.2						
	Recommendations for Austria																						M5.3

Table 5: revised Gantt chart of the GreenFin project.

We have asked for an extension of the project duration (cost free) until 30.09.2021 (i.e. 4 months extension) to better manage the challenges induced by the COVID-19 crisis. The extension has been approved by the funder on Dec. 14th, 2020. Thus, the project concluded on 30 September 2021 (22 months).

8 Publikationen und Disseminierungsaktivitäten

	Academic publications
1	Monasterolo, I., Dunz, N., Mazzocchetti, A., Essenfelder, A. (2021). Financial risk assessment and management in times of compounding climate and pandemics shocks. *Brookings Institute, Future Development*.
2	Battiston S. Monasterolo, I., Riahi, K., and van Rujiven, B. (2021). Accounting for finance is key for climate mitigation pathways. *Science*, *372*(6545), 918-920. DOI: 10.1126/science.abf3877
3	Dunz, N., Mazzocchetti, A., Monasterolo, I., Essenfelder, A., Raberto, M. (2021). Compounding COVID-19 and climate risks: the interplay of banks' lending and government's policy in the shock recovery. *Journal of Banking and Finance, 106303*
4	Ranger, N., Mahul, O., Monasterolo, I (2021). Managing the financial risks of climate change and pandemics. What we know (and don't know). *One Earth (in press)*, Oct. 2021
5	Naqvi, A., Monasterolo I. (2021). Assessing the cascading impacts of natural disasters in a multi-layer behavioral network framework. *Scientific Reports*, 11(1), 1-14.
6	Battiston, S., Dafermos, Y., and Monasterolo, I (2021). Climate risks and financial stability. *Journal of Financial Stability*, vol. 54, June 2021.
7	Dunz, N., Naqvi, A., Monasterolo, I. (2021). Climate sentiments, transition risk, and financial stability in a stock-flow consistent model. *Journal of Financial Stability*, vol. 54, June 2021.
8	Monasterolo, I. (2020). Embedding finance in the macroeconomics of climate change: research challenges and opportunities ahead. *CESIfo Forum*, 4/2020, p.25-33.
9	Monasterolo, I. (2020). Climate change and the financial system. *Annual Review of Resource Economics,* Volume 12, 1-22.
10	Hafner, S., Anger-Kraavi, A., Monasterolo, I., Jones, A. (2020). Emergence of New Economics Energy Transition Models: A Review. *Ecological Economics*, *177*, 106779
11	Monasterolo, I., Volz, U. (2020). Addressing climate-related financial risks and overcoming barriers to scaling up sustainable investments. G20 Saudi Arabia: T20's Task Force 2 "Climate Change and Environment"
12	Battiston, S., Billio, M., and Monasterolo, I. (2020). Pandemics, climate and public finance: how to strengthen socio-economic resilience across policy domains. In: *A New World Post COVID-19 Lessons for Business, the Finance Industry and Policy Makers*, edited by Monica Billio and Simone Varotto, Edizioni Ca' Foscari, pag. 259-268. ISBN [ebook] 978-88-6969-442-4 | ISBN [print] 978-88-6969-443-1
13	Battiston, S., Guth, M., Monasterolo, I., Nuerdorfer, B., Pointner, W. (2020). The exposure of Austrian banks to climate-related transition risk. In: Austrian National Bank's Financial Stability Report 2020

	Working papers
1	Battiston, S., Monasterolo, I. (2020). On the dependence of investor's probability of default on climate transition scenarios. Available at SSRN (abstract_id=3743647), to be submitted to a journal in financial economics.
2	De Angelis, L., Duranovic, A., and I. Monasterolo (2021). Portfolios' greenness and resilience to the COVID-19 crisis: the case of the Austrian stock market. Working paper. To be revised and submitted to Energy Economics.

3	Gourdel, R., Monasterolo, I, Dunz, N., Mazzocchetti, A. and Parisi, L. (2021). Assessing the double materiality of climate risks in the EU economy and banking sector. *ECB working paper, forthcoming (Nov. 2021)*, available at SSRN (https://bit.ly/2YWrRcA)
4	Kletzan-Slamanig, D., Koeppl, A. (2021). The Evolution of the Green Finance Agenda – Institutional Anchoring and a Survey-based Assessment for Austria. WIFO Working paper series.
5	Naqvi, A., Dunz, N., Monasterolo, I. (2021). Analyzing the spillover effects of climate policies in a Stock-Flow Consistent North-South model: The case of Austria and the Western Balkans. Working paper. To be revised and submitted to a journal in the field of environmental and climate economics.
6	Vismara, A., Mazzocchetti A., and Monasterolo, I. (2021). Green finance policies for the low-carbon transition in Austria: challenges and on opportunities for complementarity. Working paper. To be revised and submitted to a journal in the field of environmental and climate economics.

	Media coverage and blog posts
1	Mahul, O., Monasterolo, I., Ranger, N. (2021). Learning from COVID-19 and climate change: Managing the financial risks of compound shocks. World Bank blog, https://bit.ly/3zYqTdV
2	Die "Bio-Schiene" der Finanzwelt. Wiener Zeitung (06/08/2021) https://www.wienerzeitung.at/nachrichten/chronik/leben/2115558-Die-Bio-Schiene-der-Finanzwelt.html
3	Battiston, S., Monasterolo, I. (2021). Le système financier peut faire pencher la dynamique de la transition écologique d'un côté ou de l'autre. Le Monde (26/5/2021).
4	Battiston, S., Monasterolo, I. (2021). Transizione ecologica e rischio finanziario: il ruolo chiave delle aspettative. Il Sole 24 Ore (24/5/2021)
5	Kletzan-Slamanig, D., ea. Klimawandel gefährdet finanzielle Stabilität. Der Standard (15/02/2021)
6	Monasterolo, I. Assessing climate risks in investors' portfolios: a journey through climate stress-testing. *UN PRI* blogpost (2/03/2020)
7	Monasterolo, I., Volz, U. How to finance virus response in a sustainable way? Scale up synergies with the Green Deal. *Euractiv* (7/04/2020)
8	Monasterolo, I., Volz, U. "EU virus response to shape climate action". *OMFIF* (8/04/2020)
9	Monasterolo, I., Volz, U. "Enabling EU solidarity while preserving public finances: how the EU could finance the COVID response". *Financial Times* (The Banker) (2/05/2020)

	Presentations
1	23-24 September 2021: 22nd Global Conference on Environmental Taxation (GCET22)
2	8-10 September 2021: 12th Internationalen Energiewirtschaftstagung (IEWT)
3	1 September 2021: Central Banks and Regulators panel, GRASFI conference 2021

4	1 September 2021: invited speaker, "Divesting from Carbon-intensive towards a Sustainable and Green Infrastructure", European Forum Alpbach 2021
5	8 March 2021: ESG-Round Table Diskussion mit Experten von Amundi und WIFO
6	28 January 2021: invited speaker, "Virtual Seminar on Climate Economics", Federal Reserve Bank of San Francisco.
7	19 December 2020: Computation and Financial Econometrics (CFE) conference 2020, climate finance session (virtual)
8	10 December 2020: "Green Finance Research Advances", Banque de France, Paris (FR) (virtual)
9	9 December 2020: Central Banking conference 2020, session "Climate stress testing of the financial system" (virtual)
10	2 December 2020: Understanding Risk conference 2020, session "Multiform flood risk" (virtual)
11	28 October 2020: World Bank workshop on "Compound risks: combining COVID and climate shocks in macroeconomic models for stronger financial resilience" (virtual)
12	22 October 2020: National Bank of Belgium's International Conference 2020 on "Climate Change: Economic Impact and Challenges for Central Banks and the Financial System" (virtual)
13	21 October 2020: Bank for International Settlements (BIS)'s International Conference on Central Banks Supervision 2020, session "how the world is changing the operating environment for supervisors" (virtual)
14	24 September 2020: CREDIT conference 2020 "Environmental, Social and Governance Risks", Venice (IT)
15	4 September 2020: OECD workshop "Climate Change: assumptions, uncertainties and surprises, Organization for Economic Cooperation and Development, Paris (FR) (virtual)
16	3 September 2020: Klimatag 2020, project poster presentation and discussion (virtual)
17	2 September 2020: EAEPE conference 2020, plenary session on COVID-19 and political economy (virtual)
18	1 September 2020: 2nd European Commission's summer school on Sustainable Finance (virtual)
19	26 August 2020: Austrian National Bank (OeNB)'s summer school (virtual)
20	1 July 2020: Banca d'Italia, Rome (IT) (virtual)
21	9 June 2020, 23 Aug. 2020: COVID-19 future operations events organized by the Austrian Ministry of Finance and Chancellery, Vienna (AT)
22	27 February 2020: European Insurance and Occupational Pension Authority (EIOPA), Frankfurt (DE)
23	16 January 2019: FINEXUS2020 conference "Climate change and financial risks", University of Zurich, Zurich (CH)

24	6 December 2019: European Systemic Risk Board (ESRB) workshop "Wind of Change: Climate Risk and Dynamic Stress Testing", Austrian National Bank (OeNB), Vienna (AT)