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The Glasgow Climate Pact: A Robust Basis for the International Climate Regime in the 2020s

With close to 40,000 participants, COP26 in Glasgow was the largest UN climate conference ever, followed by Paris in 2015 and Copenhagen in 2009. This showed the appetite of the global climate policy community to engage in a large in-person event after nearly two years of the COVID-19 pandemic. While a number of logistical issues emerged during the first week of the conference, the process ran smoothly in the second week despite a resurgence of COVID-19 cases towards the end. The large number of participants led to a venue closure one day when the capacity limit of 10,000 was reached, and to restricted access to the negotiations, where each party could only send one negotiator per room, and each observer constituency could send only one observer. The otherwise impeccable UK diplomacy was thereby able to thwart reproaches for not being inclusive.

The COP26 agenda had a number of key themes: international climate finance, mitigation ambition, the finalisation of the rulebook on international market mechanisms (Article 6 of the Paris Agreement), detailed approaches to the reporting of national emissions and progress in reaching national emissions pledges (nationally determined contributions, NDCs), and common time frames for NDCs. Adaptation, loss and damage caused by climate change impacts were also sharply in focus.

In the run-up to COP26, the UK COP26 presidency worked to secure side deals on the four topics “coal, cars, cash and trees”; this was added to the previously stated aim of reducing methane by 30% between 2020 and 2030.

There was great public pressure on COP26 to produce a strong outcome, with over 100,000 people demonstrating in Glasgow on 6 November, reinforced by the Sixth Assessment Report of the Intergovernmental Panel on Climate Change published in August stating that warming has already reached 1.1 degrees Celsius. The graph showing a sea level rise of several metres by 2300 – even under low emissions scenarios – woke up many people. On the other hand, the continued pandemic, the increased rivalry between the US and China and other geopolitical tensions were forces working against a strong result at the Glasgow conference.

Emulating the successful approach in Paris, the UK Presidency scheduled the heads of state segment for the first few days of COP. This led to a positive dynamic regarding ambition and finance, as numerous mitigation and finance pledges were made. The Adaptation Fund received US $356 million, and the Least Developed Country Fund US $413 million. The US $8.5 billion Just Energy Transition programme of developed countries for coal transition in South Africa could become a blueprint for similar programmes in other coal-rich countries.

The unexpected announcement of net zero targets by key countries of the Arabian Peninsula in the week before COP26 created a welcome dynamic, with the United Arab Emirates announcing a 2050 target date, Saudi Arabia and Bahrain settling for 2060. At COP itself, the developing country giants India and Nigeria followed with 2070 and 2060 target dates, respectively. This means that 89% of global emissions are covered by net zero targets. The International Energy Agency has estimated that global warming can be limited to 1.8 degrees Celsius due to the new pledges, while the NGO-backed Climate Action Tracker still sees a temperature increase of 2.4 degrees Celsius.

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A surprise that changed the dynamics and was crucial for a positive COP26 outcome was the US-China declaration on 10 November, which clearly stated that the two countries wanted a successful outcome on the Paris Rulebook, that China would strengthen its NDC in the next year and that Chinese coal use would peak in 2025, not 2030. A similar declaration in 2014 had paved the way for China to give up on a sharp divide between industrialised and developing countries and thus enabled the Paris Agreement of 2015.

At COP26, the United Nations Framework Convention on Climate Change Secretariat and the UK Presidency cooperated well, leading to the smooth publication of negotiation texts in rapid succession. A novel feature was the avoidance of "all-night" sessions by the organisers who announced at 8 p.m. on 12 November that the final text would be available at 8 a.m. the following morning. This certainly contributed to a better outcome in the final plenary.

Brazil and Russia – as well as smaller countries like Bolivia, Nicaragua and Venezuela that had often put spokes in the wheels of COPs – had a very constructive attitude this time. A moment of high drama in the final plenary saw various "huddles" involving the African Group who wanted to ensure adaptation funding through Article 6.2 and China and India's revision of the wording on coal subsidy reduction or elimination. US climate envoy John Kerry masterfully worked the room and ensured that all negotiation threads were followed in a coordinated manner. While India and China reopened the text in order to talk about a phase-down of coal subsidies instead of a phase-out, this did not unravel the finely crafted balance and the package of decisions could be adopted by the evening of 13 November, "just" one day after the scheduled close of the conference.

The cover decisions, which included the contentious coal subsidy language, generated significant media attention but are not relevant for the actual implementation of the Paris Agreement. The key language from these decisions is the call for a further update of the NDCs in 2022.

International carbon markets through "cooperative approaches" and the Article 6.4 mechanism can now be implemented, with developing countries benefitting from capacity building support. Double bookkeeping ("corresponding adjustments") is to be done for all transactions. Non-greenhouse gas metrics are generally allowed. Developed countries do not have to pay an adaptation tax on Article 6.2 transactions. For Article 6.4, corresponding adjustments depend on the authorisation of transactions by the host country. An adaptation tax of 5% will be paid, and 2% of credits will be cancelled to achieve an overall mitigation in global emissions. All ongoing projects from the Clean Development Mechanism (CDM) can be transitioned, as well as emissions credits from such projects registered from 2013 onwards. Baseline methodologies for the calculation of emissions credits are stringent, and testing of the additionality of activities is required to prevent business-as-usual activities from receiving credits. Thus, stringent rules were combined with a lenient CDM transition.

Regarding transparency, reporting tables are mandatory for all parties but flexibility exists in filling specific cells. Confidentiality can be invoked. The review can trigger action by the compliance committee in the case of significant and persistent inconsistencies.

Common timeframes are defined by the end dates of NDCs – they will be aligned in five year periods, e.g. 2035, 2040, 2045. Regarding climate finance, developed countries were asked to double adaptation funding between 2019 and 2025, but no binding target has been set. A dialogue on funding of loss and damage will be held by 2024. The negotiations on the post-2025 collective quantified goal on climate finance will be done through an ad hoc working programme with four meetings per year, with the deadline in 2024. A two-year Glasgow–Sharm el-Sheikh work programme will be held on the Global Goal for Adaptation and address adaptation metrics. Overall, COP26 has established a firm basis for the implementation of the Paris Agreement. The short-term emissions gap still remains but these steps will help to make it smaller.

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Europe’s Path to Net-Zero Emissions

The European Union has set an ambitious target to reduce net greenhouse gas emissions to zero by 2050, while at the same time ensuring economic and social sustainability. The European Green Deal lays out a path towards realising this target, accelerating policy change that touches upon many aspects of the economy and society. What are the main challenges to the implementation of the European Green Deal? What are the costs and benefits of decarbonisation? Which industrial policy is needed to turn decarbonisation into an economic opportunity for Europe? How to finance the transition to a low-carbon economy? Which trade policy instruments could create incentives for more climate protection? This Forum seeks to answer these questions, discussing the key issues and reviewing the different policy perspectives on climate change mitigation in the European Union.

Fostering the Industrial Component of the European Green Deal: Key Principles and Policy Options

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Carbon Border Adjustment and Other Trade Policy Approaches for Climate Protection

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Green Hydrogen in Europe: Do Strategies Meet Expectations?

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Green Finance in Europe – Strategy, Regulation and Instruments

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Europe’s Climate Target for 2050: An Assessment

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Fostering the Industrial Component of the European Green Deal: Key Principles and Policy Options

In 2019, Ursula von der Leyen adopted the European Green Deal as the flagship initiative of her new European Commission (von der Leyen, 2019). With this initiative, the EU executive arm aims at making Europe the first climate-neutral continent by 2050. To get there, EU member states committed to cut greenhouse gas emissions by 55% by 2030 compared to 1990 levels. With the Fit for 55 package, the European Commission unveiled in July 2021 a set of legislative proposals to achieve its 2030 climate target (Tagliapietra, 2021).

The industrial policy dimension of the European Green Deal

As the European Green Deal seeks to unleash a major transformation in the European socio-economic structure – such as the move from fossil fuels to renewables, or from internal combustion engine cars to electric cars – this challenge is often referred to as a revolution against a deadline. As in any major transformation, there will be winners but also losers, particularly in the short run. A strategy only based on climate targets and instruments, such as raising the price of carbon or banning diesel cars, could miss the target when firms and citizens fail or even simply refuse to adjust. Only a policy creating a broader space for more winners than losers can sensibly face the challenge of such a vast transformation.

The necessity to meet climate and environmental targets, while at the same time ensuring economic and social sustainability, requires a transformation that will generate enough benefits to compensate the losers. This brings industrial policy under the spotlight of the European Green Deal. But what should a green industrial policy look like? In this article, we use insights from recent trends in the academic literature on industrial policy to identify the guiding principles for green industrial policy development and test this on the EU's steps towards developing a green industrial policy in the context of the European Green Deal.

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Green industrial policy: Where climate policy meets industrial policy

While climate policy finds its main target in fostering decarbonisation and industrial policy finds its main objective in boosting economic competitiveness and jobs, green industrial policy has the aim of reconciling the goal of decarbonising the economy (i.e. like climate policy) with economic and social sustainability (i.e. like industrial policy). We can thus define green industrial policy as an industrial policy where climate change mitigation becomes a binding constraint in the overall social welfare policy objective.

This combination of objectives immediately identifies the challenge of green industrial policy, namely to reconcile both objectives. This may be particularly difficult when they come into conflict as trade-offs will need to be made and costs will have to be attached to missing the climate change objectives. Most countries already have climate and industrial policies in place, each with their own instruments and typically residing in different governmental departments. In this context, an important question is: Would a coordination of already existing instruments from climate change and industrial policy be sufficient for a green industrial policy? Or would green industrial policy need its own dedicated policy instruments? And if so, how should this be coordinated with existing instruments in an optimal policy mix?

Insights from the new industrial policy literature for green industrial policy

Stacked with a lack of robust evidence of successful industrial policy cases and fully aware of the informational and rent-seeking problems constraining the implementation of industrial policies, a new wave of academic debate around forms of industrial policy has arisen, with the seminal work of Rodrik (2014) introducing a new industrial policy perspective. This new perspective seeks to move beyond the traditional ideological division between state-driven intervention versus purely market-based solutions, arguing for a smart combination of both – and shifting the debate away from whether governments should tackle industrial policy at all, to how they can do it well. It acknowledges both theoretical reasons for intervention, rooted in market failures, and the implementation difficulties, rooted in government failures.

The new industrial policy approach moves the debate away from the classical view of industrial policy as a mere set of tools to allocate resources towards understanding it as a process. Rodrik (2014) argues for new industrial policy to be a "process of institutionalized collaboration and dialog [between the private sector, government and civil society] rather than a top-down approach" where the government picks sectors or firms and transfers money to them. The private sector has to be one of the three fundamental stakeholders of this collaboration where the other two elements are the government and civil society. This new approach also argues for a much broader objective function, moving beyond short-term competitiveness and growth to include more long-term sustainable growth.

The principles used by the new industrial policy approach to design policy interventions rest on the notion that the role of the state in industrial policy design must be that of identifying constraints and opportunities. This will in turn generate solutions that bring together private and public capacities and information, with aligned public and private motives, in a very pragmatic way. At the same time, the new policy design needs to address the issue of rent-seeking and political capture. It should develop a process of iterative collaboration, experimenting and learning, effectively combining sticks and carrots, monitoring and evaluating, building in accountability and transparency (Rodrik, 2014; Altenburg and Rodrik, 2017; Ambroziak, 2017; Pegels, 2017; Andreoni and Chang, 2019; Hausmann et al., 2020). Government agencies have to be embedded with the private sector in order to efficiently reveal their information and leverage it to design policies. This conception requires a high degree of collaboration between the public and private sector, a collaboration that has to be iterative, since the solutions are not assumed as known, but only as discoverable.

A "new" green industrial policy

A green characterisation of industrial policy comes into play once decarbonisation is set as a societal goal, like in the case of Europe with the European Green Deal. As previously mentioned, in addition to market failures at the core of classic industrial policy, green industrial policy also has to address the greenhouse gas externality associated with climate change. As externalities have complex reinforcing interactions, the combination of classic market failure externalities and the greenhouse gas externality represents a significant challenge for green industrial policy. In this section we delve further into the challenges for a green industrial policy and how the principles of new industrial policy are particularly well suited for designing such a green industrial policy.

Compared to what is typically the case of general industrial policy, green industrial policy calls for addressing the problems associated with the transformative change that climate change brings, rather than addressing instantiations of competitiveness of targeted sectors and firms.

Longer-term broad objectives involving the whole of society allow the building of more win-win coalitions compared to the short-term competitiveness objectives of selected sectors and firms. This broader public interest is the foundation for the legitimacy of the policy. The need to address broad societal transformation creates the unique angle for a green industrial policy in the spirit of the new industrial policy perspective. Green industrial policy needs to activate a process of institutionalised collaboration and dialogue between governments, private sector actors (from various sectors and technologies and different parts of the value chain) and civil society. Public-private partnerships will be central in green industrial policy and covering a large set of private sector areas and civil society.

For green industrial policy, the lack of risk-taking can be particularly problematic in the long run, as the possibility of doing too little too late is extremely worrisome. The experimentation and learning principle from the new industrial policy perspective is key for green industrial policy, rather than a cautionary principle of only intervening if there is a certain, clear case for intervention. Green industrial policy should be taking risks, particularly helping to shape the landscape for new, yet-to-be-developed ecosystems and markets where stakeholders still need to be connected for the first time.

Green technologies are often still in the early stage or emerging, with higher levels of risk and uncertainty. In addition, green technologies seem to be more complex than non-green technologies and tend to have larger spillovers and affect a higher variety of other domains (Barbieri et al., 2020). The higher risks and uncertainty and the higher externalities from clean technologies make the case for a more directed approach aimed at supporting investments in clean technologies. Beyond the spillover arguments, an investment push directed at clean technologies is necessary to counter the lock-in of fossil fuel-based technologies and their path dependencies (Aghion et al., 2011, 2016, 2019).

Green industrial policy has to deploy a broad mix of policy instruments, balancing those of a horizontal and vertical nature. Co-financing should cover a balanced set of projects that accelerate and consolidate existing scientific and industrial capacity (e.g. electric cars), together with new projects targeting frontier technologies and markets (e.g. green hydrogen). Instruments have to cover the whole value chain from research, development and diffusion to manufacturing, distribution and sales (i.e. a combination of technology push and market pull; see, for instance, Kemp and Never, 2017).

Climate change is a global commons problem, leaving the risk of overexploiting a common good, e.g. clean air, while free riding when investments need to be made for solutions to the problem. Rodrik (2014) points to competition between countries sparking a race for innovation that solves the market failures linked to price distortion (by lowering prices) and of underinvestment in R&D (by fostering competition from Schumpeterian rents). At the same time, global cooperation in R&D, particularly the pre-commercial phases of R&D can bring cost and risk sharing advantages and higher efficiencies from combining complementary knowledge and exploiting synergies. All this implies the need for multilateral coordination on green industrial policy, which should strike a balance between cooperation and competition to reach global targets (e.g. Lütkenhorst et al., 2014).

Strong operational governance is the key to successful green industrial policy. This is needed to address coordination among the many different types of stakeholders, policy governance areas, instruments and projects, and to coordinate across different geographical layers. It requires a highly competent and empowered governance body, which is sufficiently politically independent – or detached from political pressures – yet accountable for its achievements with a set of clear realistic milestones. And as green industrial policy requires a more directed approach towards clean technologies, it relies on the government's capacity to correctly process incoming information to allocate resources. Another governance challenge has to do with high uncertainty and the need for a long time horizon for green policymaking, conflicting with the incentives of politicians to look for short-term successes. A long-term vision of paths and objectives is important (Lütkenhorst et al., 2014). At the same time, Lütkenhorst et al. (2014) underline the strong need for ensuring flexibility under these different forward-looking settings.[1]

Both the market and the state have limits to what they can deliver. Therefore, it is necessary to make them work together efficiently in order to enable successful green industrial policy. The design of public-private partnerships and a strong policy governance will make or break green industrial policy efforts.

1 One example is the use of 15-20 years guaranteed feed-in tariffs: Long-term prices are guaranteed, but the auctioning mechanism works in batches in order to adapt to technology cost changes.

Lessons from national green industrial policy experiences

We test the principles laid out in the previous section against the evidence on the strengths and weaknesses of four cases of green industrial policy implemented in the Netherlands, Denmark, Germany and the US (Tagliapietra and Veugelers, 2020).

A first lesson from all these green industrial policy cases is the importance of effective collaboration between all elements of society. Policy should be able to involve both industry and society, as new industrial policy advocates. In the Netherlands, transition pathways have long been negotiated across all stakeholder groups allowing for constructive collaboration. In Denmark, cooperative ownership structure and bottom-up political activism have been key in the successful wind industry growth. Public-private partnerships have enjoyed similar success in Germany.

Another lesson is the importance of policy stability and predictability over a longer-term horizon. The growth of the Danish wind industry was strongly supported by stable policy support. Conversely, policy inconsistency in the Netherlands arising from energy market liberalisation programmes reduced the effectiveness of transition management programmes. Yet, in view of the high uncertainties, long-term commitment needs to go hand in hand with flexibility. The German experience of progressively adapted targets for energy efficiency of buildings is a good example.

The lesson of "not putting all of your eggs into one basket" refers to a balanced set of instruments, mixing the demand pull and technology push, general, horizontal instruments, and specific, targeted instruments. With respect to selecting targets, the US experience with solar panels shows that public administrations should refrain from placing any one industry or organisation on a pedestal.

A final observation from the German feed-in-tariffs (FiT) experience is the importance of clearly defining and understanding the relative importance of "green" and "industrial policy". The German FiT arguably catalysed the global market for solar photovoltaic systems; yet, the market for solar photovoltaic systems is one that German players now hold a relatively low share in, which might appear to be a failure from a purely industrial policy perspective. Yet from a green perspective, the policy was successful; even from an industrial policy perspective, at least when taking a broader objective, the policy was a success in terms of including value added and jobs created in the servicing of solar panels. Notably, the Danish wind deployment programme was successful from both perspectives.

Green industrial policymaking in Europe

Europe remains far from having a full-fledged green industrial policy. It has at best a multitude of green industrial policy initiatives, covering different geographical layers (i.e. regional, national and EU). These initiatives are generally not coordinated – and may even be conflicting. European regions promote their own smart specialisation initiatives with the aim of exploiting their existing competitive edge or building one in certain green technology sectors. Member states often use different policy tools to push their green industrial policies, spanning from public funding for green innovation to subsidies for the deployment of green technologies; from green public procurement to clean energy standards. This represents a major issue because strongly differing green industrial policies across countries fragment the EU single market and could undermine the level playing field across Europe. This calls for a strong EU coordination in the field.

The EU level also holds several policy tools, belonging to different EU policy realms such as competition policy, climate policy, research and innovation policy, EU public investments, EU single market rules and development policy, which it can deploy for green industrial policy.

In March 2020, the European Commission (2020b) presented its “New Industrial Strategy for Europe”, a strategy primarily aimed at managing the green and digital transitions and avoiding external dependencies in a new geopolitical context. Although the “New Industrial Strategy”, being more general, does not have the explicit ambition to be a green industrial strategy, it does contain an explicit green dimension. The document notably presents the following set of green industrial policy goals: securing the supply of clean energy and raw materials; stepping up investment in green research, innovation, deployment and up-to-date infrastructure; and creating lead markets in clean technologies with regulatory policies, public procurement and competition policy.

The need for public-private partnership and the need to coordinate with member states and regions is explicitly recognised in the document, which calls EU institutions, member states, regions, industry and all other relevant players to work together to create lead markets in clean technologies and ensure our industry is a global frontrunner. It also recognises the necessity for the EU to leverage its single market.

Yet, the EU strategy document appears more as a collection of energy, climate, innovation and social policy initiatives than as a truly coherent green industrial policy framework. The strategy does not provide the convincing governance necessary to turn the green transition into an industrial opportunity in the context of the European Green Deal. Certain general elements reflecting the new industrial policy approach, such as supporting industrial ecosystems encompassing all players operating in a value chain, are going in the right direction, but much stronger action is required to develop a workable effective EU green industrial policy.

Developing an EU green industrial policy to deliver the European Green Deal

In the following, we propose a set of policy recommendations for the EU to develop a green industrial policy for the European Green Deal.

Strong governance

Given the complexities intrinsic to both green industrial policy as a policy realm and to the EU as a wide-ranging policymaking machine, strong governance represents a key prerequisite for an effective EU green industrial policy. This is the key to efficiently addressing coordination among different types of stakeholders, different policy governance areas, different instruments and different projects.

First, the various partners need to be incentivised with a set of balanced, clear, credible and time-consistent commitments. Second, it is necessary to set clear and realistic intermediate milestones throughout the process to allow for more risk-taking. Third, a flexible policy design is required in order to properly address the risks and uncertainties and the associated information problem through a learning process characterised by strong monitoring, evaluation and feedback loops into the policy process. Four, it is necessary to ensure the accountability of these milestones, matching carrots with sticks. In our view, implementing all this requires strong governance that should be based on three principles: competence, ownership and political independence.

Tackle the geographic fragmentation

The current European green industrial policy landscape remains highly fragmented, notably between a vast number of initiatives being undertaken at the EU, national and regional levels with little to no coordination. Green industrial policies strongly differ across countries, and this could undermine the level playing field across Europe – and thereby fragment the EU single market.

To tackle this geographical fragmentation, there are three major ways at the EU level to translate this into the field of green industrial policy: the state aid control instrument, the European Semester and the regional RIS3 smart specialisation programme. A regular evaluation of national and regional programmes by the European Commission could be done in the realm of green industrial policy, as it will create the space for coordination of the various ongoing policy initiatives.

Develop sound public-private partnerships with more and stronger European Alliances

Our recommendations on EU green industrial policy governance include a strong private embeddedness. We recommend expanding the use of the European Alliances format, which has been employed since 2017 on batteries and since 2020 on clean hydrogen. These Alliances represent an important tool of public-private collaboration at the EU level and should become a key tool for EU green industrial policy. Important Projects of Common European Interest (IPCEI) are a core characteristic for these European Alliances. A further broader and deeper application of IPCEI should be considered, to make the best of this tool. This implies opening-up a dialogue with the state aid arm of the EU's competition policy.

Alliances should focus on addressing problems covering the whole value chain for activating all relevant clean markets, rather than instantiations of problems.

To ensure a competitive environment stimulating innovations in the new clean markets created and supported by the EU's green industrial policy, and to avoid rent seeking, the EU should use its competition policy toolbox to assure that the competition policy arm of the Commission has sufficient dedicated expertise on clean technologies and markets.

Unleash EU green investments

EU green investments play an important role in realising the green transition, also by mobilising funds from both member states' national budgets and from the private sector. The EU decision to devote 30% of its long-term 2021-2027 budget to climate action is good news. But this target should be handled carefully. It will be of paramount importance for the EU to develop a solid methodology for monitoring climate spending and its performance on the whole budget, and to report on it regularly (Claeys and Tagliapietra, 2020).

The European Investment Bank (EIB) should be allowed to do more on climate action. The EIB currently benefits from very favourable rates for its borrowing from capital markets and it would be a shame not to use this opportunity to finance worthwhile green industrial policy projects. If EU countries are (unduly) worried about the EIB's rating, a capital increase should be given. This represents an important opportunity to take a step that would contribute to turning the EIB into Europe's true "climate bank". The EIB should also be supported in the further development of its role as intermediary governance body to address network and information imperfections in order to become a true "smart climate bank".

Foster EU green science and innovation

The EU needs to invest in green innovation to better position itself in fast-growing technologies, spanning from electronics to digital sectors that will increasingly underpin clean energy, clean mobility and smart buildings solutions. To truly develop a green industrial policy, the EU must leverage its public resources and toolkit to scale-up national and regional public resources into climate innovation, but especially private climate innovation investment. Fostering green innovation is not only about the total amount of public finance resources available, but also about how to allocate the total amount available to the best areas and projects, i.e. those with the highest socio-economic and climate returns that could not have been reached otherwise. In this respect, particular emphasis should go to high-risk, early-stage technologies with potential for general-purpose breakthroughs.

In the EU, this is the spirit of the European Innovation Council (EIC), and also of the well-established European Research Council (ERC). Although both are applicant-driven programmes for supporting frontier pushing science and ideas, without requiring a specific research focus to researchers in their calls, many ERC and EIC bottom-up proposals address climate change challenges and should thus be seen as an integral part of the toolbox for EU's green industrial policy, even if they are not explicitly directed to green technologies.

Go global

Europe produces less than 10% of global GHG emissions. To really make a difference for climate, the European Green Deal has to go beyond Europe's borders. To this end, it is of paramount importance for Europe to fill the current vacuum in leadership on the global scene, initiate and build "co-optive" global partnerships with other countries.

With respect to Europe's role relative to developing countries, we recommend leveraging Europe's external development policy and turning it into a vehicle of global sustainability. The Global Gateway initiative recently announced by the European Commission could become a key tool to export the European Green Deal, and thus become instrumental in EU green industrial policy. Such an approach would represent a triple win for the EU. First, it would help meet the EU's climate finance obligations and thus help to achieve the "conditional" emission reduction commitments assumed by most developing countries under the Paris Agreement. Second, it would enable EU industry to enter into new, rapidly growing markets – a win for EU green industrial policy. And third, it would help economic development in the EU's partner countries, providing an invaluable foreign policy dividend for the EU.

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Conclusions

The European Green Deal aims at making Europe the first climate-neutral continent by 2050. This is not going to be an easy ride. To be successful, the European Green Deal will have to foster major shifts in the European industrial structure, such as the ones from fossil fuels to renewables, or from internal combustion engine cars to electric cars.

This will represent a broad, paradigmatic change for the European industry. Shifting economies from brown to green indeed represents one of the major socio-economic transformations in history. Not by coincidence, this challenge is often referred to as an industrial revolution against a deadline.

In this context, green industrial policy emerges as a cornerstone of the European Green Deal. We are convinced that the principles and policy recommendations outlined in this article could benefit the building process of a workable EU green industrial policy that could deliver on the ambitious objectives set by the European Green Deal.

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Galina Kolev

Carbon Border Adjustment and Other Trade Policy Approaches for Climate Protection

The 14th of July will go down in history not only as the day of the storming of the Bastille, i.e. the flashpoint of the 18th century French Revolution, but also as the day, in 2021, when the European Commission published its proposal for the Fit for 55 package with trade policy measures to support climate protection (see European Commission, 2021a). On this same day, Democrats in the US Congress introduced the idea of a polluter import fee.

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Motivation for carbon border adjustment

The idea of a carbon border adjustment mechanism (CBAM) is crucial to level the playing field between domes-

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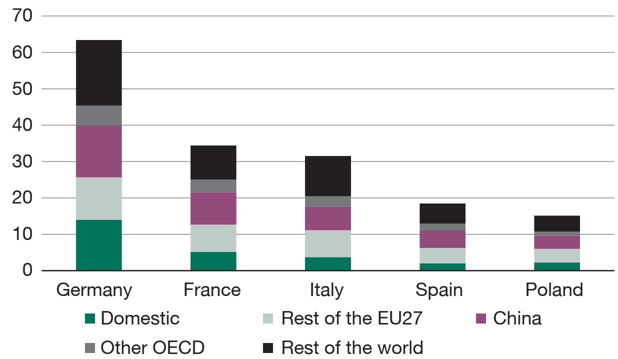
tic producers and foreign suppliers of carbon-intensive products. In 2021, only about one-fifth of global CO_2 emissions are subject to a carbon pricing mechanism and the global average price lies at just US $3 per tonne CO_2 (Parry et al. 2021; World Bank, 2021). In the European Union, the price for CO_2 certificates traded within the European Emissions Trading System (EU ETS) averaged about €55/tonne (about US $65/tonne) CO_2 from May to October 2021 and is likely to further increase as the number of certificates is set to decrease faster in the coming years as part of the Fit for 55 package. This creates incentives to outsource production of carbon-intensive products to countries with lower climate protection ambitions in accordance with the pollution haven hypothesis (see e.g. Levinson and Taylor, 2008), a phenomenon broadly known as carbon leakage. The overall effect will most likely be higher global CO_2 emissions since countries with lower climate protection standards are mostly developing and emerging economies with less CO_2 efficient technologies of production.

Figure 1

CO_2 emissions embodied in domestic final demand for basic metals, 2018

in million tonnes



Source: OECD (2021).

Currently, the EU ETS targets the problem of carbon leakage by allocating free carbon emission allowances to producers of goods with high CO_2 intensity like steel or cement. Although this system is effective in preventing carbon leakage, it is not efficient as it creates incentives to improve production technologies or to invest in green production only indirectly and to a limited extent. OECD (2021) data shows that in 2018 the net CO_2 imports of the EU27, i.e. the amount by which CO_2 emissions embedded in imported goods exceed CO_2 emissions needed to produce exported goods, were as high as 400 million tonnes CO_2 – although the EU is a net exporter of goods. These data cannot be interpreted directly as carbon leakage since the net CO_2 imports of the EU may result from specialisation patterns in the past that are not related to climate protection policies. However, the incentive for moving production to pollution havens will further increase because of the rising gap between the current CO_2 prices in the EU and other countries worldwide. With the target of reducing carbon emissions of the participating sectors by 43% compared to the level in 2005, the European Commission (2021b) decided to decrease the number of certificates by 2.2% starting in 2021 instead of 1.74% as in the previous years. Furthermore, looking ahead, there will be even stricter climate policy, and the Commission plans to phase out the free allocation of certificates over ten years starting in 2026. CBAM should be introduced as a measure to tackle the problem of carbon leakage instead.

What is CBAM?

The CBAM proposal by the European Commission (2021a) is targeted at reducing the incentives for carbon leakage by levelling the playing field in the internal market by making foreign suppliers of carbon-intensive products pay the same price for the CO_2 emissions embodied in their products as European producers. From 2026 on, CBAM will be phased in gradually while phasing out the free allocation of CO_2 certificates. For the purpose of non-discrimination, EU importers will have to buy carbon certificates corresponding to the carbon price paid for goods produced within the EU and only to the extent to which the European producers have to pay for CO_2 emissions. If non-EU producers are able to show that they have already paid a carbon price in a third country, then this carbon price may be deducted. The implementation will start in 2023 with a reporting system. A transition period until 2026 should secure legal certainty and stability while the European Commission stays in dialogue with important trading partners to explain the new measure. CBAM will initially only be applied to a limited number of goods where carbon leakage risk is especially high and embedded carbon emissions can be reliably measured: iron and steel, cement, fertiliser, aluminium and electricity generation. The revenues from CBAM are estimated at €1.5 billion in 2026 and are expected to increase to more than €2.1 billion by 2030. The European Commission plans to use them as a potential EU own resource and thus a contribution to the EU's budget.

Figure 1 illustrates the scope of CO_2 pricing for the five European countries with the highest CO_2 emissions embodied in domestic final demand for basic metals. In 2018 (the last year for which data is available) in most of the countries, almost two-thirds of the CO_2 emissions associated with domestic final demand for basic metals were emitted outside the EU ETS, and more than half of the emissions were emitted even outside of OECD countries (OECD, 2021). In all countries represented in Figure 1 more CO_2 is emitted in China than domestically to produce the basic metals needed for domestic final demand – although many producers of basic metals in the EU are currently preferentially treated within the EU ETS due to the free allocation of CO_2 certificates. It is therefore particularly important to target these CO_2 emissions from abroad, especially as the European Commission plans to phase out the free allocation of certificates.

The challenges of implementing CBAM

Whereas the European Commission's CBAM proposal addresses many important points – including the measurement of CO_2, a transition period of dialogue with important trading partners until 2026, non-discriminating exemptions for importers from countries with a comparable carbon pricing system, and the step-by-step phasing in of CBAM and phasing out of the currently prevailing free allocations of CO_2 certificates within ten years – it still has to cope with some serious challenges.

Export-oriented industries

Whereas the CBAM proposal levels the playing field of the internal market, it does not offer any incentives for export-oriented industries not to move their production to pollution havens. By introducing an import fee, the proposed CBAM will raise the CO_2 costs for foreign suppliers to the level prevailing in the EU, thereby making local production for the domestic market at least as attractive as imports with regards to the costs of CO_2 emissions. However, exporting companies will still compete with producers from pollution havens in countries outside the EU ETS. The free allocation of CO_2 certificates will be phased out, making it more attractive to move production of carbon-intensive products of EU exporters abroad in order to maintain their competitiveness.

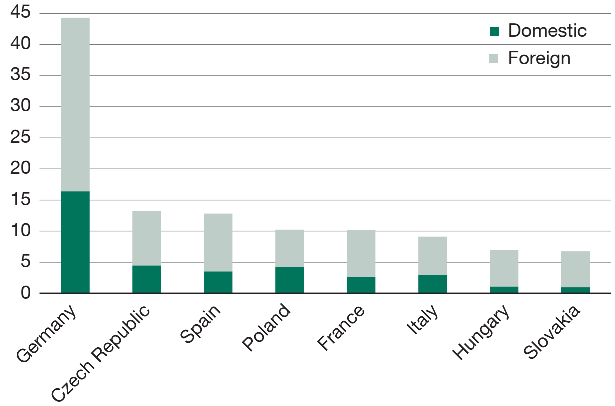
Carbon leakage in downstream industries

The CBAM proposal by the European Commission is focused on a few base materials and does not consider the incentives for carbon leakage in downstream industries which will most likely increase after phasing out the free allocation of CO_2 certificates for their suppliers. Although it is obvious that the measures should be addressed only for products for which CO_2 emissions can be adequately and reliably determined (e.g. steel, aluminium, cement), questions remain about the competitiveness of industries using these products as intermediates. Both in the domestic market and abroad, European downstream industries such as the machinery or automotive sectors compete with producers who purchase their materials and intermediates intermediates from suppliers (e.g. from steel producers) whose costs of compliance with climate regulations are lower since their countries of origin have lower or no carbon prices. Non-EU companies from downstream industries are thus able to offer their products at lower prices, all other cost factors being equal. Thus, the incentive for carbon leakage shifts due to the planned CBAM measures in combination with the phasing out of free allowances to downstream industries. In particular, it shifts to producers not covered by CBAM who purchase their raw materials or intermediate products from sectors protected by CBAM. In the end, the producers along the entire value-added chain not covered by CBAM and the end consumer will share the additional costs – depending on the extent to which the producers can pass the higher costs on to their customers.

Figure 2

CO_2 emissions embodied in gross exports of motor vehicles, trailers and semi-trailers, 2018

in million tonnes



Source: OECD (2021).

Figure 2 illustrates the scope of this challenge focusing on gross exports of motor vehicles, trailers and semi-trailers of the EU countries with the biggest automotive industries. Between 16.4% and 49.4% of CO_2 emissions in these countries embodied in gross exports of motor vehicles are emitted domestically. Due to the free allowances, some of these CO_2 emissions are still only partly subject to carbon pricing. Completely phasing out the free allocation of certificates would mean increasing carbon costs to almost € 2.2 billion for car exporters and their direct or indirect suppliers in the countries listed in Figure 2 – if the price of certificates remains at around €60/tonne CO_2. Applying the same price to imported intermediates will result in more than €4.6 billion of additional costs, thereby increasing the total costs to almost €7 billion. On the one hand, the costs are expected to be lower than suggested by these numbers as CBAM will initially target only a limited number of products. On the other hand, the price of certificates is expected to increase as the number of certificates will be reduced in the coming years. Furthermore, efficiency gains are only possible in the long run, implying increasing additional costs for carbon emissions.

While the additional potential revenue from CBAM alone is estimated by the European Commission (2021a) to be between €1.5 and more than €2.1 billion annually, the additional cost for the entire value-added chain and the consumer will be much higher. This is due to the fact that the additional revenue refers only to the fee on imports and not to the additional payments by European producers for certificates after phasing out the free allocation.

Therefore, the incentive for carbon leakage shifts to the downstream industries not protected by CBAM. By moving production abroad, European carmakers and producers of machinery can increase their competitiveness since they can purchase cheaper intermediates. CBAM does not offer a straightforward solution to this problem. It is necessary to include additional products to CBAM when more evidence is available about reliable indicators for calculating CO_2 emissions in the production of more complex goods of the downstream industries. But this will happen slowly and only to a certain extent. Therefore, the price of creating incentives for the producers of steel, aluminium, etc. to invest in green technology may be carbon leakage in customer sectors of these industries.

Alternative approaches to climate protection

Whereas the Commission's CBAM proposal considers exemptions for trade partners implementing a carbon pricing system, it does not make room for the consideration of alternative approaches to climate protection as equivalent to the carbon price. The proposal takes into account carbon pricing in third countries. The CBAM will be targeted at the gap between the local price of CO_2 certificates in the EU and the price paid in the country of origin. This will avoid double explicit carbon pricing. While the European Commission recognises that many countries worldwide pursue climate protection in the form of regulations other than carbon pricing, there will be no exemptions from the CBAM for producers coming from those countries. Indeed, it is challenging to determine the equivalence between carbon pricing and non-price regulatory measures. However, by not considering exemptions for these countries, implicit double pricing will take place. This bears the risk of retaliatory measures, trade disputes and conflicts as some consider CBAM to be discriminatory compared to domestic producers.

The debate on a polluter import fee in the US provides ideas for solutions for this challenge. In the US, CO_2 emissions are targeted by a mix of federal, state and local regulations, taxes and standards, e.g. fuel efficiency standards, state-level emissions trading systems and renewable energy portfolio standards. Although there is still no official draft for the discussed polluter import fee, US Representative Scott Peters and Senator Chris Coons proposed the FAIR Transition and Competition Act (see Coons and Peters, 2021). Their idea is promising for the international trade debate due to the proposal for an approach to mutual recognition. Concretely, the US Administration should annually determine the costs for coping with the mix of regulations used as part of their climate policy approach. This would facilitate the comparability of the US regulation-based climate policy and the EU ETS. Even better would be an independent international institution established for the purpose of coordinating climate policy approaches, support for developing countries (discussed below) and mutual recognition by estimating costs of compliance with climate regulations in countries with no explicit CO_2 pricing mechanism.

Reliability of reported CO_2 emissions in imports

CBAM will have to cope with the problem of hidden information since there is no sufficient mechanism to verify the actual CO_2 emissions at the border. If no information about actual CO_2 emissions is available, the European Commission plans to use benchmarks as default values. In principle, this offers the advantage of incentivising countries to increase their CO_2 efficiency levels. However, another problem arises. The Commission will allow importers to prove that actual CO_2 emissions are lower than the benchmark as it will accept evidence about actual emissions during a reconciliation procedure. This procedure could be abused – particularly in countries with state-owned enterprises in the steel industry like China, where renewable energy has been gaining importance, it will hardly be possible to validate whether declared CO_2 emissions are reliable. The incentive emerges to declare that exported steel has been produced with renewable energy in companies where there is no transparent production documentation.

Policies to support developing countries

The measures proposed by the European Commission do not include supporting policies for developing countries. For reasons of non-discrimination and WTO conformity, CBAM does not foresee any exemptions for developing countries. Since CO_2 efficiency of developed economies tends to be higher, the introduction of the CBAM will most likely be associated with trade diversion effects that could change the patterns of international trade. As shown in the analysis by United Nations Conference on Trade and Development (2021), the expected result is a decline in exports of developing countries in favour of developed economies. This result is indeed consistent with the target of reducing global CO_2 emissions and the aim to internalise external effects from CO_2 emissions. However, it bears the risk of dampening economic growth of developing and emerging economies. Moreover, developing countries often suffer disproportionately from the negative effects of climate change and have substantial potential for renewable energy production. It is therefore crucial to consider flanking policies by using part of the revenues generated by the CBAM to support developing countries in installing climate-friendly technology and implementing climate policy measures or, even better, implement Article 6 of the Paris Agreement to establish an efficient CO_2 trading mechanism between countries.

WTO rules

Although the European Commission has done its best to design the proposal in accordance with WTO rules, the EU is likely to be the pioneer in introducing a CBAM. The first-mover advantage of setting global standards most probably will be at least partly offset by trade disputes and retaliatory tariffs that will pose further risks to the global trading system and the WTO (Kolev and Matthes, 2021). Currently, the appointment of new judges for the appellate body of the WTO dispute settlement system is being blocked by the US as a way of expressing discontent with the way the WTO functions. Escalating trade disputes, especially with the US, cannot be solved within the WTO and the standoff could eventually bring the system to its knees. There has already been much criticism of the European CBAM proposal from numerous trading partners: the US, Australia and China, among others (Hufbauer, 2021a).

Other trade policy approaches to climate protection

Notwithstanding these challenges, the idea of a CBAM is an important stepping stone for trade policy efforts to tackle climate challenges. Trade policy has powerful instruments to create incentives for more climate protection. Furthermore, international trade is closely linked to climate protection, both due to transport-related fuel combustion and technology diffusion via exports from developed to developing countries. Carbon leakage is also just barely possible without the support of international trade as it enables companies to purchase intermediates from countries with lax climate policies or to move their production abroad and continue to sell its products in the domestic market. To reach the Paris Climate Agreement goals of containing global warming to well below 2 degrees Celsius and ideally even 1.5 degrees Celsius above pre-industrial levels requires additional measures equivalent to a global carbon price of around US $75 per tonne CO_2 by 2030 (Parry et al. 2021). Therefore, trade policy interventions in support of climate protection can be examined as part of the solution to this global challenge, as they have the potential to increase the incentive for other countries to adopt more ambitious climate protection targets. An internationally coordinated approach and good communication are therefore crucial to avoid trade disputes. To what extent trade policy will support climate protection remains a question of political priority setting.

Indeed, the role trade policy could play in environmental and climate protection has been stressed for decades. More than 25 years ago, the German economist Herbert Giersch (1995) pointed out that trade policy is not a suitable instrument for teaching other countries good ecological morals, and still he suggested that we will have to use it – one way or another – as leverage to force other countries to the negotiating table and to get them to cooperate. Some 20 years later, William Nordhaus (2015) developed the idea further and proposed building a climate club with high tariffs for countries not willing to cooperate on climate protection.

Brilliant in its simplicity, purposefulness and traceability, the idea for a climate club represents the basis for a fruitful discussion of the possible options to bring forward global climate protection ambitions (see e.g. Bierbrauer et al., 2021; Tagliapietra and Wolff, 2021). It has also found its way into political circles and was promoted by the German Minister of Finance and most likely the next German Chancellor, Olaf Scholz. Both the academic and the political discussion are focused on introducing a common (minimum) carbon price and/or a CBAM against non-participants in the initiative. A global CO_2 pricing mechanisms would indeed be the most efficient way to target this global challenge. However, there is not much hope for introducing a global CO_2 price as different stages of development, preferences, affectedness and economic and geopolitical interests motivate the different levels of stringency and approaches of climate policy measures worldwide. Furthermore, raising tariffs for the purpose of climate protection may be considered a violation of several WTO rules (Article I, II, VI and XVI of GATT; see Hufbauer, 2021b). Therefore, there is a need for other innovative approaches to enforce more climate protection by the means of trade policy pressure.

There are three potential solutions for the challenges described above:

International carbon price floor among large emitters (Parry et al., 2021). Similar to the introduction of a global corporate tax passed by the G20 summit in October 2021, a carbon price floor would serve as a minimum regulation thus eliminating part of the incentives for carbon leakage. Parry et al. (2021) suggest that international coordination on carbon pricing among large emitters might reduce domestic opposition against a carbon tax or cap-and-trade system. However, the introduction of economy-wide carbon pricing may remain a challenge for some of the biggest emitters like the US. Therefore, the authors allow for further flexibility to accommodate non-pricing approaches with emission-equivalent outcomes, as already pointed out in the discussion on CBAM above. Stressing that the flexibility provisions should ideally be the exception rather than the rule, they consider making room for recognising national level policy approaches that are different from carbon pricing if they have equivalent emission impacts at the price floor (subject to third-party verification). Although the approach of Parry et al. (2021) is clearly a step forward in the research on global climate policy, the incentives to implement the carbon price floor remain rather limited to the climate-related objectives targeted by this measure. Therefore, it may still be the case that these incentives are not sufficient to bring the main polluters worldwide to the negotiation table.

Sectoral approach (Bardt and Kolev, 2021). The idea of a climate club can also be implemented on the sectoral/industry level if the main producers of a certain carbon-intensive product agree on a common carbon emissions price, e.g. for the production of copper. With the common carbon price level or price floor, the additional costs could be passed through to buyers of the product as the agreement unites all big suppliers and there will be no relevant alternatives. As a good example for similar measures, the Montreal Protocol on Substances that Deplete the Ozone Layer can be considered. Furthermore, the recent agreement by the US and the EU to eliminate US steel and aluminium tariffs introduced in 2018 as well as retaliatory tariffs on the EU side could also be developed in this direction. Both US President Joe Biden and the President of the European Commission Ursula von der Leyen stressed at the end of October 2021 the need for sustainable carbon-based steel arrangements that target overcapacities worldwide as well as carbon emissions. One risk that a sectoral agreement introducing a common carbon price level or a price floor for the products harbours is that the higher price for the products coming from these arrangements does not necessarily imply carbon pricing but may be used as a profit leverage for the producers. Therefore, it is crucial to link such an agreement to climate protection.

A WTO of two speeds (Kolev, 2021). Nordhaus's (2015) idea of a climate club using tariff rate differentials to create incentives to participate and pursue climate-related objectives can be implemented by the means of trade liberalisation instead of the originally proposed tariff increase (which would suffer under lacking compatibility with current WTO rules). The club can be founded as a preferential trade agreement among like-minded countries willing to further liberalise trade and intensify climate protection. By liberalising substantially all the trade, the club will fulfil the requirements of GATT Article XXIV for the establishment of a trade agreement and create incentives for non-members to participate. The membership should, though, be linked to climate-related goals. As carbon pricing is not a viable option for many countries, the climate-related goals to be achieved can be set in terms of the reduction of CO_2 emissions, e.g. in accordance with obligations set out in the Paris Agreement. An independent institution should be responsible for the evaluation of different climate-related approaches and progress in achieving the climate-related goals set as a prerequisite for the membership. This approach can be considered trade friendly as it can promote trade liberalisation and establish a WTO of two speeds if a critical number of participants is reached. Canada, New Zealand, the EU and South Korea can be considered natural candidates to start with, as they already have bilateral agreements. However, it will be crucial to include the US as a founding member in order to create even higher incentives for participation. Reaching an agreement with the US may be a challenge; but including China, the biggest CO_2 emitter, may be an even bigger challenge.

Whatever approach is chosen, this article shows that trade policy has the potential to foster the incentives necessary to raise the ambitions of CO_2 emitters worldwide for climate protection. Nevertheless, both border adjustment measures and the idea of a trade club for climate are topics which require further detailed research and dialogue among the global superpowers to further develop the ideas and tackle the remaining challenges prior to implementation.

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André Wolf and Nils Zander

Green Hydrogen in Europe: Do Strategies Meet Expectations?

The possibility of producing hydrogen as an energy carrier or raw material through electrolysis of water, so-called green hydrogen, has been on the table as a technological option for a long time. However, low conversion efficiency and a dubious climate balance have stood in the way of large-scale application ever since. Within the last three to four years, however, this view has changed significantly. In addition to technological improvements, the increasing speed of the expansion of volatile renewable energies in Europe has also contributed to this, since in principle a nearly climate-neutral utilisation of excess generation is possible through the use of hydrogen as an energy carrier in electrolysis. In addition, hydrogen or products derived from it can be used in a variety of ways as a final energy carrier in all energy-intensive activities: industry, heating and transport. For this reason, green hydrogen production could play a key role in interconnecting all energy consuming sectors (sector coupling), a long-term goal necessary for achieving the decarbonisation of the European economy.

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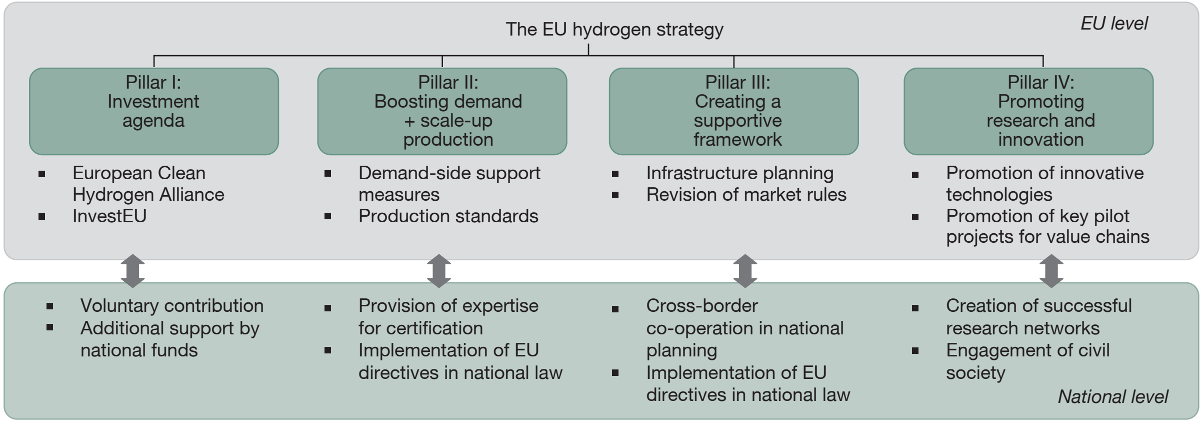
The European Commission has recognised this potential in its recent policy plans. The European Green Deal identifies hydrogen as key to a clean and circular economy. Furthermore, the European Union (EU) has issued a specific hydrogen strategy in 2020, bundling measures to promote a fast and targeted development of production capacities for green hydrogen. Nevertheless, successful implementation requires a sufficient degree of initiative at the national level. In view of the differences in economic structure and natural conditions, the EU countries understandably set different investment priorities. Despite this drawback, it is crucial that the national ambitions will eventually develop into a uniform strategy at the European level, making the continent's hydrogen economy more tangible.

This paper examines the current state of policymaking in EU countries concerning the roll out of a hydrogen infrastructure. As legislation in this area is still in its infancy, this takes the form of an examination of strategic long-term plans rather than an assessment of specific laws. In order to be able to assess the ambition of the political plans, the formulated goals are viewed through the lens of existing projections on the utilisation potentials of green hydrogen in individual countries.

The EU hydrogen strategy

In July 2020, the European Commission (2020) published its "Hydrogen strategy for a climate-neutral Europe". It consists of a roadmap for the establishment and scale up of value chains based on the production of "green" hydro-

Figure 1
Pillars of the EU hydrogen strategy



Source: Author's own representation.

gen. According to the EU definition, hydrogen is labelled "green" if it is produced through the electrolysis of water, provided that the electric energy used as input is generated from renewable sources. The roadmap sketches a path consisting of three phases. In the short-term phase until 2024, the focus is on producing green hydrogen for existing applications. These are mostly limited to the chemical industry, where hydrogen is currently being used as feedstock in the manufacturing of fertilisers. At the same time, new applications should be promoted. To this end, electrolysers with a total capacity of 6 GW are built up, producing up to one million tonnes of green hydrogen per year. In the medium term (2025-2030), the rollout of electrolysers is supposed to increase its pace, with hydrogen conquering new application fields including the role of energy carriers in energy-intensive industries (e.g. steel) and diverse transport applications. The total capacity of electrolysers is envisaged to reach 40 GW in 2030, coupled with an effective annual production of up to 10 million tonnes of hydrogen. Finally, in the long term, from 2030 onwards, the use of green hydrogen will spread to all application areas where it is technically feasible and exhibits cost advantages compared to alternative green technologies.

To promote a timely rollout, several measures at the EU level have been designed and grouped into four pillars. The first pillar consists of fostering investments with funds from InvestEU as financial support and the European Clean Hydrogen Alliance as a stakeholder platform to coordinate an investment agenda. The second pillar consists of measures supporting the growth of hydrogen supply and demand for hydrogen-based applications, including fiscal incentives such as the Carbon Contracts for Difference programme. The third pillar comprises measures creating a supportive framework for market growth, including the planning of physical infrastructure for hydrogen-based value chains and the revision of market rules to facilitate access to hydrogen for end users. The fourth pillar seeks to promote innovation by means of financing pilot projects and demonstrators through the EU regional funds. Finally, domestic measures are complemented by plans to increase cooperation with partners outside the EU on issues like regulation and infrastructure.

While these measures are designed at the EU level, their implementation requires the active involvement of legislators and private stakeholders in all member states. Figure 1 illustrates the relationships between actions at the European and national levels. This concerns all four pillars of the EU strategy. The actual extent of investment support for hydrogen projects will depend on the member states' willingness to contribute parts of their shared management funds to InvestEU ("Member State compartment") as well as on the implementation of own financial instruments at the national level. The EU-wide effectiveness of regulatory support measures for a rollout of hydrogen production requires timely transmission of related EU directives into national laws. The build-up of an EU-wide hydrogen infrastructure requires sufficient prioritisation in national infrastructure planning. The success of pilot projects hinges on the strength of networks between public and private stakeholders in member states as well as on the willingness for cross-border cooperation. Against this background, some EU members have already issued own national hydrogen strategies or at least hydrogen-related goals within overarching action plans. They reveal discrepancies both in focus and overall ambitiousness. This deserves further examination.

Table 1

Indicators for hydrogen usage potential in EU member states

Country	Final electricity consumption / Capacity electricity storage (2018)	Share of variable renewable energy in electricity production (%, 2018)	Household heat consumption per capita (kWh, 2018)	Share of chemical industry in total domestic value added (%, 2018)	Share of basic metals in total domestic value added (%, 2018)	Share of road transport in total inland freight transport (%, 2019)
Austria	0.32	10.91	1013.13	1.44	2.64	66.70
Belgium	0.54	15.24	16.58	3.82	1.52	76.60
Bulgaria	0.33	5.68	511.00	1.35	1.65	47.10
Croatia	0.42	10.35	312.77	0.51	0.17	70.70
Cyprus	0.31	8.31	-	0.32	0.26	100.00
Czechia	0.34	3.38	1060.62	1.59	1.37	73.80
Denmark	0.27	48.92	3239.39	1.25	0.23	88.50
Estonia	0.33	5.39	2868.31	0.91	0.17	58.00
Finland	0.63	8.47	3355.73	2.37	1.26	72.80
France	0.39	6.88	222.89	2.09	0.55	87.90
Germany	0.27	24.28	555.75	2.42	1.29	73.40
Greece	0.30	18.95	57.06	1.20	1.79	97.50
Hungary	0.53	3.87	541.47	1.68	1.23	68.50
Ireland	0.30	27.80	-	0.00	-	99.40
Italy	0.31	13.96	172.63	1.74	1.27	88.10
Latvia	0.26	1.83	2224.87	0.60	0.09	26.40
Lithuania	0.42	37.53	1854.95	2.24	0.05	32.60
Luxembourg	0.47	17.01	-	0.30	-	85.00
Malta	0.48	9.63	-	0.20	0.01	100.00
Netherlands	0.53	12.56	194.18	2.75	0.57	50.90
Poland	0.45	7.71	1111.90	1.54	1.13	76.00
Portugal	0.29	22.84	0.97	0.83	0.55	87.00
Romania	0.30	12.47	421.87	0.67	1.09	45.00
Slovakia	0.46	2.20	861.96	0.71	2.74	65.50
Slovenia	0.46	1.60	413.00	1.56	2.02	64.50
Spain	0.27	23.20	-	1.68	0.96	95.20
Sweden	0.35	10.42	2918.51	1.34	1.96	69.30
EU average	0.38	13.76	1087.71	1.37	1.06	72.83

Note: Values clearly above (>10%) EU country average are highlighted.

Sources: Authors' own calculations based on Eurostat (2021).

Current usage potentials across Europe

In principle, the wide range of potential application fields for hydrogen would allow EU countries to formulate tailor-made strategies for the rollout of green hydrogen. Given the current differences in economic structure and thus in sector-specific energy needs between member states, this approach would be intuitive. However, diversity in national focus complicates the implementation of an EU-wide infrastructure. Assessing the perspectives for a European hydrogen economy should thus start with an examination of existing demand potentials across member states.

Table 1 lists a selection of relevant demand-related indicators, distinguishing between the four major application areas: electricity storage, heating (buildings), industry and transport. Regarding the potential use of green hydrogen as a storage option for electricity, the current magnitude of total electricity demand in relation to storage capacity is an insightful indicator. In this respect, country differences are quite pronounced in Europe. Finland, Belgium, Hungary and the Netherlands currently exhibit particulary high consumption levels in relation to their domestic storage capacities, stressing the benefits of hydrogen as a complementary storage option. More specifically, future storage requirements will also depend on the relative importance of electricity stemming from volatile renewable sources (wind, solar, hydrothermal). In this regard, Denmark, Lithuania and Ireland stand out in EU comparison with especially high shares of volatile renewables in their electricity production.

A different picture is obtained for further usage areas. Concerning the use of hydrogen-based products as a heating source in buildings, household heat consumption per capita is a basic indicator. Here it is quite evident that the greatest demand-side potential is concentrated in the Nordic countries. Regarding the use of hydrogen in industrial production, a distinction can be made between the role as feedstock in the chemical industry (fertiliser production) and as an energy carrier, in particular for energy-intensive industries such as basic metals. Shares of these sectors in the countries' domestic value added are supposed to indicate the relative size of these industries. For this channel, usage potentials seem to focus primarily on Germany, the Netherlands, Finland or Austria. Finally, by implementing the fuel cell technology, many application opportunities arise for the transport sector. However, even though technical feasibility has by now been demonstrated for almost all modes of transport (including shipping and aviation), economic competition with battery-powered vehicles will most likely limit the scope of fuel cell drive to large vehicles like trucks within the foreseeable future (Morrison et al., 2018). Therefore, the relative importance of road transport in inland freight transport is an insightful indicator for the medium-term potential of hydrogen use in domestic transport. To this end, the small island states Cyprus and Malta with their pure reliance on road traffic, as well as significantly larger countries like Spain and Greece, exhibit a greater than average potential.

Hence, while usage potentials seem in some countries to be generally more pronounced than in others, relative differences in sector-specific needs could provide motivation for a diverse pattern of hydrogen use in Europe. However, whether this will actually materialise in terms of country-specific value chains will also depend on the priorities set by national policymaking.

Current state of national hydrogen policies

The state of hydrogen-related policies at the country level is similar in its degree of diversity to the demand-side potentials. At the time of writing this article, less than half (13) of EU countries had issued their own national hydrogen plans. Other countries (e.g. Austria, Sweden) explicitly announced the publication of hydrogen strategies for 2021. Independent of that, almost all EU countries mention green hydrogen in their 2030 National Energy and Climate Plans (NECP), the mandatory framework for member states to outline their energy and climate policies until 2030. While no country denies the long-term opportunities associated with the Power-to-Gas technology, the laid-out plans differ in ambition, scope and level of concreteness. To start with, 11 countries have set explicit targets for the evolution of hydrogen production capacities or consumption levels, including all major economies. The individual targets differ in their temporal division but share the year 2030 as a medium-term reference. France sets the most ambitious absolute target for 2030 with a capacity of 6.5 GW. Regarding hydrogen consumption, seven countries have declared explicit goals. In three countries (Bulgaria, Croatia, Slovenia), these are limited to the transport sector. Almost all countries specify their goals in absolute consumption levels, with Portugal's defined targets as percentages of total consumption being an exception. Moreover, some countries have defined more specific targets linked to production volumes or rates of fuel cell vehicles (Belgium, Czechia), shares in fuel consumption (Germany, Hungary, Italy, Slovakia, Slovenia) or number of refuelling stations (Czechia, France). In general, the specificness implies a low degree of comparability.

Existing national plans also differ in their sectoral priorities. In sketching a future vision of a hydrogen economy, not all technically feasible usage options are equally articulated. Table 2 lists the application fields that are explicitly pointed out by countries as potentially suitable either in the NECPs or the national hydrogen strategies (if available). The pattern clearly reflects the overall focus on the transport sector in the current hydrogen debate. Almost all countries are assigning green hydrogen a relevant role in decarbonising fuel use, predominantly in the context of the fuel cell technology. However, not all countries explicitly define the transport segments for which this technology is likely to become suitable. Among those that do, all see specific potentials for road freight transport in the form of fuel cell-powered trucks. Most countries also identify fuel cell-driven cars as an opportunity for the passenger traffic segment, even though the competition with battery-driven electric cars is frequently emphasised as a barrier to growth. Far less frequently mentioned is the application of hydrogen in other transport modes (aviation, shipping, trains). It is generally seen as a long-term perspective, stressing the need for further research. Regarding usage opportunities outside transport, the benefits of using green hydrogen as a new storage solution for electricity are pointed out by almost all countries. In light of future plans for an expansion of renewable ener-

Table 2
Hydrogen application areas mentioned in national policy plans of EU member states

Country \ Sector	Heating	Energy	Industry	Transport: General	Transport: Passenger	Transport: Truck	Transport: Aviation	Transport: Maritime
Austria	x	x	x	x	x	x		
Belgium		x	x	x	x	x		
Bulgaria		x		x				
Croatia		x		x				
Cyprus								
Czechia	x	x		x	x	x		
Denmark		x		x				
Estonia	x	x		x				
Finland			x	x				
France		x	x	x	x	x		
Germany	x	x	x	x	x	x	x	x
Greece		x		x				x
Hungary	x	x	x	x				
Ireland		x	x	x				
Italy			x	x	x	x		x
Latvia				x				
Lithuania		x	x	x				
Luxembourg		x	x	x	x	x		
Malta	x	x		x	x	x		
Netherlands	x	x	x	x		x		
Poland	x	x		x	x	x	x	x
Portugal		x	x	x	x	x	x	x
Romania		x	x	x				
Slovakia			x	x				
Slovenia		x		x		x		
Spain		x		x				
Sweden			x	x		x		

Sources: Bretagne Développement Innovation (2021); European Commission (2019); Federal Ministry for Economic Affairs and Energy (2020); Government of Portugal (2020); Government of the Netherlands (2020); Ministerio para la Transición Ecológica y el Reto Demográfico (2020); Ministero dello sviluppo economico (2020); Ministry of Climate and Environment (2021); Ministry of Innovation and Technology (2021); Streitner (2020).

gies, this solution is almost unanimously viewed as an important contributing factor to the stabilisation of the grids. Most countries also intend to promote the use of green hydrogen in industrial production – partly as a substitute for brown hydrogen in existing applications, and partly as a substitute for natural gas as an energy carrier. Finally, the use of hydrogen or hydrogen-derived products for heating in buildings is also propagated, but in explicit form only by a minority of countries. Implicitly, additional countries are signalling interest by announcing a revision of rules regarding the access for these products to the existing gas infrastructure.

A comparison to Table 1 indicates some connection between country-specific usage potentials and national policy focus. This specifically holds for ambitions concerning the industry sector. Countries featuring high shares of domestic value added in chemical products and/or basic metals are more likely to put emphasis on this application field. Regarding the potentials of hydrogen as electricity storage, it is striking to see that all countries that do not refer to this opportunity in their national plans exhibited shares of volatile renewables clearly lower than average. The relationship of electricity consumption to current storage capacities seems to be less relevant for policymakers in comparison. This reflects the importance that policymakers attach to the need for the system integration of renewables for the future architecture of power systems in EU countries. Plans and potentials in other areas are less consistent. For instance, the use of green hydrogen as an energy source in residential heating currently plays a surprisingly small role in the plans of the Nordic countries, in view of their high heat demand.

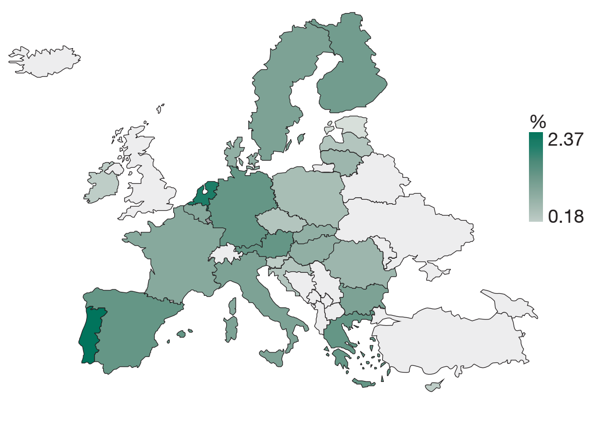
Future relevance of green hydrogen

To discuss the future perspectives for green hydrogen across Europe, long-term energy needs and country-specific expansion goals for renewable energy carriers should be accounted for as well. In general, based on what has been said, countries with more ambitious expansion paths for renewables and/or higher growth of energy consumption are, *ceteris paribus*, expected to have greater incentives to turn to hydrogen as an additional energy source. Regarding the future evolution of energy demand at the national level, the EU Reference Scenario 2020, an energy outlook published by the European Commission (2020) based on the policy framework, provides the best overview for comparison. Accordingly, changes in consumption patterns are governed by significant country discrepancies. Comparing the situation in 2030 with the base year 2020, seven of 27 EU member states are expected to reduce their total energy consumption, including France and Germany. Conversely, data predicts that a number of large Central and Eastern European countries (Hungary, Poland, Bulgaria, Romania) may experience quite sharp increases where consumption levels are expected to increase by more than 10% by 2030 (European Commission, 2021a). At the same time, however, these countries are comparatively less ambitious regarding their expansion goals for renewable energies. Assess-

Figure 2

Potential future hydrogen coverage in the EU

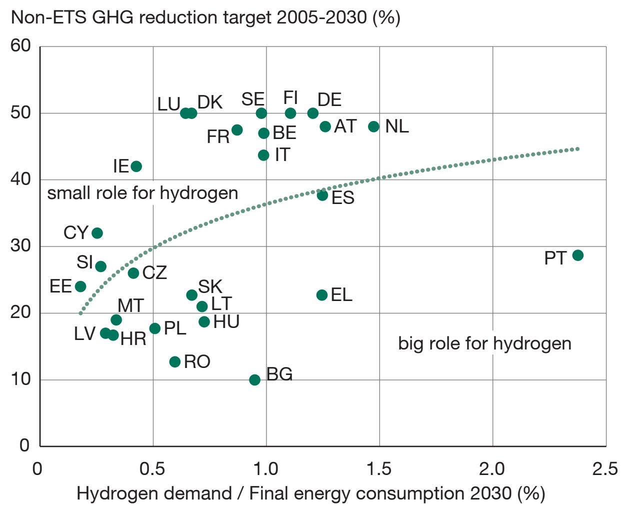
Hydrogen consumption / Final energy consumption 2030 (%)



Sources: European Commission (2021a); Trinomics and LBST (2020); author's own calculations.

Figure 3

Relationship between emission reduction goals and hydrogen potential in EU member states



Sources: European Commission (2021a); European Commission (2021b); Trinomics and LBST (2020); author's own calculations.

ing the future role of hydrogen in country comparison thus requires careful investigation of both policy goals and demand-based requirements.

Against this background, a recent study commissioned by the European public private partnership Fuel Cells and Hydrogen Joint Undertaking has developed demand and production scenarios for green hydrogen in EU countries based on their infrastructure, economic structure and policy environment. They have estimated low and high scenarios for production capacities of electrolysers and required inputs of renewable energies for the year 2030. While the range opened up by the two scenarios reveals a high degree of uncertainty, average differences between countries are still significant. Due to its high demand potential, Germany is expected to have the highest production capacities by far. On scenario average, projected capacities for Germany (8.35 GW) are more than twice as high as those of the second largest producer France (3.25 GW). Spain (2.55 GW) and the Netherlands (2.2 GW) are also predicted to become relevant producers in absolute terms (Trinomics and LBST, 2020). However, to assess the future relevance of hydrogen at the national scale, the projected expansion paths must be viewed in relation to the evolution of total energy demand. Seen from this angle, the pattern changes quite substantially. Figure 2 maps the relation of projected national hydrogen consumption by Trinomics and LBST (2020) to the EU forecasts of total energy consumption discussed above. The total span of hydrogen coverage ranges from less than 1% to more than 2%. While Austria, Finland, Germany, Greece, the Netherlands and Spain exhibit higher than average coverage rates, the highest rate by far is observed for Portugal, where 2.37% of total final energy consumption in 2030 is projected to be satisfied by hydrogen.

The strategic relevance of hydrogen becomes even clearer when the demand potential is contrasted with the level of ambition in pursuing climate targets. This applies above all to the decarbonisation of the transport sector and heating in buildings, as these are currently not yet subject to Europe-wide regulation via EU emissions certificate trading (EU-ETS). As defined in the Effort Sharing Regulation (ESR), individual targets for GHG emission reduction in non-ETS sectors have been assigned by the EU Commission to member states, taking differences in adjustment capacities into account. As part of its Fit for 55 package, the Commission recently made proposals for adjusting these targets to meet the new EU-wide objective of reducing emissions by at least 55% by 2030 compared to 1990. Total reductions in ESR-sectors over the time span 2005-2030 would have to amount to 40% instead of the 30% underlying the current regulation. At the same time, the Commission maintains the practice of setting the expected national contributions at very different levels.

Figure 3 plots the proposed adjusted national targets together with the rates of hydrogen coverage discussed above. In general, it shows an intuitive positive correlation: Countries with more ambitious requirements regarding emission reductions exhibit a bigger potential for green hydrogen in their future energy consumption. However, some country clusters are visible. Northern and Western European countries are facing by far the most ambitious emission goals but, in relation to their energy demand, are not located at the absolute forefront of green hydrogen potential in Europe. In comparison, a group of Eastern European countries is assessed to have similar levels of hydrogen potentials, albeit with significantly weaker climate obligations. Moreover, the large hydrogen potentials expected for some Mediterranean countries, in particular for Portugal, stand out even more when viewed in relation to their only medium overall reduction targets. In parts, this reflects geographical conditions. These countries exhibit the highest potentials for solar-based electricity generation in Europe. The large coastal areas also represent significant opportunities for offshore wind power. At the same time, their spatial proximity to Northern Africa as one of the regions with the best natural conditions for volatile renewables worldwide (DTU, 2021; Solargis, 2021) also suggests considerable long-term potential for green hydrogen import.

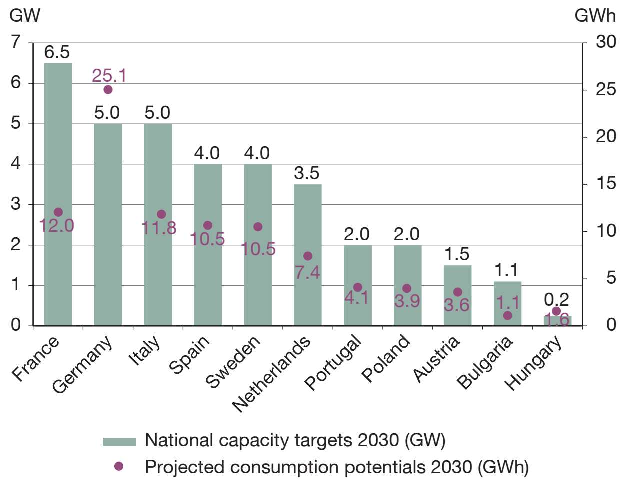
Realising the identified potential requires tailor-made strategies at the country level, with proper focus on country-specific usage potentials and plans for capacity rollout. As discussed above, the level of concreteness in member states' current plans can be considered insufficient in this regard. When writing this article, 11 of 27 EU countries had published concrete targets for capacity building of electrolysers. Among those, the relationship to consumption potentials is not always coherent (see Figure 4). Germany has set itself a lower capacity target than France, even though its projected consumption potential is more than twice as high. Spain possesses almost the same potential as France but is currently considerably less ambitious in its policy goals. Hungary has published the most modest plans for the future enrolment of electrolysers, even though its usage potential lies in the range of countries of comparable economic size. For other countries, including potential major consumers like Italy, Sweden and the Netherlands, plans are more in line with mid-term consumption opportunities.

Conclusion

Against the backdrop of the EU's more ambitious climate targets, the technology of green hydrogen production has gained increasing importance in national plans to implement the energy transition. Currently, hydrogen strategies are published or are under way in almost all EU countries. However, plans differ both in concreteness and level of ambition. Viewed in relation to the expected national consumption potentials, different groups of countries can be relatively clearly distinguished from one another. For example, green hydrogen can play a particularly important role in decarbonisation in the Mediterranean countries. But hydrogen can also make a

Figure 4

Green hydrogen: Capacity targets and consumption potentials in the EU



Sources: Bretagne Développement Innovation (2021); European Commission (2019); Federal Ministry for Economic Affairs and Energy (2020); Government of Portugal (2020); Government of the Netherlands (2020); Ministerio para la Transición Ecológica y el Reto Demográfico (2020); Ministero dello sviluppo economico (2020); Ministry of Climate and Environment (2021); Ministry of Innovation and Technology (2021); Streitner (2020); Trinomics and LBST (2020).

major contribution in the Eastern European region in relative terms, given the less stringent emission reduction targets. For a successful implementation of the hydrogen economy, it is important not to restrict the planning to a race for electrolysis capacities. The development of infrastructure and value chains should be geared to the utilisation potentials and the country-specific differences that exist in this context. The structural differences between EU countries offer potential for a new European division of labour within a common hydrogen network, both in terms of production and consumption. This stresses the need for cross-country collaboration in planning a European hydrogen infrastructure. National plans in the medium term should be harmonised based on EU-wide consultation under the umbrella of the EU hydrogen strategy. Investment support as part of the European Green Deal will be crucial in this regard, assigning the European Commission a leading role for the steering of investments.

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Green Finance in Europe – Strategy, Regulation and Instruments

The publication of the 6th assessment report by the Intergovernmental Panel on Climate Change (IPCC, 2021) on 9 August was another wake-up call for policymakers around the world that there is an urgent need for action to fight climate change. The report delivers once more the scientific evidence that global warming of the atmosphere, oceans and land is caused, to a large extent, by human activities. The observed acceleration of climate change increases the pressure to implement greenhouse gas (GHG) reduction measures on a global scale.

A green transformation of nearly all parts of our economy is necessary, including but not limited to energy production and consumption, mobility, manufacturing and agriculture. The enormous investment volume required is very hard to quantify due to the global, multisectoral nature of the problem and the lack of reliable data. Nevertheless, estimates of the investments required to achieve the low-carbon transition range from US $1.6 trillion to US $3.8 trillion annually between 2016 and 2050, for supply-side energy system investments alone (IPCC, 2018, 154). Although climate finance has reached record levels, funding still falls far short of what is needed under a 1.5°C scenario (Buchner et al., 2019). Of the global climate finance volume of US $579 billion (two-year average 2017/2018), about US $326 billion was provided by the private sector and US $253 billion by the public sector. In light of this, the financial sector plays an important role for a successful sustainable transformation of the global economy.

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The European Green Deal stipulates that the EU will become climate-neutral by 2050 (European Commission, 2019). The intended transformation of the EU will require enormous investments from both the public and the private sector. The EU estimates that approximately €350 billion of additional investment is required in the energy system alone each year up to 2030 in order to meet the 55% emission reduction target (European Commission, 2021b).

To finance the Green Deal, the EU Commission has announced that a total of €1 trillion will be invested in the green transformation of the European economy. The funds will be generated, inter alia, under the 2021-2027 Multiannual Fi-

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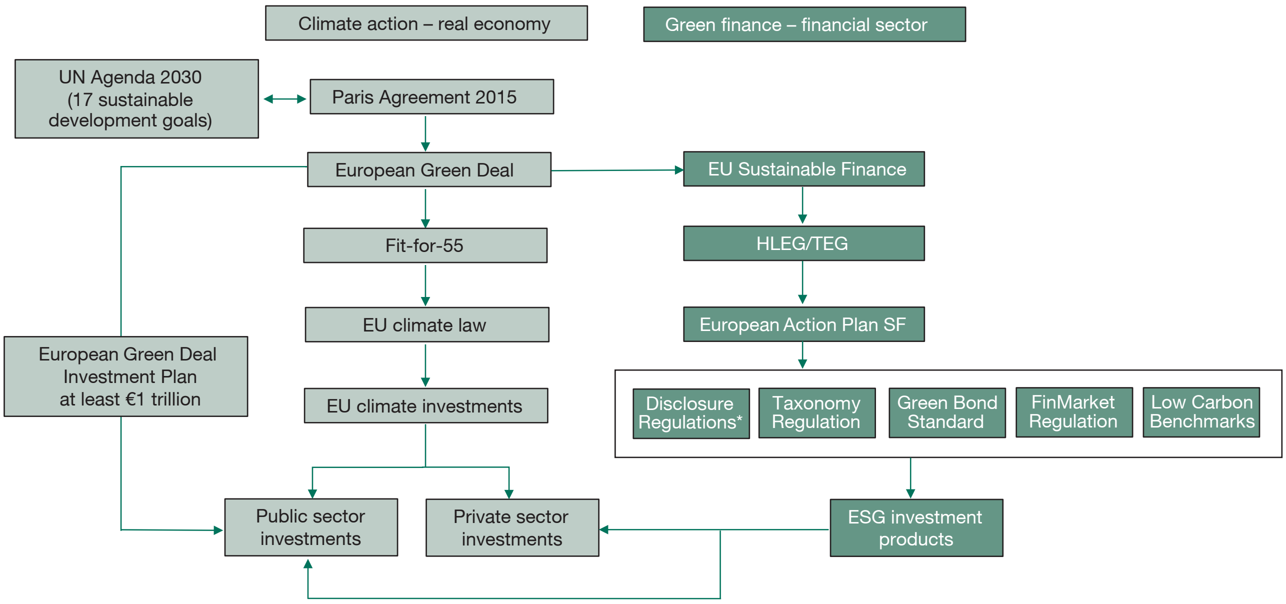
Figure 1

The interaction between climate protection and green finance in the EU



Notes: SF = Sustainable Finance, HLEG = High-level Expert Group, TEG = Technical Expert Group, *Sustainable Finance Disclosure Regulation, Non-Financial Disclosure Regulation, Corporate Sustainability Reporting Directive.

Source: Author's own illustration.

nancial Framework (MFF) and Next Generation EU fund with a total volume of €750 billion. Although this is a large sum, a huge gap of at least €2.5 trillion remains to be financed predominantly by the private sector, for which appropriate regulatory framework conditions and incentives are needed to further promote environmental, social, governance (ESG) investments.

This article illustrates the interdependence between the various climate protection programmes and the sustainable finance activities established so far in the European Union. Key regulatory initiatives such as the Taxonomy Regulation as well as disclosure frameworks and other aspects of financial market regulation are explained in the context of the European Sustainable Finance Strategy. Finally, some missing elements that could help to further mobilise capital to finance the European Green Deal are discussed.

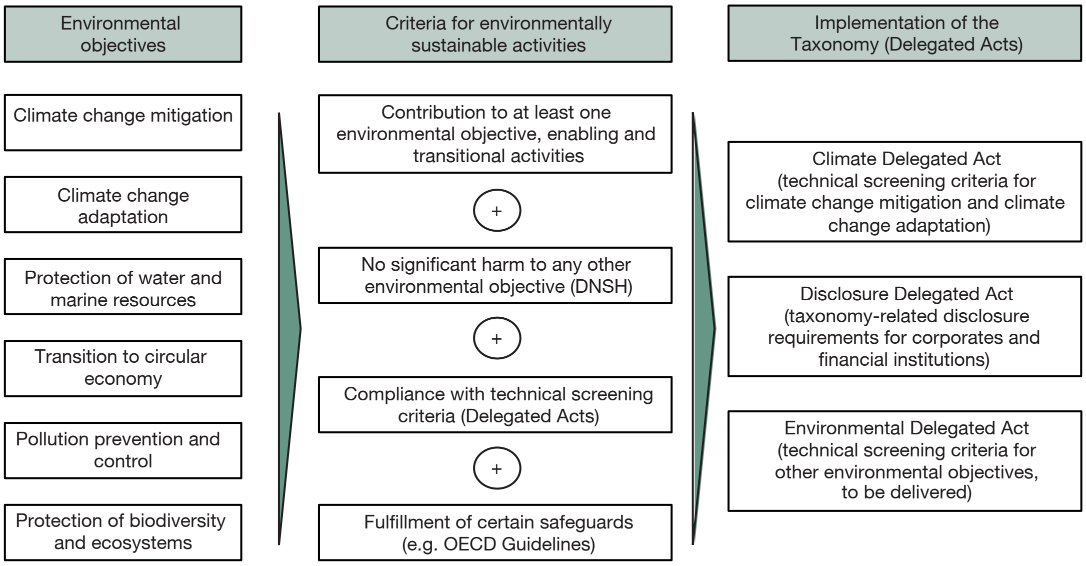
The EU's Sustainable Finance Strategy

In light of the critical role of the financial sector for providing sufficient capital, sustainable finance is receiving more attention in both academic research and the financial sector. Leading asset managers and investment firms offer ESG financial products that claim to take sustainability factors into account throughout the entire investment process. However, while they are often used interchangeably, one needs to differentiate precisely between sustainable finance and green finance or climate finance.

Sustainable finance refers to the process of taking ESG considerations into account when making investment decisions in the financial sector. Environmental considerations might include climate change mitigation and adaptation as well as the preservation of biodiversity, pollution prevention and the circular economy (European Commission, 2021e; Berrou et al., 2019).

Within the context of sustainability, there are manifold ways of defining green finance (European Commission, 2017). For the purpose of this paper, we define green finance as the financing of investments that provide environmental benefits such as reductions in air, water and land pollution, reductions in GHG emissions, improved energy efficiency and mitigation of and adaptation to climate change. This definition is in line with the Taxonomy Regulation and the targets of the European Green Deal and is also close to the definition provided by the G20 Green Finance Study Group (2016), as we understand green finance as a subset of sustainable finance. In that context, climate finance refers to the financing of public and private investments that seek to support mitigation of and adaptation to climate change and can therefore be considered as a subset of green finance (Hong et al., 2020).

Figure 2
Cornerstones of the Taxonomy Regulation



Source: Author's own illustration.

Figure 1 illustrates the development of and interdependencies between the climate protection initiatives in the EU and the corresponding key elements of the European Sustainable Finance Strategy to ensure that the required green financing can be generated. The EU Commission has established a High-level Expert Group on Sustainable Finance, which presented its final report in 2018 and subsequently a Technical Expert Group (2020) that has elaborated detailed recommendations on certain aspects. These recommendations form the basis of the European Action Plan on Sustainable Finance (European Commission, 2018), which has been refined through the Renewed Sustainable Finance Strategy (European Commission, 2021a) and the April package presented earlier this year (European Commission, 2021d).

Establishing an EU taxonomy for sustainable activities

A precise classification system is needed to exactly define the criteria that have to be fulfilled by sustainable or green investment products. Such a taxonomy should support investor decisions, avoid greenwashing and help to channel capital flows into sustainable investments. The Taxonomy Regulation (Regulation (EU) 2020/852 on the Establishment of a Framework to Facilitate Sustainable Investments) came into force on 12 July 2020, but many details are established through Delegated Acts.

As shown in Figure 2, the Taxonomy Regulation distinguishes six environmental objectives by which economic activities can be classified as sustainable. Firstly, climate change mitigation covers activities that contribute to a reduction of greenhouse gas emissions in line with the goals of the Paris Agreement, e.g. through greater use of renewable energies. Secondly, climate change adaptation refers to activities that substantially reduce the adverse impacts of current and expected future climate change on people or nature (e.g. reforestation). The other environmental objectives set out in the Taxonomy Regulation concern the sustainable use and protection of water and marine resources, the transition to a circular economy, the prevention of pollution and the protection of biodiversity and ecosystems.

For an economic activity to qualify as sustainable, it needs to make a substantial contribution to at least one of the defined environmental objectives while at the same time doing no significant harm (DNSH) to any of the other objectives. Furthermore, detailed technical screening criteria (defined by Delegated Acts) need to be fulfilled in order to ensure that a measurable positive impact on the respective target is achieved. Finally, minimum requirements on responsible management (e.g. OECD Guidelines on Multinational Enterprises and the UN Guiding Principles on Business and Human Rights) have to be met by the respective market participants.

According to the Taxonomy Regulation, three types of economic activity can be classified as sustainable: activities that directly contribute to the defined sustainability goals, enabling activities that facilitate the achievement of such goals by providing technologies or services and transitional activities that support the transition to a CO_2-neutral economy as long as technological alternatives are not available. The Taxonomy Regulation applies from 1 January 2022 for the objectives climate change mitigation and climate change adaptation and for the other environmental objectives from 1 January 2023 onwards.

The first Delegated Act has established the technical screening criteria for activities that substantially contribute to climate change mitigation or climate change adaptation (C(2021) 2800 final, the Climate Delegated Act, see Figure 2). It will apply from 1 January 2022 and will cover sectors that are responsible for almost 80% of direct GHG emissions in Europe. It includes sectors such as energy, forestry, manufacturing, transport and buildings. The Delegated Act on the remaining four environmental objectives (the Environmental Delegated Act) must be adopted by the Commission by 31 December 2021 and shall apply as of 1 January 2023.

The taxonomy is a pivotal element of the European Sustainable Finance Strategy as it affects the disclosure regulation of both financial institutions and corporates as well as the Green Bond Standard. In light of the granularity and the preciseness of definitions for sustainable activities and the technical criteria to be met, the EU taxonomy is by far the most advanced compared to other alternatives in the market (OECD, 2020).

The second pillar of a sustainable finance strategy refers to the disclosure requirements of financial institutions and corporates that enable investors to make informed investment decisions and to provide other stakeholders with sustainability-related information. We can already observe that portfolio managers from large asset management firms and investment funds are challenging the boards of listed companies regarding sustainability issues, especially as the demand for ESG investment products has been increasing in recent years. According to a recent survey (Blackrock, 2020), many investors are planning to double their sustainable assets under management in the next five years with the “environmental factor” clearly seen as the top priority for most investors (88%). However, 53% of participating investors mentioned that the poor quality of ESG data so far is one of the biggest barriers to larger ESG investments. Therefore, a proper regulatory framework for non-financial reporting of both corporates and financial institutions is important in terms of turning the increasing investor appetite into actual investment decisions. Hence the Sustainable Finance Disclosure Regulation, the Non-Financial Reporting Directive and the new Corporate Sustainability Reporting Directive are important components of a successful sustainable finance ecosystem.

The Sustainable Finance Disclosure Regulation

The Sustainable Finance Disclosure Regulation (SFDR), which in general applies as of 10 March 2021, imposes mandatory ESG disclosure obligations for asset managers and other financial market participants (Regulation (EU) 2019/2088). The SFDR is a directly applicable regulation extending the already existing disclosure requirements of financial market participants according to relevant sectoral legislation (AIFMD, UCITS, Solvency II, IDD and MiFID II). The SFDR requires asset managers and financial advisors to disclose how they consider sustainability risks in their investment process. Furthermore, they have to disclose principal adverse impacts (PAIs) on sustainability factors that an investment decision or advice might have. The regulation sets forth sustainability disclosure obligations for financial products and financial advisers both on an entity and product level. At the entity level, the SFDR requires firms to disclose information on how an entity integrates sustainability risks in its investment decision-making process or financial advice. At the product level, the SFDR requires firms to disclose further information depending on the objectives of a given financial product. This applies to all the firm’s products, whether they are intended to meet sustainability goals or not. For products that promote environmental or social characteristics, there must be additional information on how these are met, including disclosure on the degree of taxonomy alignment of underlying economic activities (Article 8 products). For products that have sustainable investment as an objective, there must be an explanation of how the objective is achieved as well as additional disclosure on alignment with the Taxonomy Regulation (Article 9 products). While the requirements in the SFDR relating to the entity-level disclosure apply from 10 March 2021 on a comply or explain basis, the additional detailed entity and product level disclosures apply from 1 January 2022.

Based on Article 8 of the Taxonomy Regulation, the Disclosures Delegated Act (C(2021) 4987 final) specifies the content, methodology and presentation of information to be disclosed by large financial and non-financial companies on the share of their business, investment or lending activities that are aligned with the EU taxonomy. This applies to certain large institutions that are required to publish non-financial information under the Non-Financial Reporting Directive (NFRD). If the NFRD were to be amended by the proposed Corporate Sustainability Reporting Directive, the scope of institutions covered by Article 8 of the Taxonomy Regulation would be expanded. The Taxonomy Regulation specifies the key performance indicators (KPIs) related to turnover, capital expenditures and operational expenditures that non-financial companies have to disclose. The Disclosures Delegated Act provides precise definitions, calculation methods and reporting requirements for each KPI. However, the Taxonomy Regulation does not define similar indicators for financial institutions, as meaningful KPIs depend largely on the underlying business model.

Therefore, the Disclosures Delegated Act sets forth specific sustainability-related KPIs for banks, asset managers, investment firms, insurance and reinsurance firms in order to enable investors and other stakeholders to assess the proportion of taxonomy-aligned economic activities performed by the respective financial institution. Asset managers and investment firms should therefore disclose the proportion of investments they have made in taxonomy-aligned economic activities resulting from both their collective and individual portfolio management activities. The main performance indicator for credit institutions will be the green asset ratio, which shows the proportion of exposures related to taxonomy-aligned activities compared to the total assets. Furthermore, banks have to disclose the allocation of their trading book and the proportion of their fees and commission income derived from taxonomy-aligned activities of their clients. Similar obligations apply to insurance and reinsurance companies, for example to disclose the taxonomy-aligned proportion of their underwriting and investment activities.

Due to the extensive additional reporting requirements, financial and non-financial firms have to implement them gradually. From 1 January 2022 to 31 December 2022, non-financial firms will only disclose the proportion of taxonomy-aligned economic activities in their total turnover, capital and operational expenditure supplemented by some additional qualitative information relevant to this disclosure. More granular information may be disclosed from 1 January 2023. In a similar way, financial institutions have to disclose the taxonomy-aligned proportion of their business from 1 January 2022 to 31 December 2023. More detailed disclosure obligations apply from 1 January 2024 or, for some parts, from 1 January 2026.

Non-Financial Reporting Directive

The SFDR and the Taxonomy Regulation, including their Delegated Acts, have to be viewed in conjunction with the already established non-financial reporting requirements. Since 2017, larger capital market-oriented European companies and financial institutions have been obliged to report certain non-financial aspects of their business activities. The Non-Financial Reporting Directive (NFRD, Directive 2014/95/EU) has established rules for the disclosure of non-financial information for certain large companies in order to enhance their transparency on sustainability-related issues. Capital market-oriented companies, banks, insurance companies and other larger non-listed firms with more than 500 employees have to report in particular on matters regarding the environment, employees, respect of human rights and anti-corruption issues. Companies have to disclose the impact of their business activities on such matters and how they work towards achieving non-financial targets in each of these areas. Furthermore, the risks imposed by the company's business on the environment as well as the risks the company is exposed to are important reporting areas. Many companies use guidelines provided by the Global Reporting Initiative and the recommendations from the UN Global Compact. The Commission has published legally non-binding guidelines to help companies implement the disclosure requirements in a clear, consistent and comparable way both for climate-related information (C(2019) 4490 final) that are broadly in line with the recommendations of the Task Force on Climate-related Financial Disclosures (FSB, 2017) and for other non-financial aspects (C(2017) 4234 final).

Corporate Sustainability Reporting Directive

There has been criticism that only a small proportion of firms need to comply with NFRD requirements and that the disclosed information is often not relevant or detailed enough for investors to integrate sustainability information into their investment process (e.g. Umweltbundesamt, 2021). On 21 April 2021, the Commission adopted a proposal for a Corporate Sustainability Reporting Directive (COM(2021) 189 final), which will extend the scope of sustainability reporting to all larger companies. Furthermore, it is intended to broaden and deepen the content of sustainability reporting, which will be harmonised and aligned with the requirements set out in the Taxonomy Regulation and the SFDR. The structure, content and format of sustainability reporting will be standardised and more detailed to facilitate comparability and external assessment of sustainability risks. As the reported information will be part of the management report, at least a limited assurance (audit) by a third party will be mandatory. The draft standards will be developed by the European Financial Reporting Advisory Group based on the work of established initiatives such as the Global Reporting Initiative, the Sustainability Accounting Standards Board, the International Integrated Reporting Council or the Climate Disclosure Standards Board. If the legislation is finalised in the first half of 2022, the new set of reporting standards for companies could apply to reports published in 2024, covering financial year 2023.

Standards and labels for green financial products

The aforementioned regulatory initiatives to improve the disclosure of sustainability information pave the way for building the bridge between business activities in the "real economy" and products/services in the financial sector. The development of standards for “green” financial products can support the further development of ESG-oriented financial market segments by helping investors to identify products that comply with low-carbon criteria, for instance. If investor confidence in the credibility of such standards increases over time, barriers to investments and transaction costs could be reduced. In order to credibly fight greenwashing, strict supervision of the asset management industry by the responsible authorities is vital to ensure that green product features and reporting requirements are constantly fulfilled. An important example is the European Green Bond Standard, which is a first step towards a broader spectrum of green financial products (European Commission, 2021f). The project to create an EU Ecolabel for Retail Financial Products could especially facilitate sustainable investment decisions for retail investors (European Commission, 2021c).

The European Green Bond Standard

The market for green bonds continues to experience strong growth, especially over the last five years, with an estimated total issue volume of US $270 billion, representing a compound annual growth rate of 60% since 2015 (Jones, 2021). In order to avoid greenwashing, several market standards have been established, of which the Green Bonds Principles formulated by the International Capital Market Association have so far been widely used in Europe. However, rather than a precise classification scheme, these guidelines provide more of an exemplary list of green activities suitable for financing via green bonds.

Hence the European Green Bond Standard (COM (2021) 391 final) is supposed to create a voluntary European high-quality standard available to all issuers (private and sovereign within or outside the EU) to help finance sustainable investments. To overcome the weaknesses of existing market labels, bonds that qualify as green according to European standards have to fulfil, inter alia, the following criteria: The funds raised by the bond have to be fully allocated to economic activities that are sustainable according to the Taxonomy Regulation. In addition, the use of the funds has to be reported annually by the issuer in a European Green Bond Allocation Report. Compliance with the standards has to be monitored by external reviewers that are registered and supervised by the European Securities and Markets Authority. External reviewers shall publish pre-issuance reviews and post-issuance reviews of the use of proceeds. Furthermore, a European Green Bond Impact Report on the positive and potentially negative environmental effects of the activities has to be prepared at least once during the maturity of the bond. These strict criteria are designed to foster market integrity by avoiding greenwashing, enhancing investor confidence and issuer transparency.

EU Low Carbon Benchmarks Regulation

Benchmarks perform an important role in financial markets, as they serve as a reference point for pricing financial instruments and transactions, e.g. in credit markets, equity and debt capital markets and derivative markets in various asset classes. Benchmarks are also used to measure the performance of financial instruments and determine the financial obligations arising from financial contracts. Therefore, a high level of transparency and quality regarding the underlying methodologies and data are crucial for benchmarks to function efficiently. In the EU, the Benchmarks Regulation that has been applicable since 1 January 2018 (Regulation (EU) 2016/1011) provides the regulatory framework for benchmark administrators. The regulation requires the publication of benchmark statements to help users understand the benchmark’s field of application and calculation method as well as the reliability of input data and its susceptibility to manipulation. Furthermore, appropriate governance and control processes need to be implemented to avoid conflicts of interest and to ensure the protection of consumers and investors. As many institutional and retail investors invest in benchmark portfolios, it is important to establish regulated sustainable investment benchmarks to attract further capital flows to green investments.

On 27 November 2019, the Benchmarks Regulation was amended to introduce EU Climate Transition Benchmarks, EU Paris-aligned Benchmarks and sustainability-related disclosures for benchmarks (Regulation (EU) 2019/2089), which entered into force on 10 December 2019. The Delegated Regulations ((EU) 2020/1816 and (EU) 2020/1817) for ESG disclosure came into effect on 23 December 2020. The introduction of such benchmarks is supposed to facilitate investments into diversified ESG portfolios with assets from issuers committed to a pathway of decarbonisation by enhancing transparency and comparability.

An EU Climate Transition Benchmark is a benchmark where the underlying assets are selected, weighted or excluded in such a manner that the resulting benchmark portfolio is on a decarbonisation trajectory. An EU Paris-aligned Benchmark denotes a benchmark portfolio whose carbon emissions are aligned with the objectives of the Paris Agreement without doing significant harm to other ESG objectives. To that end, a decarbonisation trajectory means a measurable, science-based and time-bound trajectory towards alignment with the objectives of the Paris Agreement. It should be noted that decarbonisation entails carbon emissions directly generated from the respective entity (scope 1), emissions from the consumption of purchased electricity, steam, or other sources of energy (scope 2) and all indirect emissions that occur along the value chain of the reporting company (scope 3).

Administrators of such low carbon benchmarks have to disclose the calculation method of the respective benchmark as well as the methodology for selecting, weighting and excluding the underlying assets. Moreover, it must be disclosed how the carbon emissions of the underlying assets were measured, their respective values, the total carbon footprint of the benchmark and the type and source of the data used. Administrators of ESG benchmarks have to provide in their benchmark statements detailed information about whether and how ESG factors are reflected in each benchmark. In addition, the Delegated Regulations prescribe the use of specific disclosure templates to ensure standardised formats and facilitate comparability for investors. It includes a forward-looking, year-on-year decarbonisation trajectory and the degree to which the IPCC decarbonisation trajectory (1.5°C with no or limited overshoot) has been achieved on average per year since creation.

Amendments to financial market regulations

On 21 April 2021, several amendments to financial market regulations were adopted (the April package) in order to ensure that client preferences for sustainable investment products are discussed by investment advisors, to clarify the obligations of financial firms when assessing sustainability risks of investments and the need to consider sustainability factors when designing financial products. These measures are expected to help prevent greenwashing of financial products. Therefore, important financial market regulations have been amended, such as the Undertakings for Collective Investment in Transferable Securities Directive, the Alternative Investment Management Directive, the Insurance Distribution Directive, Solvency II and the MiFID II. These changes are expected to come into force by October 2022 (European Commission, 2021d).

Additional instruments

The EU's Sustainable Finance Strategy has significantly improved the regulatory framework for ESG financial products by establishing a precise taxonomy, enhancing transparency for both corporate and financial institutions and amending financial market regulations. However, in light of the apparent necessity to accelerate the implementation of the European Green Deal, additional financial incentives to foster green investments should be discussed. One aspect could be the establishment of tax incentives for green investments in the corporate sector. These could be provided by, for example, allowing accelerated depreciation schedules for green capital expenditures in the industrial sector.

Another component in efforts to align business activities more effectively with climate protection targets could be to require that the remuneration of top management be linked to concrete reduction targets for GHG emissions. Although ESG criteria already play a role in the remuneration of board members at a number of larger, predominantly publicly listed, companies, target-setting is often very vague, only of qualitative nature and of minor overall importance compared to KPIs measuring the financial performance of a company. Therefore, a rebalancing of the relative importance of financial and non-financial targets should be considered, with the latter having a clear focus on environmental objectives. One possibility could be to use the technical screening criteria of the taxonomy to clearly define targets and corresponding metrics to measure the environmental performance of the management.

A highly controversial element concerns the introduction of a "green supporting factor" into banking regulations so that banks do not have to commit as much capital when granting green loans. Promoters of such an initiative hope that bank lending would contribute more than before to accelerating the transition to a climate-neutral economy. Consequently, green loans would be treated as less risky than more carbon-intensive "brown" loans, which could ultimately lead to reduced financing costs for green investments. However, such a green supporting factor would essentially imply a departure from the fundamentally risk-based regulation of capital requirements for banks and other financial institutions that was established in the aftermath of the financial crisis.

Over the last ten years various regulatory initiatives have contributed to a much more robust and resilient financial sector, and this progress should not be put in jeopardy. Nevertheless, it would be beneficial to learn more about the impact of climate risk on the default risk of companies from different sectors and geographies and how to integrate climate risk into current models that measure credit, market and operational risks. So far there is no empirical evidence that green exposures are less risky than others. In addition, it is questionable whether such a green supporting factor would have a substantial impact on banks' lending decisions (Dankert et al., 2018).

The idea of a "green branding" could be applied not only to bonds but also to other financial products such as stocks, loans or asset-backed securities. Finally, the integration of ESG factors into the architecture of major stock-market benchmarks should also be considered (Brühl, 2020).

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Richard S. J. Tol

Europe's Climate Target for 2050: An Assessment

The European Union has set ambitious targets for greenhouse gas emission reduction. Net emissions should fall to 45% of their 1990 levels by 2030, and to zero by 2050. What are the costs and benefits of this? Do the benefits exceed the costs?

The European Commission has not answered this question. This is unfortunate, as the decision has been made to pursue these goals. The European Commission (2020) has published an Inception Impact Assessment, which is largely qualitative.[1] The in-depth analysis accompanying the Communication for the earlier, less ambitious targets does not report a cost-benefit analysis either (European Commission, 2018), even though the European Commission (2014) has continuously promoted its use. Studies by independent academics find that EU climate policy does not pass the cost-benefit test (Pearce, 2004; Tol, 2007; 2012). However, these studies do not assess the latest plans. This paper fills that gap.

Cost-benefit analysis should not dictate policy. It should inform policy along with other concerns. Yet, economic efficiency is an important criterion. If the costs exceed the benefits, all other policy demands would be harder to meet as there is less money to go around.

This paper reviews the targets set by the European Union, discusses the costs of greenhouse gas emission reduction as well as some political claims about those costs, surveys the benefits of avoided climate change and concludes by comparing costs and benefits, in total and at the margin.

The scale of Europe's ambition

Figure 1 reveals just how ambitious the EU target really is. Between 1990 and 2019, greenhouse gas emissions fell

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1 It does refer to a more detailed report, but that link is dead and the report could not be located by me. Some believe the results of the analysis were "predefined" (Simon, 2020).

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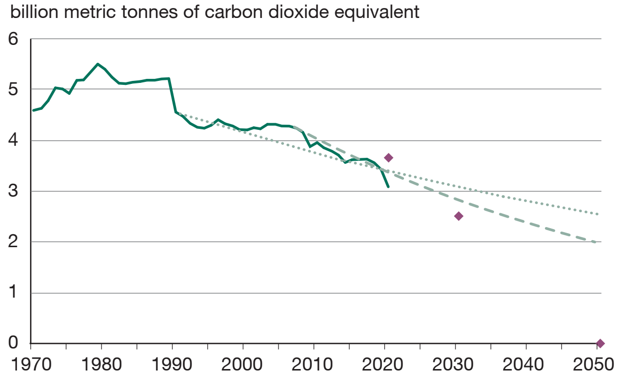
Figure 1
Total greenhouse gas emissions from the 27 member states of the European Union



Notes: The solid green line represents the observations, the dotted and dashed light green lines are simple trend projections, the pink diamonds are the targets.

Source: Author's own illustration.

by 1% per year. This accelerated to almost 2% per year between 2007 and 2019.[2] The 2030 target requires that the rate of decarbonisation doubles again, to almost 4% per year. The 2050 target is more ambitious still.

This simple calculation is, in fact, too optimistic. Renewable sources of electricity are one of the key drivers behind the drop in past emissions. In 2019, wind and solar power made up about one-third of all electricity supply (Eurostat, 2021). However, the technical challenges of integrating non-dispatchable sources grow with their share in power generation. Moreover, electricity is probably the easiest sector to decarbonise. Decarbonisation is harder for transport, heating, industry and agriculture. That is, a doubling of the decarbonisation rate requires much more than a doubling of the policy effort. The low-hanging fruit has been picked.

The problems do not stop there. The energy sector, where most of carbon dioxide emissions originate, is characterised by long-lived capital. The year 2050 may seem a long way in the future – six general elections – but a lot of the buildings, power plants, steel mills and chemical plants we use today will still be around in 2050, and even some of the machinery and vehicles (Davis et al., 2010; Tong et al., 2019). That is why the European Union's target is *net* zero. *Gross* zero would require capital destruction at a large scale, with bankruptcies, lay-offs and claims for compensation. Net zero emission requires offsets (emission reduction paid for by the EU but outside the EU), afforestation in Europe (large plantations of rapidly growing trees) or negative carbon energy (electricity generated from biomass with carbon capture or storage). The problem with offsets is that there are few or none if the whole world has a net zero goal. Scale and speed are the problems with afforestation. Agricultural lands are already converting back to nature in Europe. This can be accelerated but not by much. Besides, we prefer diverse forests, including slow-growing species. Scale is also the problem with bioenergy. Cheap biofuel requires large, heavily mechanised mono-plantations. The acreage needed to supply the EU is large, the acreage for the world is unfeasibly large (Wise et al., 2009). The EU strategy for net zero thus seems to bank on the rest of the world not following suit.

The costs of emission reduction

Emission reduction costs money (Weyant, 1993; Clarke et al., 2014) as climate policy forces people and companies to use different technologies and different fuels than they would have without climate policy. Most studies agree that a complete decarbonisation of the economy could be achieved at a reasonable cost if policies are smart, comprehensive and gradual and if targets are sensible. Models disagree, however, on how much emission reduction would cost. Estimates vary by an order of magnitude or more (Clarke et al., 2014). The main reason is that predicting the future is hard, but modellers could also pay more attention to model calibration and validation (Tol, 2014).

Using the IIASA SSP Database,[3] Tol (2020a) reports that meeting the targets of the Paris Agreement would cost between 0.5% and 10.5% of GDP in 2050, with a model average of some 3%. This would increase to between 1% and 21% in 2100, with a central estimate around 5%. The carbon price would rise to €500/tCO_2 in 2050, a price inflation of 24% per year between now and then in the EU,[4] and above €2,000/tCO_2 in 2100, a price inflation of 7% per year.

Barker et al. (2007) and Clarke et al. (2009) found that the 2 degrees Celsius target is unfeasible for physical, technical, economic or political reasons. There is a political demand for the analysis of ambitious climate targets, ini-

2 I ignore the sharp drop in emissions in 2020, which is due to the COVID-19 pandemic and unlikely to have a large structural effect on emissions.

3 https://iiasa.ac.at/web/home/research/researchPrograms/Energy/IPCC_AR5_Database.html.

4 The carbon price is higher in the EU than elsewhere, and many countries have no carbon price at all.

tially focused on the 2 degrees Celsius target and more recently on 1.5 degrees Celsius.

Modellers have met that demand by expanding options for negative emissions. This includes negative carbon energy, e.g. biomass with carbon capture and storage (Wise et al., 2009), and direct air capture, e.g. artificial photosynthesis or some other chemical process to remove carbon dioxide from the atmosphere (House et al., 2011).

As the market for carbon dioxide is saturated, negative emissions require a carbon subsidy (and deserve one, as this is a negative externality). Reviewing recent estimates, Tol (2020a) finds that the central estimate of these subsidies amounts to 4% of world income by the end of the century, with one model putting it at almost 17%. Carbon subsidies may thus pose a very substantial burden either on other public expenditure or on taxpayers. Incidence may be politically problematic. Energy crops will be grown in monoculture on large, corporate, heavily mechanised farms in foreign countries. Processing will similarly be done by large firms. An electoral strategy based on large subsidies to agri-energy multinationals is hard to sustain, particularly if negative carbon energy is successful and the threat of climate change recedes.

The cost estimates above assume cost-effective implementation of climate policy. Under ideal conditions, first-best regulation is straightforward: The costs of emission reduction should be equated, at the margin, for all sources of emissions (Baumol and Oates, 1971). Governments routinely violate this principle, with different implicit and even explicit carbon prices for different sectors and for differently sized companies within sectors. Although climate change is a single externality, emitters are often subject to multiple regulations (Boehringer et al., 2008; Boehringer and Rosendahl, 2010). Regulations are often aimed at a poor proxy for emissions (e.g. car ownership) rather than at emissions directly (Proost and Van Dender, 2001). Instrument choice may be suboptimal (Webster et al., 2010), and conditions are not ideal. Optimal policy deviates from the principle of equal marginal costs to accommodate for market power (Buchanan, 1969), for multiple externalities (Ruebbelke, 2003; Parry and Small, 2005) and for prior tax distortions (Babiker et al., 2003). Such deviations are subtle and context specific, and rarely observed in actual policy design. All of this means that *actual* climate policy is far more expensive than what is assumed in models (Boehringer et al., 2009).

Creating jobs is a central part of the political appeal of climate policy in the EU, the UK and the US. Relatively labour-intensive, domestic renewables expand at the expense of more labour-extensive, imported fossil fuels. Job creation in the green economy is partly offset by job destruction in the brown economy.

Furthermore, only a small fraction of the labour force is employed in the energy sector. Changes in the labour intensity of the energy sector therefore cannot have a substantial impact on overall employment. More expensive energy has only a small negative effect on employment in sectors other than energy, but this small proportional effect can, in absolute terms, outweigh the impact in the energy sector as it applies to so many more workers (Patuelli et al., 2005) – unless the revenue of a carbon tax or permit auctions is used to stimulate the economy or reduce the cost of labour (Bovenberg and Goulder, 1996).

Historically, productivity has increased, and wages with it, as capital and energy were used to complement labour. Needing more workers for the same output of energy – the very definition of an increase in the labour intensity of the energy supply – is thus a sign of *regress* rather than *progress*. Baumol's Cost Disease, a rise in wages without a concomitant rise in labour productivity (Baumol and Bowen, 1966), affects renewable energy. Decentralised power generation means decentralised installation, maintenance and retirement of equipment. Technicians thus spend more time travelling and are less productive. Yet, their wages need to compete with those in other sectors of the economy.

The benefits of emission reduction

The total impact of climate change

Tol (2018) reviews the 27 published estimates of the total economic impact of climate change, a rather thin basis for any conclusion. The central estimate of the welfare change caused by a century of climate change is comparable to the welfare loss caused by losing a year of economic growth.

Initial warming is positive on net, while further warming would lead to net damages. The initial benefits are due to reduced costs of heating in winter, reduced cold-related mortality and morbidity, and carbon dioxide fertilisation, which makes plants grow faster and more resistant to drought. These initial benefits are sunk, unaffected by current and future emission reduction. For more pronounced warming, the negative impacts dominate, such as summer cooling costs, infectious diseases and rising sea levels.

The uncertainty about the welfare impact of climate change is large and right-skewed. Negative surprises are more likely than positive surprises of a similar magnitude. Feedback that accelerates climate change is more prevalent than feedback that dampens warming, and the impacts of climate change are more than linear in climate change. In that light, the above conclusion needs to be rephrased: A century of climate change is no worse than losing a decade of economic growth.

Estimates are not only uncertain but incomplete too. Some impacts, e.g. on violent conflict, are omitted altogether because they resist quantification. Other impacts are dropped because they do not fit the method such as higher-order impacts in the enumerative method and non-market impacts in computable general equilibrium models. Assumptions about adaptation are stylised, either overly optimistic such as rational agents with perfect expectations in markets without distortions, or overly pessimistic, for example dumb farmers doggedly repeating the actions of their forebears. Valuation of non-market impact is problematic too as benefit transfer, i.e. the extrapolation of observed (or rather inferred) values to unobserved situations, has proven difficult (Brouwer, 2000) but is key to predicting how people will value risks to health and nature in the future.

The social cost of carbon

The social cost of carbon is the damage done, at the margin, by emitting more carbon dioxide into the atmosphere. If evaluated along the optimal emissions trajectory, the social cost of carbon equals the Pigou tax (Pigou, 1920) that internalises the externality and restores the economy to its Pareto optimum (Pareto, 1906) where no one can be made better off without making someone else worse off. The social cost of carbon also equals the marginal benefit of emission reduction.

The social cost of carbon is a central parameter in the economics of climate change and therefore much estimated and debated. Tol (2021) counts 5,791 estimates in 201 papers, published between May 1982 (Nordhaus, 1982) and April 2021 (Taconet et al., 2021). Table 1 shows the mean and standard deviation of the published estimates and of a fitted kernel density (see Tol, 2021, for details), which better reflects the right-skewed uncertainty about these estimates. The table also splits the sample by the pure rate of time preference, or utility discount rate, used as this is the key driver of the estimates (Anthoff and Tol, 2013).

The sample mean is €42/tCO_2, well below €59/tCO_2, the emission permit price on 5 November 2021. The social costs of carbon tend to be higher for lower pure rates of time preference. The kernel density assumes that the uncertainty is right-skewed and fat-tailed. The kernel mean is therefore substantially higher than the sample mean. The standard deviation is large relative to the mean, as predicting the future is hard and estimates of the social cost of carbon require many, often controversial assumptions.

Table 1

Empirical and kernel average of estimates of the social cost of carbon by pure rate of time preference

in euro per tonne of carbon dioxide

Pure rate of time preference	Empirical mean (standard deviation)	Kernel mean (standard deviation)
3%	12 (15)	22 (22)
2%	74 (160)	213 (207)
1%	43 (79)	115 (139)
0%	110 (145)	226 (219)
all	52 (110)	148 (161)

Note: The estimates are in 2021 euro per metric tonne of carbon dioxide, for emissions in 2020.

Source: Author's own calculations.

As noted above, the social cost of carbon can be used to put a value on the emissions reduced. The European Union, however, expresses its emission reduction targets in percentages of 1990 emissions, rather than in tonnes of carbon dioxide not emitted. Figure 1 gives a rough idea of emissions avoided. In 2030, depending on the scenario, between 317 and 577 million tonnes of carbon dioxide equivalents would not be emitted. This increases to between 1,978 and 2,535 MMTCO_2eq in 2050. If the social cost of carbon increases by 2.2% per year, the EU's planned emission reduction is worth between €29 and €53 billion in 2030 and between €283 and €363 in 2050.

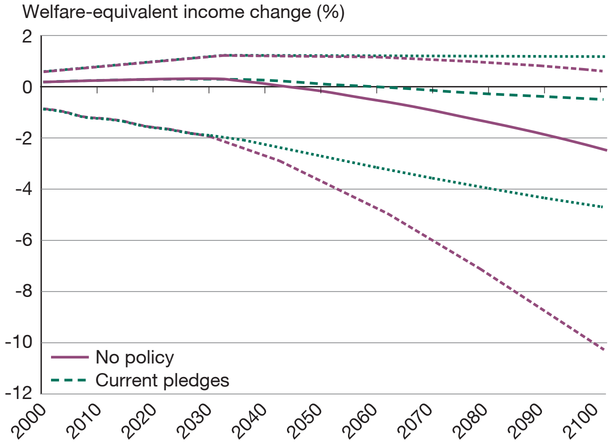
The benefits of climate policy

Instead of using the marginal benefits to approximate the impact of EU climate policy, implicitly assuming linearity, we can also estimate this directly. Tol (2018) fits seven alternative damage functions to the 27 published estimates of the total economic impact of climate change. Figure 2 shows the weighted average of these damage functions, using the relative likelihoods as weights. Two scenarios are shown: no (additional) policy and current pledges (see Ou et al., 2021). The horizontal axis is time, the vertical axis the Hicksian equivalent variation, i.e. the change in income that would make the average person feel as unhappy as they would about climate change.

There is no discernible difference between the two scenarios in 2030. The momentum in emissions, concentrations, atmosphere and ocean is simply too large to expect much if anything within a decade. By 2050, the "no policy" scenario shows a negative impact on climate change (at

Figure 2

The global total annual impact of climate change for two alternative policy scenarios



Source: Author's own calculations.

least in the central estimate) while the "current pledges" scenario still has positive impacts on climate change. The difference is 0.3% of world income or, for today's output, some €220 billion.

Discussion and conclusion

The numbers reviewed above are sobering. The total cost of greenhouse gas emission reduction could be 3% or more of GDP. The benefits would be only 0.3% of GDP, a benefit-cost ratio of one in ten. The marginal costs and benefits give the same message. The marginal costs of greenhouse gas emission reduction would reach €500/tCO_2 by 2050 while the marginal benefits would be less than €150/tCO_2, a benefit-cost ratio of three in ten.

It is often argued that the impacts of climate change are underestimated. Impact estimates are certainly incomplete (Arent et al., 2014). However, arguing that the impacts are off by a factor of ten or even a factor of three is quite a stretch. In fact, the percentage above is the *global* average; a rich region such as Europe would be less vulnerable (Tol, 2018). The social cost of carbon is the *global* social cost of carbon; the EU social cost of carbon would be a fraction of this (Tol, 2019).

Besides, the costs of climate policy are underestimated too, based on the rather unrealistic assumptions of a first-best implementation in an economy without other distortions. In reality, we observe a jumble of policies, uncoordinated not just between countries but within countries as well, and sharp shifts over time as political whims and electoral fortunes come and go.

That said, the above estimates assume stringent climate policy outside the EU too. If climate policy elsewhere were more lenient, then the costs of greenhouse gas emission reduction in Europe would be lower as there would be less competition on the markets for renewables and offsets. At the same time, the benefits of climate policy would be larger. While this would improve the benefit-cost ratio, it is unlikely to make a factor of three, let alone ten difference.

It is therefore safe to conclude that the benefits of the European Union's climate policy do not outweigh its costs. There are no immediate political implications of this finding. The European Union has put stringent emission targets front and centre of its entire policy agenda. There is little political opposition. However, in the longer term, the stringent targets are vulnerable as the costs and other implications of meeting them become apparent to a growing number of people. As climate continues to change, it will also become clear that the weather disasters foretold will not have materialised. At that point, public and political support for the EU's climate policy will likely crumble, and result in a tax revolution as predicted by Dowlatabadi (2000) and observed with the *gilets jaunes* in France in 2018.

Further research is needed on all aspects of climate policy. I do not expect much progress on the economic impacts of climate change, not until the literature gets itself out of the rabbit hole of confusing weather shocks and climate change, despite previous warnings not to (e.g. Dell et al., 2014). More progress can be expected from the new empirical literature on the costs of greenhouse gas emission reduction, the somewhat belated realisation by economists that climate policy started in 1991 and can be studied *ex post* as well as the more common *ex ante*. The resulting papers suggest that climate policy is more difficult and expensive than is commonly assumed (Leahy and Tol, 2012; Fowlie et al., 2018; Lin and Wesseh, 2020; Runst and Thonipara, 2020). Yet more progress lies in the study of second-best climate policy, with studies revealing again higher policy costs (Barrage, 2020; Tol, 2020b).

Until research has progressed, the conclusion remains that the costs of EU climate policy far exceed the benefits.

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Giovanni Dosi

Policy Lessons From Medical Responses to the COVID-19 Crisis

This article discusses the medical/therapeutical responses to the COVID-19 pandemic and their political economy context. First, the very quick development of several vaccines highlights the richness of the basic knowledge waiting for therapeutical exploitation. Such knowledge has largely originated in public or non-profit institutions. Second, symmetrically, there is longer-term evidence that the private sector (essentially big pharma) has decreased its investment in basic research in general and has long been uninterested in vaccines in particular. Only when flooded with an enormous amount of public money did it become eager to undertake applied research, production scale-up and testing. Third, the political economy of the underlying public-private relationship reveals a profound dysfunctionality with the public being unable to determine the rates and direction of innovation, but at the same time confined to the role of payer of first and last resort, with dire consequences for both advanced, and more so developing countries. Fourth, on normative grounds, measures like ad hoc patent waivers are certainly welcome, but this will not address the fundamental challenge, involving a deep reform of the intellectual property rights regimes and their international protection.

It is useful to distinguish between the direct and indirect impact of the COVID-19 pandemic. The former includes the epidemiological effects, which are modelled in Bellomo et al. (2020). The latter concerns the effects of the institutional and policy responses to it. In turn, among such effects one may further distinguish the socio-economic impact of the measures of containment and mitigation. We discuss them with their deeply asymmetric implications among social classes and groups in Dosi et al. (2020). Finally, there are the medical/therapeutical responses, which are the focus of this article.

Medical/therapeutical facts revealed by the pandemic and the policy responses

A few months after the identification of the COVID-19 virus, there are at least eight vaccines available (Pfizer, Moderna, AstraZeneca, Sputnik V, Johnson & Johnson, Sinopharm, Sinovac, Covaxin) and at least seven others will be available very soon (Curevac, Novavax, Convidicea, EpiVacCorona, Soberana, Abdala and Mambisa).

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Normally, a vaccine takes years of research, development and testing. The quick release is the result of an extremely rich body of knowledge waiting for its therapeutic application. It relates to several avenues of exploration, including around sixty potential vaccines in the pipeline as of January 2021.[1] Many of them, but not all, are broadly associated with the genetic engineering paradigm and, more specifically in our case, often associated with immunotherapies for cancer. Indeed, some of the new vaccines (Pfizer, Moderna) were obtained by imaginative re-applications of mRNA studies originally concerning cancers.

Equally striking is that such knowledge largely originated from public or non-profit institutions (Oxford University, MIT, Harvard, Gamaleya Institute, University of Mainz, public Cuban laboratories, etc.) and explored either there or in spin-offs thereof (e.g. BioNTech, Moderna).

This should not be surprising. Basic research is almost entirely supported and often also performed by the public sector in both Europe and the USA. So, for example, in the USA, all 210 new chemical entities approved by the Food and Drug Administration (FDA) in the period 2010-2016 received funding, to different degrees, from the National Institutes of Health (Cleary et al., 2018).

1 A thorough discussion is in Rawat et al. (2021).

Symmetrically, there is longer-term evidence that the private sector (essentially big pharma) decreased its investment in basic research, as witnessed by the diluted output of scientific papers cited in patent applications (Arora et al., 2018). Therefore, it is not surprising that big pharma has been found largely unprepared, at least concerning basic knowledge on vaccines. Among the new molecular entities approved by the FDA since the year 2000, less than 6% concerned antibiotics or anti-viral drugs (Walker, 2020).

Attention to vaccines has always been low. Even the public-private initiative regarding AIDS vaccines, which had raised many hopes (Chataway et al., 2007), failed. Vaccines for AIDS, and later Ebola were never developed. After all, they affected "special groups" or poor populations. It is more rewarding to invest in cures which ideally make chronic otherwise acute diseases (docet the anti-retroviral drugs for AIDS). But, of course, the business is different for a virus which is quite egalitarian in terms of national per capita incomes and social classes (of the infected, not of the casualties).

In this case, the whole private sector has immediately been eager to undertake focused applied research, production scale-up and population testing in exchange for an enormous amount of financial transfers.[2] Approximate estimates suggest €8 billion from the European Union and around $18 billion in the United States. Nobody knows exactly for what: Research? Manufacturing? Testing? Advance payment of the vaccines themselves?[3]

Be that as it may, the developed Western societies ended up with a limited vaccine supply – with the exception of the USA and Israel. And the developing world – including India, which, incidentally, produces around 40% of the world vaccine supply – fared far worse.

The political economy of the public-private relationship revealed by the policy responses to the pandemic generally highlights how governments and regional institutions are often (voluntarily?) held hostage by big pharma. The few countries not rationed have been those giving in to any demands – even at the expense of others, while the EU is in a losing position despite signing pathetic contracts.

Here, we are well beyond the "regulatory capture": It is the reversal of the relationship between the state and private actors, enshrined even in the most pro-market constitutions. In this respect, however, there is a major difference between the European Union (and its member states) and the United States. The EU epitomises the complete abdication of public authorities from their functions (basically telling private actors to do whatever they deem appropriate, in exchange for whatever they ask).

Conversely, the United States has kept a thorough system of command and control in place within the framework of the Defense Production Act of 1950 (Pub.L. 81–774) that authorises the president to order the production and distribution of goods and equipment and to requisition properties deemed necessary for national security. Written large, the Act has been repeatedly invoked in reference to COVID-19 by both Presidents Trump and Biden. Failure to comply with it is a federal felony.

More specifically, regarding pandemics and other health-related threats, the Pandemic and All-Hazards Preparedness and Advancing Innovation Act (PAHPAI, Pub.L. 116-22) of 2019, which expands the Pandemic and All-Hazards Preparedness Act (PAHPA, Pub.L. 109-417) of 2006, establishes a system of responses whose philosophy is a comprehensive mix of compulsory previsions and allocation of resources to the private sector in order to comply. One of the main instruments is the Biomedical Advanced Research and Development Authority, established in 2006 under the PAHPA, which has been the main vehicle for the transfer of the roughly $18 billion mentioned above.

Essentially, the USA represents a model where the fighting of wars is privatised – which is bad enough – but the state maintains the authority to set objectives and strategies. The EU's philosophy is basically the equivalent of allocating money to recruit others to fight whatever war they themselves decide, and without even the compulsory task of winning it. (Because the market knows better.)

Developing countries are, by and large, in a much weaker situation, often plagued by incompetent and corrupt bureaucracy. Only a few have the manufacturing capabilities to make vaccines under license, and even fewer feel the political power to invoke articles 27, 31 and 73 of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) permitting exceptions to intellectual property rights (IPR) sales with compulsory licenses in the case of health and security crises.

Last, but not least, the COVID-19 pandemic crisis has dramatically highlighted the damages of the neglect or, in some countries, the retreat by the state from a universal public good – health, and the corresponding extension of the market domain (Nelson, 2005). The scenes of seriously ill patients unable to reach hospitals are unfortunately common in developing countries, but the pandemic has shown the policy-induced scarcity of public services also in developed ones.

2 Note that this represents a major discontinuity vis-à-vis the historical record of anti-flu vaccines usually developed under a regime of open science.

3 Incidentally, notice that also some patents crucial for mRNA techniques have a public origin and are detained by public institutions (e.g. University of Texas and the National Institute of Allergy and Infectious Diseases of the National Institutes of Health).

General lessons

This pandemic will not be the last one. It is a profound sign of the changes in the relationship between humans and nature that occurred after the Industrial Revolution and rapidly accelerated over the last half century. Some scholars go as far as to say that we have entered the Anthropocene (Coriat, 2020; Crutzen, 2006).

Certainly the destruction of biodiversity, the elimination of any distance between wild and human habitats, the exponential increase in the industrial farming of animals, e.g. poultry, are all recipes for culture of viruses and bacteria mutations and their quick transmission to humans.

Even if vaccines are an ex-post mitigation and not a long-term answer, advanced societies, let alone developing ones, turned out to be largely unprepared. The fundamental reason is the deeply dysfunctional relationship between the private and the public in the generation and exploitation of innovative knowledge, in our case of health-related knowledge. And, in turn, the dysfunctionality rests upon the extent, depth and distribution of IPR.

The Bayh-Dole Act (1980) in the USA, and imitations in other countries, including the EU, which allowed for the patentability of the outcome of publicly funded research, tends to distort the search efforts of e.g. universities, which should be mainly curiosity driven. (Fortunately, the evidence supports that, at least in top universities, such distortions have not been too deep, but the risk is always there.) Public institutions generate promising “basic” knowledge that is then sold often at ridiculous prices to big pharma or incorporated into spin-offs that might generate enormous rents to successful academics. Additionally, testing is done in vitro and finally on humans. Note here the potential conflict of interest involved in a process whereby drug companies test their own products.[4] At the end, it is the public who continue to support fundamental research, while it is ultimately big pharma that masters the rates and directions of innovative activities. Finally, drugs and vaccines are sold back, directly or indirectly, to the public at prices that have little to do with either the private costs of research or the costs of production.

It is often said that the fight against the pandemic is a war. If it is, wars are too serious a business to be left to the markets. During WWII, the USA had become, for very good reasons, a nearly fully centrally planned economy. Roughly three months after Pearl Harbor, it was capable of producing circa one tank per hour (Gross and Sampat, 2020, 2021; Best and Bradley, 2020). Conversely, after the COVID-19 outbreak, California received, with delays, a largely insufficient number of faulty testing kits; after three months the Italian government was unable even to map who was able to produce masks; ventilators had been scarce for months.

Policy lessons

The most fundamental policy lessons are long-term. The illusion of control over nature, and the use of nature as a sink (Brock and Taylor, 2005) must be reversed before it is too late.

Equally important, health must become a universal human right, and knowledge concerning health a global common good.

The crisis has shown the deep pitfalls of a health system partly or nearly fully left to the market. If health is a universal right, this must be taken care of by the public as much as, e.g. justice or public security. On the contrary, even when there is universal health coverage, like in most European countries, public hospitals have often been the prime victim of austerity policies. This must be urgently reversed. What is needed is a massive increase of the overall public expenditure for the health system and the strengthening of local hospitals and laboratories: a capillary hospital system is able to cope with widespread diseases. Basic health-related research is part of a global health mission, thus not subject to the mean calculation of cost-benefit analysis by economists.

During crises like the current one, it should be obvious that vaccines must be made available to the entire world. This, in turn, demands generalised compulsory licensing.

More fundamentally, in the near future, it is crucial to reform the prevailing system of protection of IPR and its international projection via the TRIPS agreements within the World Trade Organization. As we argue at greater length in Dosi and Stiglitz (2014), it is bad for science in developed countries, for global science, and for the economies of both developed and developing countries alike. It has been designed not to maximise innovation but to maximise rents for those who have had the good fortune of receiving a patent (and the two are not the same).

While it is not clear that IPR in general promotes innovation, there is good evidence that there may be adverse effects, especially with poorly designed tight IPR regimes: Access to life-saving medicines may be restricted as well as access to knowledge that is necessary for successful development, and even for follow-up innovation. As governments have to spend more money to purchase the drugs they need, because of reduced availability of low-cost generic medicines, other expen-

4 Typically this is also done for the majority of drugs based on low number of treated and placebo subjects, on the grounds of very weak statistical tests. Vaccines are an exception, and in the case of COVID-19 testing has become intermixed with a sort of pre-sale marketing.

ditures – from those necessary to promote growth to those devoted to alleviating poverty – are reduced. Conversely, there may be perverse links between IPR protection and income distribution.

In some circumstances, such as in the pharmaceutical industry, the evidence is particularly striking. Before TRIPS, generics obtained under loose IPR regimes were able to dramatically reduce the cost of drugs available to developing countries. A vivid illustration concerns antiretroviral drugs against HIV infections where generics were able to reduce the cost by between 70% and 98% (Coriat et al., 2006; So et al., 2014).

Especially in the case of pharmaceuticals, where patents are indeed a major mechanism of rent appropriation, I propose that the public, which, to repeat, finances and performs most of the phase I of research, ought to move all the way to phase III (i.e. experimentation on humans), and when successful, transfer to big pharma, on nonexclusive base, the license to produce – which at that point should yield costs and thus prices not be too different from marginal costs.[5] There would be three major gains.

First, the public would regain the control over the search priorities, that is on the rates and directions of innovative activities. Second, it would certainly be a reform at massive negative costs for the collectivity. Third, it would be a major equaliser in the access to lifesaving drugs between developed and developing countries.

5 President Biden's proposal to waive patents related to COVID-19 vaccines is certainly not the solution to the general problem of IPR in pharmaceuticals, but can be a significant step in the right direction. Many of the reactions are disarming. A few commentators argue, first, that the waiver would be ineffective for most developing countries because they do not possess the tacit knowledge to produce vaccines even in absence of patents, and, second, that the waiver would be a bad precedent decreasing the incentives for big pharma to do research. Of course, both points cannot apply together. (Ugo Pagano has repeatedly pointed it out in personal communication). In the substance, the first point is certainly true, but this just reinforces the argument in favour of the development of local technological capabilities – Cuban style. The second is strikingly false, in general (see above, and the discussions in Cimoli et al., 2014; Angell, 2004; Dosi and Stiglitz, 2014), and with reference to vaccines in particular. The pharmaceutical industry has a historic record of negligible interest in vaccines and it will turn to this neglect, unless flooded by public resources, in terms of both knowledge and money. For sure, proposals like Biden's trigger the "generosity" of big pharma, offering billions of doses at lower prices. Personally, I am all in favour of universal rights rather than premodern charity.

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Labour Market Participation of Older Workers: Drivers and Obstacles

From an international comparative point of view the paper deals with driving forces and potential obstacles for the labour market participation of older workers. It goes into depth by focusing on four case studies that seem to be typical for different contexts. Germany, Israel, Italy and Sweden were selected in order to examine the development and the situation of older workers in detail. Each country stands for a specific configuration, e.g. because it may represent a trend reversal, a continuously outstanding performance, or lasting problems. The cases also provde information on pension reforms and approaches to better manage ageing workforces, in some cases including a new balance of work and retirement. Being aware of the different country situations, it becomes obvious that one size of politics does not fit all. Independent of national policies, employability over the life cycle should gain more attention. Regarding future developments, continuous skill improvement and a healthy work environment are indispensable to keep older workers in work.

Demographic change is a great challenge for the economy as well as the labour market. It is likely that the population in most industrialised countries will grow slower or even shrink in due course, and so will the labour force. Additionally, people and workers are generally growing older. The process of ageing causes numerous questions for economic systems. What does it mean for economic development and trends in labour productivity in the long term? To what extent can implicit knowledge be maintained and skill shortages be avoided? Are social security systems based on contributions by workers sustainable?

A key factor is the employment-to-population rate of workers, particularly of older workers. How far this growing part of the workforce can be utilised is of particular relevance to the future size of labour supply in a given country. A labour force that grows slower or even shrinks has the potential to reduce economic growth and income opportunities for older workers. The more older workers are employed, the more they contribute to economic activities, facilitate knowledge transfer, offer valuable skills, relieve the burden on social security systems and generate their own income.

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From a comparative point of view, this paper deals with the driving forces of employment-to-population rates of older workers. The comparison particularly focusses on the process of ageing in European workforces. The paper consists of four case studies that are particularly typical in different contexts: Germany, Israel, Italy and Sweden were selected to examine the development and the situation of older workers in detail. Each country stands for a specific configuration, e.g. because it may represent a trend reversal, a continuously outstanding performance or unsolved problems. The conclusion summarises the main findings and gives tentative recommendations for labour market policies.

Labour market participation of older workers

Due to the differences in employment rates of older workers over time and between countries and their great significance for future developments, a major question is what may drive the evolution of these ratios. Employment rates of older workers can be influenced by three main factors (Walwei, 2018a). First, differences in the labour market situation and economic development of a country are of relevance. A favourable labour market development improves the outlook of all groups of workers, including older workers. This argument can perfectly be illustrated with Kennedy's (1963) famous phrase that "a rising tide lifts all boats". Secondly, changes in characteristics of jobs and workers may also play an important role. Modified job requirements, differences in labour market participation by gender and educational attainment, and variations in the health situation of the population can be associated with the labour market participation of older workers. Thirdly, institutional reforms may create incentives or disincentives for older workers to participate in the labour market. Regulations dealing with pension schemes and unemployment benefits as long as older persons are concerned are of particular importance.

The case studies of Germany, Israel, Italy and Sweden present different cultural backgrounds and typical developments in industrialised countries. In addition, all of them represent different welfare state models.

Table 1
Ageing of population and workforce

		Germany	Israel	Italy	Sweden	OECD
Median age of total population (years)						
2018		46.0	29.8	46.3	40.6	39.8
Total employment rates by age groups (%)						
1993	25-54	76.8	68.9	66.7	83.2	74.4
	55-64	35.9	45.2	30.4	63.4	46.1
2018	25-54	84.9	80.1	69.8	86.6	78.4
	55-64	71.5	67.3	53.7	78.2	61.4
Employment rates by gender, age group 55-64 (%)						
1993	Male	47.8	62.2	48.2	65.9	59.7
	Female	24.2	29.6	14.1	60.9	33.4
2018	Male	76.1	73.7	64.2	80.5	70.2
	Female	66.9	61.2	43.9	75.8	53.1
Employment rates, age group 65+ (%)						
2018		7.4	21.9	4.7	16.9	15.1

Sources: United Nations (2019); OECD (2021).

Four country case studies

Germany has been chosen for its trend reversal regarding the labour market integration of older workers; Sweden for its consistently high participation rate of older workers; Italy for its difficulties with achieving a high labour market participation of older workers; and Israel for its rather young population as an interesting counter model. Table 1 illustrates the differences between the four countries. It indicates that in 2018 the employment rate of older workers (55 to 64 years) was highest in Sweden for both men and women. The largest increase of the employment-to-population rate of older workers between 1993 and 2018 can be observed in Germany, while Italy shows the lowest increase. Israel has by far the youngest population – as measured by the median age – and the highest share of workers older than 65 years.

The following case studies do not aim at providing any causal explanation for developments of employment-to-population ratios of older workers in the particular countries. Instead, they offer circumstantial evidence in order to illustrate which factors may have been of importance for varying developments.

Germany

Before entering the COVID-19 pandemic, the German labour market was in rather good shape (Bauer et al., 2020; Schneider and Rinne, 2019). While employment-to-population ratios increased across the board since the mid-2000s, the increase has been particularly strong among older workers. Moreover, there is clear evidence that older workers profited from the recent employment boom (Walwei, 2018a). Like several other European countries, Germany is confronted with continuous population ageing. The labour market situation of older workers was poor compared to those in other countries and younger workers until the early 1990s. This applies even more to women than to men. In recent years, however, the labour market participation of older workers has improved considerably. The positive development of the employment-to-population rate of older workers is associated with the higher stability of already existing employment relationships, i.e. one can observe a lower exit rate of older workers (Dietz and Walwei, 2011). The positive trend refers not only to workers aged 55 to 64 who are still part of the workforce but also to those who are already retired (Anger et al., 2018; Walwei, 2018b). Due to increasing skill shortages, firms have made great efforts to retain workers who were eligible for pensions (Czepek et al., 2017). Further evidence shows that a stable employment biography before entering the retirement age favours the likelihood of labour market participation of retired persons (Westermeier, 2019).

Nevertheless, the older workers are, the lower their labour market participation (Walwei, 2018b). Especially if older persons are already unemployed, they experience severe difficulties (re-)entering the labour market (Dietz and Walwei, 2011). The potential devaluation of marketable competencies over time, reservations of employers regarding their flexibility and resilience, and the potential of elevated health risks of older people are a few of the factors that may explain the low entry rates of older workers.

The positive trend of an increased labour market participation of older workers started long before the beginning of the boom period in 2005. One contributing factor relates to the skill level of workers, which has significantly increased over time (Bosch, 2011). Studies indicate a positive relationship between the skill level of workers and their employment-to-population ratio independent of their particular age (Dietz and Walwei, 2011). This means that being advanced in age does not necessarily translate into lower chances of being employed. However, the combination of higher age and lower skills markedly deteriorates the chance of being employed.

Further evidence reveals that the improved labour market performance of older workers relies to a considerable extent on higher employment-to-population ratios of women (Walwei, 2018b). This implies that each female worker entering the old age level incorporates a stronger labour market affinity and pushes the labour market participation of older workers. The favourable development of health over time also plays an important role. Regular reports indicate an improved health of the German population over time (Gesundheitsberichterstattung des Bundes, 2020). Since the 1990s work accidents decreased by one half. In addition, the EU-SILC-survey indicates for Germany a steady improvement in self-assessed health, particularly for the group aged 50 to 65 years.

In Germany, a number of relevant institutional changes have been implemented in the 1990s and at the beginning of the new millennium. They have considerably increased work incentives for older workers (Dietz and Walwei, 2011; Steiner, 2017). Already at the end of the 1990s, the retirement age for unemployed, women, disabled and long-term insured[1] increased. In 2008, the general retirement age went from 65 to 67 years. In 2014, workers who were 63 years or older were offered the opportunity to receive their pensions earlier without any penalty. Although this new option has been frequently used, it should not be seen as a substantial rollback of retirement policies in Germany (Börsch-Supan et al., 2014). Institutional changes also put more pressure on unemployed in general by activating people instead of financing unemployment. The so-called Hartz reforms introduced a means-tested tax-based unemployment benefit II complementary to the contribution-based unemployment benefit I. This level of social protection became less generous, especially for long-term unemployed. Additionally, the maximum duration of entitlement to regular unemployment benefit I for older workers was reduced from 32 months to 24 months. Findings indicate that these reforms have contributed to a stronger individual search intensity and a greater willingness of the unemployed to accept less attractive jobs (Eichhorst and Marx, 2011; Möller, 2015; Walwei, 2015).

1 At least 45 years of qualifying pension contributions.

Israel

Israel is still a young country making it particularly interesting.[2] Israel will unavoidably age in the future. However, even in 2050, it will remain comparatively young, with the smallest age group of 65 years or older of all countries in focus (OECD, 2021; Deller and Walwei, forthcoming). Israel's youngest age group will become slightly smaller: In 2018, it was about one-third of the population, and more than 20% will belong to this group in 2050.

According to Larom and Lifshitz (2018), the Israeli labour market was performing well before entering the COVID-19 pandemic. It was characterised by high employment, low unemployment and increasing hourly wages. Nevertheless, two population subgroups, the Arab population (20% of Israel's total population) and the ultra-Orthodox (Haredi) Jewish population (10%) still lag behind today's majority group (non-Orthodox Jews). This is true for both employment and earnings. However, in the upcoming decades the proportions will shift and, together, Arab and Haredi will represent half of the total population (Larom and Lifshitz, 2018, 11). In order to continue the positive labour market development, it seems necessary to further increase the employment rates among these groups.

Israel's employment rate increased by ten percentage points during the last 15 years, hardly affected by the global financial crisis. Axelrad (2020) reports an overall labour force participation rate of 19.5% for individuals aged 65 and older compared to 10.4% in 2004. These higher rates make Israel second only to Denmark compared to 20 European countries (Axelrad, 2018). They may result from the increased retirement age, from immigrants without pension plans and entitlements or only low social security retirement benefits (Axelrad, 2020). Unemployment has followed a reversal trend. In 2000, the unemployment rate in Israel was around 10%. Since 2004, it has declined rapidly, virtually without a gender gap, to about 4% by 2015.

The high-tech sector employs about 8%-9% of Israel's workers (as of 2017; Fuchs and Weiss, 2018) and is highly relevant for Israel's exports (42%). Employment rates dif-

2 In addition to others, this case study especially uses the works of Fuchs and Weiss (2018) as well as Larom and Lifshitz (2018). This literature is well suited for further readings.

fer by sex and across population groups. By 2015, the overall male employment rate had risen to 81.4%, slightly below the OECD average. The change among women was even more noticeable. By 2015, the employment rate among women in Israel reached 72%, 7.8 percentage points higher than the OECD average. The employment gap between men and women in Israel was only 9.4 percentage points in 2015 (compared to 17.9 percentage points in OECD countries). The data on the participation rates show a similar picture.

The increase in employment was accompanied by higher wages and household incomes. Although individuals who are low-skilled, older and from large families experienced the fastest growth in employment, significant gaps still exist, with especially low employment among Arab women and Haredi men.

The change in employment is largely due to a series of policy measures. Some have increased the incentive to work, while others have cut unemployment benefits. In 1990, Israel improved access to higher education. A much higher proportion of the population now has a college degree. The share of college students in a cohort reached 50% in 2013, higher than in the OECD as a whole. According to Larom and Lifshitz (2018), 30% of the increase in employment can be attributed to the educational attainment.

Retirement age is characterised by a gender gap. This gap is not expected to close. In 2004, the mandatory retirement age was raised from 65 to 67 for men and from 60 to 62 for women. For over a decade, the government has been trying to raise women's retirement age to 64, without success however (Fuchs and Weiss, 2018). The higher retirement age had a direct effect on employment. Compared to other age groups, the 55-64 age group has the lowest employment rate but the fastest increase in employment. As the employment of both Arab and Haredi women continues to have low rates in the 55-64 age group, there would have to be a behavioural change to realise more participation in the labour market. As a result, a discussion has commenced about the importance of support for these groups, e.g. through higher education and designated training centres.

Reforms of Israel's welfare and benefit system since 2002 have tried to increase the incentive to work and to decrease the benefits of non-employment. The level of both the unemployment benefits and period of entitlement were reduced (Larom and Lifshitz, 2018). These changes substantially reduced the number of eligible individuals. Following these reforms, the levels of income support, child allowance and entitlement were also cut dramatically. The reform lowered the payment per child and disconnected it from the number of children in the family. The effect was positive on employment, but negative on fertility.

Italy

The case of Italy[3] is quite similar to Germany in some respects, e.g. continuous ageing as well as a substantial increase in the labour force participation of older workers (aged 55-64). It differs, however, in others ways, e.g. the lower labour force participation of younger individuals (aged 15-24). The share of the elderly population (65 and over) as part of the total population increased from 1988 to 2018 by 8.5 percentage points, while the working age population (15-64 years) shrank. According to Socci et al. (2017), Italy needs a "New Deal" among all stakeholders to develop a national strategy for older workers.

Italy is one of the largest economies in Europe. Its labour market is characterised by differences across age groups, including high youth unemployment. Another key challenge is a north-south disparity with the north continuing to be more dynamic (Marino and Nunziata, 2017). Recently, the share of inactive workers in the Italian labour market increased, and the labour market shrank (Colussi, 2020). The youth (age 15-24) face high unemployment and low participation rates, which decreased between 2000 and 2016 by 15 percentage points (Marino and Nunziata, 2017). Only about a quarter of this group is working. This is also due to the emergence of the NEET youth (those not in education, employment, or training), which totals about one-fifth of the age group. Additionally, the undeclared employment level is high. Since 2009, job vacancies have increased. Italy has experienced a moderate recovery. The large increase of youth unemployment, however, remains a major problem.

Since 2000, older workers' (aged 55-64) labour market participation has accelerated and increased substantially after the 2011 "Fornero" pension reforms. There was an increase of 25 percentage points between 2000 and 2016, standing at 53.4% in 2016 (Marino and Nunziata, 2017).

Although female labour force participation is still low, it has increased by five percentage points from 2000 to 2016. There is a large variation between regions, with specific regions in the north and south alike being above the median of the increase in participation. The low female participation rate can be explained by institutional characteristics including a lack of childcare options and

3 In additon to others, this case study especially uses the works of Marino and Nunziata (2017) as well as OECD (2018). This literature is well suited for further readings.

of flexible working arrangements. The female participation rate ranges from 60% to 67% in the north and 37% to 53% in the south. At the same time, male participation in the labour force remained quite stable. Real earnings have increased; however, productivity remains at relatively low levels compared to other European countries.

Employment policies for older workers in Italy are partly drafted by the regions, not the national government (Socci et al., 2017). The OECD (2018) identified Italy's tactics to promote longer working life as raising the statutory age of retirement, enhancing participation in training and strengthening workplace health and safety as well as targeting workers at risk of unemployment in some regions. Three core policy areas are mentioned: rewarding work and later retirement, encouraging employers to retain and hire older workers, and promoting the employability of workers throughout their working lives.

Italy tried to reward work and later retirement in three different ways. First, by enhancing incentives to continue working at an older age. In 1995, the Italian pension system switched from a defined benefit pension scheme to a notional defined contribution scheme. The "Fornero" pension reform in 2011 accelerated this transition in a more "coercive way" (Socci et al., 2017). At retirement, the accumulated notional capital is converted into an annuity, taking average life expectancy at retirement into account. The second tier is an income-tested "old-age social allowance" entitling employees to a severance payment benefit. Private pension plans form the third tier. In 2012, the retirement age for men was set between 66 and 70 years of age, the respective age for women was set at 62 to be raised to 66. There are incentives for employees to continue working as the pension level increases if the person postpones retirement. Since 2008, it is possible to combine pension income, including early retirement pensions, with income from self-employment or project work. The percentage of retirees working after the age of 65 is very low. Those who do work either have low skill profiles or are highly skilled professionals.

Second, pension reforms restricted the use of early retirement schemes. A new early retirement programme was introduced to have a positive effect on the entry of young workers into the labour market. This effect, however, is widely discussed as the impact is likely to be low over the long term (Bertoni and Brunello, 2017). Workers in arduous and hazardous jobs can access early retirement pensions more easily. Third, different measures to prevent welfare benefits from being used as alternative pathways to early retirement have been introduced. Overall, active ageing has only been developed quite recently in Italy (Socci et al., 2017).

Sweden

Sweden is one of the European countries with the highest population growth over the last few decades. Besides a considerable positive net migration, the fertility rate (1.85 children per woman) is closer to the population replacement level than in most other European countries.

Although overall employment rates in Sweden were already comparatively high in the late 1980s, they increased even further for almost all groups of workers in recent decades. They are still among the highest in the European Union. The economic crisis in the early 1990s brought about a significant increase in unemployment and a temporary decrease in labour force participation (OECD, 2020). Nowadays, unemployment in Sweden is lower than the EU average (Eurostat, 2020). Overall, the 2008 financial crisis had small negative impacts on the Swedish labour market (Albin et al., 2015). Nevertheless, the unemployment rate in Sweden is currently more than twice as high as it was in the 1970s and 1980s. Workers without upper secondary school education do poorly in the Swedish labour market, and their problems appear to be growing.

The high female labour market participation is one of the major explanations for steadily high employment-to-population rates for all groups of workers, but especially for older workers. The labour market participation of women increased particularly until the 1990s when a "feminisation of the labour force" took place (Albin et al., 2015). "Housewives" have more or less disappeared in Swedish society. Nevertheless, the part-time employment rates of women are still much higher compared to men (OECD, 2020). The employment rate among older workers is comparatively high and still trending up (Laun and Palme, 2018). Recently, even the 65-69 age group showed an increase in employment-to-population ratios.

Structural change is also of relevance for transitions between work and retirement because certain industries and their particular jobs might be affected by the transformation more than other industries and corresponding jobs. One can identify a clear socio-economic gradient in the age of retirement: Low-skilled jobs have lower wages and worse working conditions, working environments and occupation protection (Laun and Palme, 2018). Although the incidence of long-term unemployment as part of total unemployment is higher for older workers than for the so-called "best agers" (25 to 54 years), the level is still rather low compared to other countries.

The comparatively high employment-to-population ratio was not only favoured by labour market developments, but also by changes in characteristics of workers and jobs. Circumstantial evidence addresses four influential factors. First, failing health has been identified as the most common reason for retirement (Albin et al., 2015). Overall, statistics indicate that the population in Sweden shows improved health over time. Particularly between the 1960s and 1980s, mortality decreased and surveys report a steady improvement in self-assessed health, especially regarding older men (Laun and Palme, 2018). Research shows that good mental and physical work environments potentially avoid high-risk jobs, physical exposure and disability. Second, education in Sweden is an important gradient for retirement age. In this respect, one can observe significant changes in educational attainment in Sweden. Current cohorts of older workers are more educated than previous ones and tend to retire later (Venti and Wise, 2015). Third, the retirement age is also associated with retirement decisions by life partners or close friends (Laun and Palme, 2018). Couples' joint decision-making leads to an earlier exit for women and later exits for men. Fourth, regarding work requirements there are hints in Sweden that jobs are getting less demanding, e.g. the number of deaths due to work accidents has decreased. Self-reported assessments indicate lower physical demands (Laun and Palme, 2018).

In the 1980s, worries about the viability of pension systems started against the backdrop of an ageing population and lower economic growth. Several political decisions were taken from the early 1990s onwards to counteract early retirement and increase the actual retirement age (Laun and Wallenius, 2015). They aimed at increasing work incentives, influencing retirement behaviour and, as a consequence, delaying exit from the labour force. Such reforms consisted of several elements. The level of pensions is now more proportional to contributions. A payroll tax reduction for retired persons was implemented, combined with a reduction of the income tax. This regulation contributed to the delayed labour force exit, which also has helped to keep employment-to-population rates of older workers high (Laun and Palme, 2018). The increase of the mandatory retirement age was not so relevant for persons aged 64 or younger but more so for the 65-69 age group. However, the strongest effect on persistently high employment-to-population rates of older workers can be attributed to stricter rules for the disability insurance programme.

Conclusions

This comparative paper reflects drivers and obstacles of labour market participation of workers with a specific focus on older workers in four country cases. Each case stands for a specific situation, as well as for specific regulations and changes. Additionally, the cases include information on pension reforms and approaches to better manage ageing workforces, in some cases including a new balance of work and retirement.

In Germany, one can observe a longer-lasting trend of an increasing employment-to-population ratio of older workers. The economic upswing vitalised the labour market in general with a rather positive effect on older workers. However, the situation was already improving in times of weak economic and employment growth – thus, it is not only growth-induced. Pension and labour market reforms can claim a considerable share of success for increasing the number of older workers (Steiner, 2017). Other issues such as a growing educational attainment and increasing labour force participation also seem to play an important role.

Israel is a young country, and its labour market has improved considerably. A series of successful policy measures have laid the foundation. Following a period of exceptionally rapid increase, the employment rate went up more than ten percentage points and unemployment has fallen to 4%. However, serious challenges face two minority groups: Arabs and Haredi Jews. They lag behind in both employment and earnings. While men and women have different legal retirement ages, this finding is highly interesting: Regarding early versus later retirement, Israel has both a strong group of individuals leaving early and another strong group leaving late, thus creating an interesting research case.

Italy has a challenge employing age groups equally. The labour market is characterised by growing participation of the oldest age group while the youngest has major difficulties entering the labour market, partially due to the high share of NEET youth. The second challenge is to continue the development equally in both the north and south. It is necessary to strengthen this. Italy is also a good example of demographically driven pension reforms leading to behavioural change. However, they may also contribute to unbalanced groups in the labour market. The importance of education is demonstrated by the persistant problem of NEET youth. Shaping this development successfully may set an example for other countries as well.

Sweden has one of the highest labour force participation rates among older workers, driven to a large extent by high female labour market participation. There is evidence that retirement policies may have led to delayed labour market exit, mainly through stricter rules for disability eligibility. Exit patterns from employment to retirement have become increasingly heterogeneous. They augment inequalities between older people in retirement, particularly regarding educational attainment. Findings for Sweden suggest that good health and high education are the most important factors for a long career and late retirement. It is argued that policies should focus more on providing education and training to vulnerable groups (Albin et al., 2015).

Given the different country situations, we have not looked for best practices but for design options. Some aspects are similar, others very different. Case studies show that it is important to understand the mechanisms behind different developments. A comparatively young country like Israel may have advantages from a constant inflow of young and well-educated workers. At the same time, it faces challenges like the integration of diverse population groups into the labour market, groups that so far have shown very different labour market behaviours. Compared to Israel, the situations in Germany, Italy and Sweden are quite different. Thus, being aware of the country situations, it becomes obvious that one size of politics does not fit all. Changes must be tailor-made.

The current COVID-19 pandemic may have various consequences for older workers. The reluctance to recruit older workers may be enforced in the current pandemic, when employers may have additional concerns about their health risks. Flexible work is often seen as a suitable way to encourage older individuals to remain in workforce longer, e.g. by facilitating working from home. Digitisation has been pushed by the pandemic, implying an increased need for new capabilities of workers. Therefore, employability over the life cycle should gain more attention. Continuous skill improvement and a healthy work environment are indispensable to keep older workers in work.

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European Technological Sovereignty: An Emerging Framework for Policy Strategy

The COVID-19 crisis has revealed the deep technological and production dependencies of the EU on third countries in sectors deemed as particularly strategic and has thus fuelled the debate on (the lack of) European technological sovereignty in critical fields. This article argues that in the light of a renewed interest in relaunching a European industrial policy, technological sovereignty considerations must be fully incorporated into policy objectives and instruments.

The discussion at the EU level on the concept of technological sovereignty started before the COVID-19 crisis (Edler et al., 2020; Centro Economia Digitale, 2021). In 2019, the newly elected European Commission President Ursula von der Leyen claimed, "We must have mastery and ownership of key technologies in Europe. These include quantum computing, artificial intelligence, blockchain, and chip technologies" (European Commission, 2019a). In the same vein, the EU's Internal Market Commissioner, Thierry Breton, declared:

> Europe cannot make its digital and green transition happen without establishing technological sovereignty. We need to work together at European level in areas of strategic importance such as defence, space, and key technologies such as 5G and quantum. In doing so, we must focus on bridging the digital gap and involving all Europe's regions (European Commission, 2019b).

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He highlighted how a radical change needs to be achieved quickly to manage the green and digital transitions and to avoid external dependencies in the new geopolitical context.

Outside European borders, the geopolitical context is rapidly changing, with important implications for the global economy and the distribution of technological capacities across major economic players, including the United States and China. There is a growing competition between the US and China for technological and industrial leadership not only in the configuration of global value chains, but also in geostrategic matters related to security, performance and robustness of digital networks, and international financial and payment infrastructures. In this context, major US technological companies do not have access to the Chinese market, while at the same time there are Chinese companies that are "unwelcome" in the US.

Other countries find themselves in the middle of these tensions. Europe, in particular, has structural dependencies on both the US and China in a variety of domains, from digital platforms to telecommunications infrastructure. Such dependencies call for the need to increase the level of technological sovereignty through a centralisation of efforts in strengthening technological and digital capabilities in key producing areas (Renda, 2021; Archibugi and Mariella, 2021) and an intensification of coordination activities in both decision-making and action at the EU level (Bongardt and Torres, 2021).

In this article, we argue that technological sovereignty can represent an emerging framework in which the renewed interest in European industrial policy can be incorporated (Mazzucato et al., 2015; Pianta et al., 2020). In particular, we claim that the choice of objectives (missions), strategies and instruments of industrial policy should take the actual context, constraints and ambitions (in terms of a European technological sovereignty) into account. In this respect, the paper contributes to the debate on technological sovereignty by highlighting that the public discussion cannot be limited to stating the need to achieve a greater European autonomy on the global scene, but it must define more clearly the scope of the discussion and the reasonable objectives to be achieved in order to effectively protect Europe's own interests and, above all, its values.

Technological sovereignty: Key definitions

The term sovereignty has ancient origins. It was first developed in the 16th century by philosophers Jean Bodin and Thomas Hobbes as a way to conceptualise supreme authority over a political entity (Dunning, 1896).[1] It also assumed different meanings depending on the historical and political context; however, until the 20th century it was primarily used to express authority within a territory.[2] In this vein, sovereignty is linked to the idea that states are autonomous and independent from each other: within their own boundaries, they are free to choose their own form of government and one state does not have the right to intervene in the internal affairs of another (Krasner, 2001, 2).

More recently, as noted by Couture and Toupin (2019), the notion has been reframed in various directions that differ from earlier interpretations.[3] In particular, the concept of sovereignty has been increasingly used to describe various forms of independence, control and autonomy over digital technologies and contents; however, interpretations and definitions of this term can significantly vary.

According to its early definitions, technological sovereignty is conceived as a nationalist concept, in the sense that its goal is to promote the development of national industries and local capacity for innovation.[4]

Though this aspect is still present, the current debate on technological sovereignty recognised that no country is able to rely only on its own capacities and market size to maintain sovereignty in a globalised and interconnected world. This suggests that sovereignty does not simply imply technological autonomy, but rather the need for a country to develop or preserve, with respect to key technologies, its own autonomy or, alternatively, to have the lowest possible level of structural dependence (Edler et al., 2020). This underlines the opportunity to avoid unilateral dependencies, especially with respect to international partners considered less reliable. Following this perspective, *technological sovereignty* can be defined as the ability of a country (or a group of countries) to generate autonomously technological and scientific knowledge or to use technological capabilities developed outside through the activation of reliable partnerships (Edler et al., 2020; ASD, 2020; Centro Economia Digitale, 2021).

Recently, the notion of technological sovereignty has been put in the context of a series of related concepts, such as strategic autonomy/sovereignty, economic sovereignty, innovation sovereignty, regulatory sovereignty and digital sovereignty. These terms are often used interchangeably (Kelly et al., 2020), a factor that contributes to confusion in the debate, avoiding a clear definition of the perimeter of objectives to be achieved and therefore the identification of appropriate policy strategies.

Even if technological sovereignty is often used indistinctly from *digital sovereignty*, the latter should be considered separately as representing the ability to act independently within the digital world.[5] This term refers to a particular form of management of the cyberspace that involves a country's control of networks and data transmitted through them. The nationality of companies that collect the largest quantities of data defines not only the strength of a country in terms of digital technological capacities, but also its full sovereignty over its digital assets.[6] Large amounts of data expose consumers' preferences and exploit them. Moreover, big data feeds and enables the application of technologies such as artificial intelligence.

There is also confusion about the interpretation of the concept of *innovation sovereignty* (Edler et al., 2020). In order to clarify the issue, it is possible to state that technological sovereignty enables the achievement of innovation sovereignty, i.e. the ability to locally exploit technologies for the development of present and future economic

1 It should be noted that the concept of sovereignty, albeit under different denominations, has been present since the time of Aristotle, as a fundamental principle of the national and international political order (Besson, 2012).
2 As noted by Hollis (2012), this concept of sovereignty is not limited to the landmass itself: "international law has extended the label 'territory' (and the sovereign rights and duties that accompany it) to categorize additional resources, such as the man-made infrastructure lying within a state's territory, the air space above it, mineral and oil resource below the surface, and twelve miles of the adjacent sea and seabed" (4).
3 Examples are the definition of "food sovereignty", "energy sovereignty", "body sovereignty" and "technology sovereignty" (see Couture and Toupin, 2019, 2309 and following for more details on this).
4 One of the first definitions of the technological sovereignty concept was proposed by Grant (1983), who described it as "the capability and the freedom to select, to generate or acquire and to apply, build upon and exploit commercially technology needed for industrial innovation" (239). Even earlier, as reported in Globerman (1978), the annual report of the Science Council of Canada (1977) proposes some suggestions for improving the technological capabilities of Canadian industries, pointing out that it has advocated a strategy of technological sovereignty since its first annual report in 1967. The Council defines technological sovereignty as the ability "to develop and control the technological capability to support national sovereignty" (Globerman, 1978, 42).
5 See in this regard, with specific reference to Europe, Anghel (2020).
6 The digital business platforms on which most transactions take place are from US and Chinese companies, representing 74% and 21% of the market share respectively in the "platform business market", while Europe represents only 4% (Buest et al., 2021).

activities. In other words, scientific-technological capacities become relevant – and indeed constitute a fundamental precondition within the system – only if there are the necessary capabilities to exploit these skills from the economic-productive point of view.

If there are adequate infrastructures, institutional conditions and capacity for innovation and production, technological sovereignty contributes to *economic sovereignty*, i.e. the ability to generate value added and prosperity through independent activities or through a mutual exchange with other economies, avoiding unilateral dependencies. Economic sovereignty is based on the need for unimpeded access to natural resources and capital, as well as technologies, innovations, skills and data.

In turn, economic sovereignty also contributes to the achievement of the broader goal of *strategic autonomy*. This can be defined as the ability of a country (or a group of countries) to play an autonomous and strategic role in the geopolitical context, being an active participant in issues of global importance.[7] Strategic autonomy implies the ability to maintain independence in strategic choices while ensuring interdependencies with other countries, a necessary factor in a globalised and highly interconnected world. Once again, strategic autonomy does not imply a process of isolation or decoupling from alliances and the rest of the world, but rather describes the ability to independently pursue and manage alliances and partnerships (Bauer and Erixon, 2020).

Achieving an adequate level of technological sovereignty is a precondition for the country's strategic autonomy, as it fosters the creation of new opportunities to compete on the frontier of technological development and on international markets, with positive impacts on the country's ability to influence the global scene.

Thus, the concept of technological sovereignty proposed here does not aim at a general expansion of technological activities in areas where the country's international competitiveness is perceived to be too low. From a country's point of view, there is often an effort to achieve technological competitiveness in as many sectors as possible, however, the pursuit of technological sovereignty must take place in selected fields that are considered important according to very specific criteria.

On the other hand, it should be emphasised that the identification of crucial technologies does not provide an absolute answer as to where technological sovereignty should be achieved; it is always a choice based on considerations such as economic affordability, future risks and ease of access to imported alternatives. These considerations must be balanced against each other.

Strategic sectors and technological sovereignty

The identification of strategic technologies is far from being straightforward. This is particularly true in a multilateral geopolitical entity, such as the EU, where the concept itself of sovereignty becomes a function of the achievement of shared objectives. According to the recently published first work programme for the European Innovation Council (2021), the strategic fields are those strictly interlinked with the EU's priorities for a sustainable, digital and healthy society. These challenges will require deep technological and innovative breakthroughs in the digital (advanced high-performance computing, edge computing, quantum technologies, cybersecurity, artificial intelligence, block-chain, cloud infrastructure technologies and technologies for the Internet of Things) and environmental (e.g. new pathways for green hydrogen production, engineered living materials) fields, as well as healthcare (artificial intelligence-driven tools for early diagnosis, point-of-care diagnostics, new approaches in cell and gene therapy, bioprocessing 4.0, health intelligence services and e-health solutions).

With regard to the pharmaceutical and healthcare sectors, the strategic content in terms of technological sovereignty can also be inferred from Germany's reaction to the recent European Commission (2020a) communication on the regulation of takeovers by foreign groups in the form of direct investments. On the basis of this communication, which urges member states to preserve their technological and industrial structures from operations that might appear hostile, the German government dissuaded the US from taking control of Curevac, a laboratory working on the development of mRNA vaccines. Meanwhile, there has been a relevant shift in the vision of the EU health policy (Greer and Jarman, 2021). In particular, to accelerate vaccine development, production and deployment by leveraging pharmaceutical research and technology, the European Commission allocated a significant budget for vaccine research through two key initiatives: the EU Vaccine Strategy COVID-19 (European Commission, 2020b) and the Pharmaceutical Strategy for Europe (European Commission, 2020c). In the latter, the European Commission (2020c) explicitly claims the need for the Union to address "unmet medical needs", highlighting, among others, the "shortcomings [that] concern the lack of development of new antimicrobials, treatments or vaccines for emerging health threats (including those

7 On the strategic autonomy concept, see among others Järvenpää et al. (2019), Leonard and Shapiro (2019), Leonard et al. (2019), Helwig (2020) and Hobbs (2020).

similar to the present pandemic, such as the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)".

This new EU strategy follows a vaccination campaign that showed the EU to be dependent on extra-EU producers, i.e. the UK (Oxford-AstraZeneca) and the US (Pfizer, in cooperation with the German company BioNTech, Moderna and Johnson & Johnson). Moreover, this external technological dependence has caused serious delays in the development of the vaccination campaign in the EU, with major implications for the spread of the infection and its consequences in terms of hospitalisations and human lives, but also in terms of delayed economic recovery due to later reopenings compared to global competitors.

This has had a huge impact in terms of the perception among policymakers and EU citizens of the need for a European public health system (Lucchese and Pianta, 2020) as well as the relevance of European technological sovereignty (Anghel, 2020). This makes the case of COVID-19 vaccines particularly interesting.

The use of patent indicators for the analysis of technological positioning in strategic fields

With regards to vaccine research and, more generally, to any sector considered strategic in the perspective of technological sovereignty, it can be useful to implement an analysis based on a combination of quantitative and qualitative indicators for technology intelligence. These tools are useful for assessing the distribution of technological competences as well as possible dependencies in global value chains. At the EU level, this kind of analysis allows for the determination of the extent to which member states can rely on intra-EU and/or national resources and competences and, conversely, their degree of dependence from other countries.

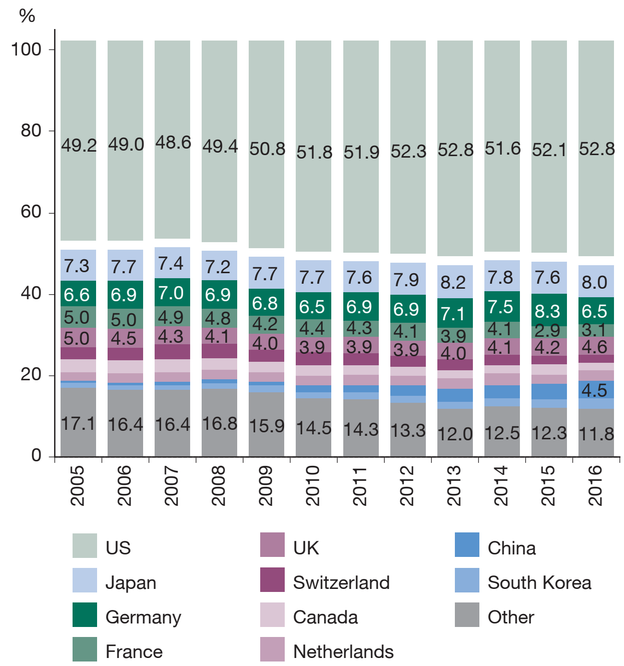
Relevant information in this regard is provided by patent data and derived indicators, such as patent shares and measures of technological specialisation in various technological areas. In fact, patent data allow the identification of possible technological gaps in strategic areas. This comes from the possibility to identify the specific domain in which the new knowledge has been produced through technological classes defined according to the International Patent Classification (IPC) and considering different levels of detail depending on the scope of the analysis.

For instance, with regard to COVID-19-related technologies, the World Intellectual Property Organization (WIPO, 2021) has recently provided a list of IPC classes related to technology areas that are relevant to the detection, prevention and treatment of COVID-19. This list contains several knowledge domains, covering both medical devices/equipment and medicines, and includes the IPC classes closest to vaccine research, e.g. A61K39 – medicinal preparations containing antigens or antibodies. Focusing on this specific patent class, it is possible to identify the relative technological positions of countries based on data extracted from the OECD-REGPAT database. For a better comparison between countries, information should be built on the most relevant patents, such as triadic patent families (TPFs) registered over time by the world's most important patent offices, the US Patent and Trademark Office, the European Patent Office and the Japanese Patent Office.

Figure 1

Leading countries in the generation of COVID-19 vaccine-related technologies, 2005-2016

Country shares of A61K39 – TFPs



Notes: A61K39 IPC class – medicinal preparations containing antigens or antibodies. TPF – triadic patent families.

Source: Authors' elaboration based on OECD-REGPAT database, January 2021.

As it will be shown in the case of vaccine-related technologies, this kind of analysis can provide straightforward information on possible technological dependencies in key areas.

Building on patent data, a first ranking of countries in terms of their capacity to generate knowledge in this domain is shown in Figure 1, which reports the A61K39-TPF

Table 1

Revealed Technology Advantage index for the top 10 countries in A61K39 IPC class, 2016

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Netherlands	24.6	30.9	38.6	44.2	39.3	50.1	47.5	46.7	49.0	54.8	49.0	65.6
US	32.7	33.3	33.7	35.2	38.2	41.2	42.6	44.0	47.3	49.9	53.4	60.3
UK	28.3	23.0	24.1	22.1	22.5	20.3	21.6	22.6	30.1	34.9	42.5	59.3
Canada	60.6	65.6	68.5	62.9	58.8	57.7	53.2	47.9	50.5	46.5	59.4	39.4
France	13.6	11.9	9.4	9.1	2.5	9.4	8.6	9.4	7.1	16.5	-9.8	4.4
Switzerland	37.5	43.6	54.3	50.4	40.9	44.1	36.5	28.5	28.3	29.1	13.7	-1.1
Germany	-33.3	-26.9	-22.0	-19.4	-18.5	-19.1	-12.1	-10.7	-7.6	-1.0	11.2	-10.3
China	-61.7	-68.6	-68.9	-71.4	-66.4	-59.8	-52.7	-45.6	-37.2	-33.9	-27.6	-11.7
South Korea	-84.2	-78.0	-77.7	-78.4	-78.0	-80.0	-79.9	-74.8	-73.2	-69.5	-68.3	-56.0
Japan	-87.9	-87.2	-88.4	-89.3	-87.8	-88.2	-88.7	-87.7	-87.6	-89.5	-90.4	-90.8

Note: A61K39 IPC class – medicinal preparations containing antigens or antibodies.

Source: Authors' elaborations based on OECD-REGPAT database, January 2021.

country shares during the 2005-2016 period. In this case, the technological supremacy proxied by patent indicators is undoubtedly held by the US, which filled more than half of the TPFs in this class and increased its quotas from 49.2% in 2005 to 52.8% in 2016. Japan, which usually tends to slightly outperform the US in other areas, had a share between 7% and 8%, while the weight of China and South Korea appears rather marginal compared to their increasing trend of growth in other strategic fields, such as 5G and edge computing (Centro Economia Digitale, 2021). Concerning the EU, in 2016, the top performers were Germany (6.5%), France (3.1%) and the Netherlands (2.4%).

The analysis of the Revealed Technology Advantage (RTA) index (Table 1) provides complementary evidence. Positive (negative) values of RTA[8] indicate whether a country is specialised (or not) in a technology, building on the comparison between the relative frequency of patenting in a given technology, with the relative frequency of patenting in the same technology at the global level.

The US has emerged as the main player in this sector, showing a dominant position both in terms of patent shares and in terms of technological comparative advantage, with an RTA value of 60.3 in 2016. It is followed by the UK, the country of origin of AstraZeneca's vaccine, which has improved its specialisation trend since 2013, by reaching an RTA value slightly below 60 in 2016. Interestingly, Germany, which occupies the third position in terms of patent share in this class between 2005-2016, shows a negative RTA during the same period. China, South Korea and Japan record the lowest RTA values, revealing a deep de-specialisation in such a critical field. However, unlike Japan, both South Korea and, to a greater extent, China have significantly increased their RTAs in recent years.

The patent data analysis, hence, clearly provides evidence of the lack of an EU technological specialisation in the examined field, which translates into EU members' external dependence on COVID-19 vaccines.

Towards European technological sovereignty in critical fields

US leadership in the field of COVID-19 vaccines and its implications in facing the health and economic consequences of the pandemic have paved the way for a discussion on (the lack of) European technological sovereignty in critical fields. Indeed, the strong technological and productive dependence shown by the EU with respect to the US and China in key areas (ranging from health to digital devices) translated into a particular weak condition when dealing with unpredictable and serious events, such as the current health crisis.

The analysis provided in this article suggests that in the context of a renewed interest in relaunching a European industrial policy (Mazzucato et al., 2015; Pianta et al., 2020; Archibugi and Mariella, 2021), technological sovereignty considerations should be included in the design of policy objectives and instruments. In this perspective, technological sovereignty can become a policy framework into which the priorities and targets of industrial poli-

8 The revealed technological advantage index is calculated as the share of country's patents in a particular technology field relative to the share of total patents in that country.

cies are selected and appropriate instruments designed and implemented. This requires, as a first step, a shared European understanding of what should be intended for technological sovereignty, in order to reach a shared definition of this concept at the EU level. Technological sovereignty does not imply the search for a full technological independence in all strategic fields, but the need to develop or preserve, with respect to key technologies, a certain degree of autonomy or, said otherwise, the lowest possible level of structural dependence. Thus, avoiding unilateral dependencies, especially in relation to international partners, is considered less reliable.

Once the relevant technologies from the point of view of technological sovereignty have been identified, it is necessary to carry out a qualitative/quantitative analysis to establish the positioning of EU countries in the different technological areas with respect to international competitors in order to identify strengths and weaknesses.

Hence, targeted industrial policies, supported by consistent and persistent investments in the technologies identified as critical from the technological sovereignty perspective, represent the way for achieving appropriate levels of technological sovereignty at the EU level. On the demand side, these can include the adoption of "sovereignty clauses" to be attached to innovative public procurement where necessary. Moreover, general principles could be introduced whereby public administrations must procure digital goods and services from companies that respect ethical and data sovereignty principles defined at the European level.

With regard to the digital environment, the EU should work at ensuring an advanced, secure and competitive European digital space. This would require the development of a system of coherent policies for a number of purposes related to the use of data, such as increasing the development of scientific skills, removing obstacles to the creation of a digital single market, stimulating the development of new technologies, promoting the use of new technologies (e.g. high-performance computing, artificial intelligence and Internet of Things) and competitive data and cloud infrastructures as well as establishing clear and consistent legislation, especially with regard to cybersecurity issues and data transfer.

In this area, the European Union can make a decisive contribution to the definition of rules by bringing its leadership to this field. An example is represented by the General Data Protection Regulation, where the EU has required companies around the world to comply with its privacy rules and has encouraged the development of similar regulations in other jurisdictions (even parts of the US). The EU has had a global impact on the design of the data sharing regulatory framework, demonstrating its strength in this area. Another example is provided by the eIDAS Regulation on digital identity and trust services: The construction of a common accountability and service framework in Europe has driven homogenisation in other parts of the world, such as Latin American countries, while inspiring the work of a UN working group to revise international regulation. This best practice shows how the EU can not only lead the way in the production of legislation by homogenising positions on new issues, such as the protection of personal data or electronic signatures, but can also act as a guide in regulating frontier issues, namely digital identity, blockchain, artificial intelligence and liability in human-machine interactions.

Finally, EU members have to boost their strategic autonomy in production systems by turning technological capabilities into innovative and productive capacities able to fuel international competitiveness and independence in key sectors. Actions in this direction concern supporting strategic value chains and extending their scope from industrial fields (batteries, high-performance computing and microelectronics) to services (such as digital trust) through coordinated measures on raw materials, research and innovation, investment financing, regulation, trade and skills development.

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Modern Monetary Theory: A Wrong Compass for Decision-Making

In the last few years, the so-called Modern Monetary Theory (MMT) has been gaining prominence in the media and the public. This article presents the MMT approach to money and monetary policy, and discusses its recommendations regarding fiscal policy and aggregate demand management, the structural policies it advocates as well as the international aspects of MMT. Overall, it appears that MMT is based on an outdated state of economic science and that its claims regarding economic policies are much exaggerated: The meaning of MMT is more that of a political manifesto than of a genuine economic theory.

Georg Friedrich Knapp's (1905) *The State Theory of Money* (STM) provides the main theoretical underpinning of the Modern Monetary Theory's (MMT) approach to money. We briefly expose STM's link with MMT and then analyse the recommendations of MMT related to money, monetary policy and the role of the central bank. We also consider historical precedents and a possible implementation of MMT in the USA.

An erroneous representation of monetary policy

The main ideas expressed in STM that are used in MMT can be summarised as follows: Money is a creature of the law; it is a means of payment; it is a token, a representation, hence the reference by Knapp to the Latin word *charta* that he translates into token and that has given rise to the word "chartalism" to refer to Knapp's and his followers' ideas. Both approaches also hold a narrow vision of money as a means of payment, thus neglecting its other roles as a unit of account and a store of value.

STM and Knapp as well as MMT and MMT economists both present themselves as unorthodox, at odds with "mainstream" economists. Indeed, their attempt to produce a theory has been seriously questioned. For instance, reviewers noted that STM says nothing about the value of money and lacks correspondence with historical facts, while Ocampo (2020) has labelled MMT "Magical Monetary Thinking".

However, one important difference between STM and MMT is that, although this does not seem to be stated in any MMT publication, money is considered in MMT as a pure asset that the state can create at will, whereas STM views money as both an asset and a liability.

Money, monetary policy and the role of the central bank

Regarding money, MMT adopts what Tobin (1963) calls the "fountain pen" approach to money (i.e. the belief that money can be created *ad libitum*, by the stroke of a pen), applying it to the government – systematically called "the state" – instead of the banks in the Chicago Plan (Pfister, 2020). For instance, Wray (2014, 28) writes, "There is no limited supply of either private or state IOUs – so long as either is willing to issue IOUs, they can be supplied" and he derives from this truism that "the limit is on the demand side". According to Wray (2014), what matters

> is acceptability on the demand side. As a sovereign power, however, the state can mandate at least some demand for its IOUs by imposing obligations that must

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> be paid in the state's currency. Beyond that, by sitting at the apex of the "money pyramid", the state's IOUs are demanded for clearing purposes and also for reserves of the most liquid assets (29).

As Wray (2014) does not define what he means by the "state's IOUs", we identify this notion with the more common one of "monetary base", i.e. the sum of cash in circulation and reserves, defined in the literature as the demand deposits held by monetary policy counterparties (i.e. banks) with the central bank. On that basis, and keeping in mind that banks use reserves to settle their net positions after clearing (with a quasi-null impact on the aggregate demand for reserves), it appears that Wray (2014) confuses something. This confusion, in line with the definition by STM of money as a means of payment, is between legal (or fiat) currency (e.g. the euro or the dollar) and cash (or forced course currency, i.e. currency that has to be accepted in payment and that cannot be exchanged for outside money). Furthermore, the use of cash by economic agents is nowadays limited and reserves are used by banks only as a vehicle to settle transactions, with almost no impact on the aggregate demand for them; instead, economic agents use private money in most of their payments. This confusion is also common to other MMT authors (see e.g. Kelton, 2020, 15-41); however, none of them ever explains why modern literature on money defines what makes legal currency "acceptable" by the public, i.e. monetary policy credibility. Neither do they envisage the possibility of currency competition. Instead, they prefer to insist on the constraints that "the state" puts on the public.

Regarding monetary policy and the role of the central bank, in contrast with standard monetary economics, MMT does not provide an explanation of monetary policy strategy or a description of the monetary transmission mechanism from monetary policy decisions to the broader economy. Instead, it considers that law should set the objectives and the conduct of monetary policy, possibly in the details – e.g. prescribing a given interest rate level – and it focuses on one specific aspect of monetary policy implementation: liquidity management by the central bank, usually regarded as the "nuts and bolts" of monetary policy. Even more specifically, it focuses on the interaction between this management and the operation of the Treasury's account with the central bank, starting from the correct observation that the central bank and the Treasury need to coordinate for the former to be able to manage bank liquidity properly. Indeed, this coordination is useful: Since the central bank keeps the account of the Treasury, any flow into or out of this account impacts banks' liquidity. However, MMT never explains what "coordination" entails, instead letting the reader assume that the central bank would receive instructions from the Treasury that dictate the amount of liquidity to be provided or withdrawn. In fact, the central bank receives no more than the Treasury's forecast of the expected changes on its account with the central bank over the forecasting period of the "autonomous factors" (i.e. the period before the next open market operation).

MMT economists also consider the monetisation of public debt that takes place through central banks' asset purchases (quantitative easing) as "business as usual". In that regard, Kelton (2020), apparently considers money as an asset that the government could create *ex nihilo*, a sort of celestial manna, and gives the example of Japan. There, "half of its [the government's] debt has been retired (i.e., *paid off* [emphasis added]) by its central bank. And it could easily go all the way to 100 percent. If it did, Japan would become the least indebted country in the world" (Kelton, 2020, 93-94). In fact, Kelton overlooks that reserves created by the central bank to purchase public securities would leave the amount of public liabilities unchanged, which is clear when one consolidates the balance sheets of the government and the central bank. Even if one leaves out this extreme example, it appears that, in MMT's approach to monetary policy, fiscal dominance is the rule.

Historical precedents and possible implementation in the USA

Both historical precedents and an attempt to measure the impact of the MMT programme in the USA through public debt monetisation provide strong cautionary tales against such an approach.

According to Edwards (2019),

> Almost every one of the Latin American experiments with major central bank-financed fiscal expansions took place under populist regimes and all of them ended badly.... In most of these episodes..., policy makers used arguments similar to those made by MMTers to justify extensive use of money creation to finance very large increases in public expenditures (3).

Ocampo (2020) also mentions the case of Argentina under Peron (1946-1955) or Peronist regimes, particularly the years 1946-1948, 1973-1974, 2007, 2012 and 2020, and the one of Nazi Germany between 1937 and 1945.

Palley (2019a) evaluates that the full monetisation by the central bank of the increase in the public deficit caused by the implementation of the MMT programme in the

USA would imply a fiftyfold increase in the monetary base-to-GDP ratio relative to the 2018. He highlights that those money supply dynamics “would almost certainly trigger high inflation in both asset markets and goods markets, as well as causing significant inflationary and destabilizing exchange rate depreciation” (Palley, 2019a, 153).

Indeed, already in 1982, Sargent had studied the end of four big inflations (Austria, Hungary, Poland and Germany in the 1920s) showing that

> it was not simply the increasing quantity of central bank notes [in modern economies, reserves] that caused the hyperinflation…, it was the growth of fiat currency that was unbacked, or backed only by government bills, which there never was a prospect to retire through taxation (89).

A limitless “fiscal space”

Lerner’s (1943) Functional Finance Theory (FFT) builds on Knapp’s STM and on Keynesian theory, and has provided the fundamental building block for MMT’s fiscal doctrine. Lerner adds a radical fiscal doctrine, referred to as “functional” because it focuses on the macroeconomic outcome of fiscal policy rather than on its budgetary impact (Wray, 2018). Fiscal policy should be judged only by “the *results* of [its] actions on the economy and not by any established traditional doctrine about what is sound or unsound” (Lerner, 1943, 39). Lerner (1943) prescribes three principles to achieve full employment and price stability:

- public spending should be increased when aggregate demand is too low and taxes increased when aggregate demand is too high;
- public borrowing should be adjusted “in order to achieve the rate of interest which results in the more desirable level of investment” (41), i.e. the level conducive to full employment;
- the government should “print, hoard or destruct” (41) money as needed to carry out the first two principles.

Lerner sees no reason for assuming that the government must always be borrowing more money and increasing the national debt because the application of functional finance would maintain the proper level of total demand for current output and provide an automatic tendency for the budget to be balanced. Moreover, he sees “no danger for society” of a continually increasing national debt because debt “is not a burden on the nation in the same way as an individual’s debt to other individuals is a burden on the individual” (Lerner, 1943, 42-43).

However, Lerner acknowledges that FFT would be invalidated if government debt were foreign held or denominated in foreign currency. The level of debt would then be a constraint because the government would not be able to print money to service the debt. According to Lerner, FFT is only applicable to countries that can borrow long term in their own currency.

Fiscal policy and aggregate demand management

MMT’s fiscal policy doctrine builds on FFT’s dismissal of debt constraints on government borrowing (Mitchell, 2020). It also argues that a sovereign currency issuer (i.e. with debts denominated in its own currency and a floating exchange rate) is financially unconstrained, rejects the “orthodox” notion of fiscal sustainability and adopts a very specific conception of “fiscal space”. Within this approach, when the economy is at full capacity, the emergence of inflationary risks can be controlled through a tax increase. Tax adjustments serve to control aggregate demand, not to finance the fiscal deficit, because whenever the government spends, money is created (as mentioned above, MMT confuses money with the monetary base, i.e. currency and reserves). Following the same line of reasoning, bond sales are not viewed by MMT as financing operations. As indicated above, bond sales are considered as interest rate management in which the issuance of government debt, weighing on bank liquidity, increases interest rates as if the central bank were not neutralising these effects, precisely in order to make its monetary policy stance prevail.

MMT rejects the orthodox loanable funds theory, deemed irrelevant for understanding the inflationary risk attached to fiscal expansion. The crowding out effect on private spending does not exist in MMT because an expansionary fiscal policy is supposed to lower interest rates by providing liquidity to banks rather than raising them by crowding out the private demand for debt financing. Therefore, interest rates do not reflect the size of the current or expected future levels of deficits and debt as posited by the loanable fund theory (Fullwiler, 2007).

The conclusions drawn by MMT are overstated:

- Even a temporary monetised fiscal stimulus could trigger expectations, especially from the government, that a one-time use could easily become permanent. In turn, a permanent recourse to monetary issuance would lead to a flight from currency and to hyperinflation.

- MMT's claim that government spending is only constrained by the "inflationary" ceiling, which binds when all productive resources are fully employed (Mitchell, 2020), is incomplete. MMT does not address the opportunity costs and distributional consequences of the monetisation of deficits by the central bank, e.g. its impact on asset prices, that may affect both the demand and the supply side of the economy and therefore the inflation constraint, even before full employment is reached.

- MMT argues that the normal interest rate for government debt should be very low or even zero. This assumption begs the question of the plausibility of interest rates permanently below the growth rate of the economy.

- A government deficit may lead to an increase in longer-term interest rates (Lavoie, 2019; Palley, 2019b) if financial markets expect high future inflation well before full employment has been reached. If the debt is not willingly absorbed by the market, the recourse by the government to financial repression would not prevent interest rates rising in private credit markets with adverse consequences in terms of monetary and financial stability.

- The assumption that a sovereign currency issuer will not default on a debt issued in its currency because the central bank can always print the money needed to service and repay this debt is overstated (Buiter and Mann, 2019; Ocampo, 2020; Palley, 2019b).

MMTers believe that fiscal policy is much more effective than monetary policy at managing aggregate demand. Therefore, fiscal policy should be adjusted when necessary to maintain full employment and moderate inflation while monetary policy should passively support the financing of the fiscal deficit by printing money and keeping interest rates at very low, near-zero levels.

A major criticism that can be addressed to MMT is that its proponents are unable to prove their claims given the lack of formal modelling. In line with this criticism, the following appraisal reviews MMT's key assumptions on inflation, monetary policy, fiscal policy and their (lack of) feedback.

According to Palley (2019b), MMT is especially dismissive of the problem of inflation and lacks a doctrine. For instance, Wray (2019) writes: "Fortunately – or unfortunately depending on one's view – modern economies usually operate with sufficient slack that even large boosts to aggregate demand are not likely to put much pressure on wages and prices. Our critics continue to fight an inflation battle that was won almost two generations ago" (7).

As regards monetary policy's role in managing aggregate demand, MMT's discarding of interest rates as a tool of stabilisation policy is problematic. First, Tymoigne and Wray (2013) posit that the "sensitivity" of aggregate demand to interest rates is low. As interest rates are seen as affecting the cost of borrowing, which influences costs of production and prices, low interest rates may lead to lower inflation; however, such a cost-push argument is purely short term in nature. Second, discarding interest rates as a stabilisation tool would create political economy and instrument shortage problems (Palley, 2019b). From a political economy point of view, monetary policy is the preferred instrument to manage aggregate demand because fiscal policy is difficult to use to stabilise the business cycle. In addition, the loss of an instrument would compound the difficulty for a policymaker to achieve her policy targets. Third, MMT's prescription to keep nominal interest rates at a very low, near-zero level would also foster macroeconomic instability, with, during the upward phase of the cycle, real rates falling and potentially causing higher inflation, which would in turn lower real interest rates.

Structural policies focused on full employment in the USA

In MMT's view, full employment would be achieved through a government job creation programme, which would act as an automatic stabiliser, and by large-scale spending on infrastructure, climate adaptation and the environment, i.e. the "Green New Deal", which would employ workers in the job creation programme.

The Public Service Employment Programme and the Green New Deal

MMT believes that a modern capitalist economy, which is inherently instable, will fail to produce and maintain "true" full employment; involuntary unemployment is a persistent characteristic of such economies (Fullwiler, 2007; Tcherneva, 2012; Haim, 2021). Therefore, MMT advocates for the implementation of a US public job creation programme funded by the federal government, called the Public Service Employment (PSE) programme (Wray et al., 2018). The PSE programme is a job guarantee programme

> that provides employment to all who need work by drawing from the pool of the otherwise unemployed

> during recessions and shrinking as private sector employment recovers.…[T]he PSE programme would pay a wage (whose level would be gradually incremented to reach $15 per hour in 2022) for full- and part-time positions and offer benefits that include health insurance and childcare. In addition to guaranteeing access to work on projects that serve a public purpose, the PSE programme establishes effective minimum standards for wages and benefits (Wray et al., 2018, 1).

The programme would not aim at competing directly with private sector employment: Jobs created would provide public services in non-profit community organisations, public schools, and state and local governments.

According to MMT economists, the implementation of PSE would bring many benefits (Tcherneva, 2012; Wray et al., 2018; Ehnts and Höfgen, 2019). It would stabilise economic activity and household incomes. The government's budget would also move in a countercyclical manner as spending on the programme would fluctuate with the cycle, which would further help to smooth cyclical fluctuations. Moreover, the PSE programme would provide a price and wage anchor.

The Green New Deal (GND), a resolution introduced by US Congresswoman Ocasio-Cortez and Senator Markey, is a comprehensive programme calling for an economic mobilisation in the USA at a scale not seen since the New Deal era. Its chief aims are to radically decarbonise the US economy with a set of policies combining public investment by 2030 while significantly reducing economic inequality. The goal of creating "millions of good, high-wage jobs and ensure prosperity for all" would be achieved through a job guarantee, a central component of the GND (Galvin and Healy, 2020).

A central role but an uncertain success

Palley (2019b) notes that the government job creation programme is much more central for MMT than would seem at first glance, because fiscal policy, as envisaged by MMT, would have trouble fine-tuning the economy. Therefore, the PSE would function as a counter-cyclical automatic stabiliser, delivering productive non-inflationary full employment. However, the success of such a programme rests on a number of conditions (Buiter and Mann, 2019) that may not all be met. In particular, the authorities must manage a permanent inventory of productive, meaningful jobs and job openings, ready to be filled at short notice in the public sector. By contrast, public sector employment in activities that add little economic value or maintenance of skills at a guaranteed wage would simply be equivalent to unemployment benefits in disguise. The PSE may have other drawbacks, such as the displacement of private sector production if workers prefer better paid or less intensive PSE jobs. Moreover, the fact that the PSE sets the effective minimum wage floor for the entire economy may have inflationary consequences and cause job losses in other parts of the economy. Finally, the GND and the PSE nevertheless reflect MMT's view that government intervention is more desirable and sustainable than private sector action in responding to climate change.

A US-centric open-economy analysis

Bonizzi et al. (2019, 47) note that "MMT analysis of open economy issues, particularly those faced by developing and emerging countries, is relatively scant." Indeed, most of MMT's analyses rely on a closed economy assumption (Ocampo, 2019). When they do not, they appear as US-centric and closely aligned with long-standing US government official views. For example, Kelton (2019) writes, "America's trade deficits are not optional. Much of the world simply *must* run trade surpluses with America" (143). MMT views current account deficits as a reflection of foreign demand for financial assets, rather than as the result of domestic consumption and investment exceeding productive capacity. The underlying assumption – that the liabilities associated with current account deficits are denominated in the currency of the deficit nation – does not match the reality of the majority of the international trading and financial systems (Bonizzi et al., 2019), except for the US and a few other major reserve currency issuing economies.

MMT's framework is presented by its exponents as applicable to all sovereign currency issuers. Even developing and emerging countries are urged to adopt its prescriptions, as if external constraints on policy and development, driving them to choose an exchange rate peg or to borrow abroad in a foreign currency, were self-imposed and did not reflect limited macroeconomic policy autonomy. However, Bonizzi et al. (2019) consider that the criteria identified by MMT are insufficient to achieve policy autonomy and that "[a]dvocating deficit monetisation under conditions of sustained current account deficits, exchange rate volatility and potential capital flight is at best misguided and at worst irresponsible" (58). In turn, Epstein (2019) considers that "MMT policy is relevant, at best, to only a few countries: those with significant international currencies" (8). Perhaps as a result of these critical remarks, Kelton (2020) advises developing and emerging economies to sign South-South trade agreements and put in place capital controls to gain "monetary sovereignty" (155). However, such measures are likely to

Table 1
What MMT deems wrong and right

	Wrong	Right
Explicitly		
Government expenditure is financed by…	taxes	issuing currency
Public debt sustainability…	can be an issue	cannot be an issue
Public bonds are issued…	to finance the public deficit	to distribute income as part of an interest rate maintenance strategy
Access of government to central bank financing…	should be limited	is unlimited
Public debt purchased by the central bank…	should be paid off	is paid off
Crowding out…	can be an issue	cannot be an issue
Monetary policy…	has a role to play to stabilise the economy	has no role to play to stabilise the economy
Interest rates…	are a market variable	are set by the government
Inflation…	is a monetary policy issue	is a fiscal policy issue
Unemployment…	cannot be fully eliminated	can be fully eliminated
Conventional structural policies…	are positive	are negative
A sovereign economy…	should be competitive	does not have to be competitive
Skills…	are important determinants of income	are loosely linked to income
Social welfare…	has a cost	has no cost
Implicitly		
Currency…	is both an asset and a liability	is an asset “manufactured” *ad libitum* by the state
Currency competition…	exists	does not exist
Incentives and expectations…	play an major role in economic dynamics	play a minor role in economic dynamics
Competition in the goods and services markets…	exists and is useful	can be ignored
Climate change…	can be addressed primarily by setting a social price of carbon	necessitates primarily public investment

Source: Authors’ own elaboration.

hamper the building of the “deep capital markets” that she deems necessary – and rightly so – to develop a demand for their currencies (144) and thus gain “monetary sovereignty”.

Conclusion

Table 1 summarises the main contrasts between MMT’s approach and mainstream economics.

Such a stark contrast with mainstream economics analysis and recommendations would be understandable if MMT economists engaged in a debate with their colleagues to explain and justify their positions from both a theoretical and empirical point of view. However, their academic publications are repetitive and lacking in empirical analysis, which does not allow for the verification of their assertions or the comparison with the recommendations of other schools of thought. As Hartley (2020) notes, MMT “is not a falsifiable scientific theory: it is rather a political and moral statement by those who believe in the righteousness – and affordability – of unlimited government spending to achieve progressive ends”. Its meaning is more that of a political manifesto than of a genuine economic theory.

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The Loss of Raw Material Criticality: Implications of the Collapse of Saudi Arabian Oil Exports

Raw material criticality has played an important role in geostrategic thinking, especially since the crisis surrounding the price and supply of rare earths at the beginning of the 2010s. However, once dependency and strategic importance grow too strong, substitution efforts will take place that could reduce or even eradicate the previous criticality. Critical resources rarely become obsolete very quickly. However, this could happen in the case of crude oil because climate policy is forcing defossilisation, but also because artificial scarcity is falling as a result of geostrategic rivalries that are causing oversupply. This article analyses this process and the possible consequences using Saudi Arabia as an example. The development of a green hydrogen industry has potential, but it should not be overestimated in view of the absorption capacity of the economy.

The two oil price crises in the 1970s as well as skyrocketing prices of rare earths ten years ago have revealed the dependence of the developed world on certain critical raw materials. When geostrategic aspects are added (especially those relating to national security), scarcity at the business level results in a vulnerability at the national level. Counter-strategies may include hoarding or, due to recent societal pressure for increased sustainability, a more intelligent design of materials, products or deconstruction possibilities that enable efficient recycling. Finally, substitution strategies may be considered for materials (copper against glass fibre in landline communication), technologies (movies against TV) or goods (personal visits against web conferences). These could turn critical resources into non-critical ones.[1]

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Resource-rich countries, overwhelmed by income from resource sales, have three options that are listed here in decreasing order of economic efficiency: (i) forced investment strategies that use income for modernising the economy in an attempt to prepare the country for a period in which income from resources falls, but which may overstress the adaptation capacities of societies; (ii) investment in funds in preparation for periods of declining sales; (iii) domestic use, which in most cases overstresses the absorption capacities of national economies and leads to price hikes in local goods, endogenous deindustrialisation and a revaluation of the currency, thus reducing national competitiveness. This follows transfer theory (Samuelson, 1964; Balassa, 1964) and is the basis of what is called the resource curse (Auty and Mikesell, 1993).[2]

The three strategies often appear as hybrids; however, dominant characteristics can be identified. For example, Shah Reza Pahlavi applied the first strategy in the 1960s and 1970s when trying to propel Iran into modernity.

1 For a survey, see Blum and Wehrspohn (2021).
2 Five hypotheses widely accepted in the resource curse literature explain how natural resource endowment might impede economic development (Frankel, 2012): high volatility of the commodity price; the crowding-out of manufacturing sectors by the natural resource sector; the tendency to develop an autocratic and oligarchic institution; the tendency to develop an anarchic institution; and the appreciation of local currency.

This failed because of inner opposition but left the mullahs with a formidable industry structure. Today, Norway commands one of the world's largest investment funds. The Netherlands, on the other hand, spent gas income on domestic programmes that led to price hikes followed by wage increases in the non-tradable sector that subsequently spilled over into manufacturing. The loss of competitiveness drove the rail, car and aircraft industries out of the markets. It is known as the Dutch disease or the East German disease because of the similar effects of the stabilisation transfers from West Germany after unification (Blum, 2008).

It is clear that the loss of criticality will hit a type iii country hardest, and even if type ii funds are available, they may be syphoned off. Moreover, this may completely reverse financial flows in large countries and have a devastating effect on international financial stability.

Oil has been a critical resource for a long time; however, this is beginning to change. We use the Kingdom of Saudi Arabia, a major oil producer, as a reference. The country is in danger of economic collapse if oil prices suddenly fall – which is not beyond the realm of possibility.

The remainder of the article is organised as follows: In the next section, we analyse the roots of crises from a resource perspective. Using oil as an example, we point to the problem of managing financial inflows efficiently and to the impact of geostrategic rivalry. We then concentrate on two major factors that have led to a regime change in the balance between global oil production and consumption: fracking and defossilisation.[3] We subsequently apply this to Saudi Arabia and point to the medium- to long-term challenges for global stability given this regime change. Finally, we conclude that a substantial turnaround in investment management is required of (Middle Eastern) oil-producing countries to guarantee global stability.

Geostrategic environment, criticality and crisis

Cheap oil has promoted the rapid industrialisation of the Western world and benefited oil-exporting countries by providing a sufficient influx of oil money, especially to those that joined forces and co-founded the Organization of the Petroleum Exporting Countries (OPEC) to set oil prices.[4] Many of these oil-rich countries have achieved oil-driven economic growth and joined the group of middle- and high-income countries.

Oil has been a critical energy resource since the 19th century. In 2018, crude oil made up 33% of the world's annual primary energy consumption (BP Energy, 2020). Since its wide industrial use from the late 19th century onwards, partly due to Rockefeller's efforts to monopolise the oil market and then the antitrust-led breakup of the Standard Oil Company, global oil consumption and production have been steadily increasing. In the 21st century, soaring demand in emerging economies has compensated for the stagnating oil demand from the developed world.

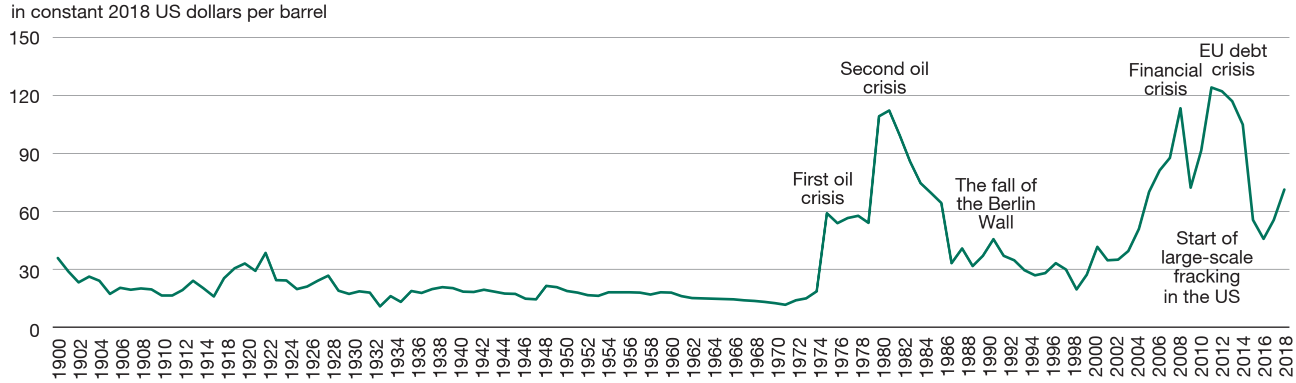
Today, oil still has a relatively low degree of substitution, particularly with respect to technology (transport sector, chemicals) and transport (large tankers, pipelines). This guarantees a stable demand despite volatile prices. Empirical studies support the relatively low price elasticity of the global oil demand, especially in the short run (Cooper, 2003; Caldara et al., 2016). Due to its low substitutability and the oligopolistic market structure, oil has provided its suppliers with a steady stream of revenues.

Having experienced an ever-increasing demand for fossil fuel, the second half of the 20th century was besieged by the economic threat of "peak oil". However, this concern about a negative supply shock has now mainly shifted to "peak demand". According to recent predictions, oil's dominance, and therefore criticality, will decrease rapidly in the coming 30 years. The main driver of this profound shift in mindset is environmental concerns about greenhouse gas emissions. In addition, fracking turned the US from an importer to an exporter of oil and gas. This has not only put pressure on prices, it decoupled the US strategically from the Middle East as a military safeguard of global oil supplies. In response, Saudi Arabia launched an oil price offensive, trying to drive the US fracturing industry from the market and indirectly hitting its biggest regional rival, Iran, in its strategy to modernise its industries. In fact, Saudi Arabia had switched from swing pricing, which tries to equilibrate oil prices to levels that satisfy both producers and consumers, to limit pricing.

3 We prefer to speak of defossilisation instead of decarbonisation because the principal momentum must be to limit the emission of fossil carbon.

4 The OPEC cartel was at the centre of a veritable economic war in the 1960s. It was founded in 1960 to achieve a lasting monopolistic position. During the Yom Kippur War, there was a supply boycott against the Western states to support the Arab states' attack on Israel. It has lost a considerable degree of influence through resignations and an increasing supply by many unaffiliated countries and the support of the Saudi regime by the United States, which tried to moderate prices for a long time.

Figure 1
Development of crude oil prices, 1900-2018



Notes: 1900-1944: US average; 1945-1983: the posted price of Saudi Arabian Oil F.O.B Ras Tanura; 1984-2010: Dated Brent.

Source: Authors' own illustration based on Nasdaq Data Link Crude, oil price from 1981, 2021.

Figure 1 shows the oil price development from 1970 to 2018. One of the first slumps started in the years before the Berlin Wall came down. It accelerated the breakup of the Soviet Union, leaving the US as the sole superpower.[5] In the summer of 2015, the Iranian nuclear treaty drove up the global crude oil supply, which, after 30 years of boycotts and sanctions, opened up Iran's access to the world market. Later, the US withdrawal from this treaty in 2018 again led to tensions on global oil markets; in addition, the US extraterritorial enforcement of sanctions on trading partners has also put pressure on the global economy.

The apparent oil price conflict described above is not only a multipolar economic war (Blum, 2020), it is also a hybrid military war in which economic rivalry serves as an essential and embedded driver. US fracking has not only reduced the scarcity on the international oil market, it has also reminded the traditional supplier countries of the finiteness of their competitive position, something which defossilisation is further eroding. Gundersen (2020), for instance, calculates that the US import shock, reflecting its domestic shale oil supply shock, accounts for 13% of the global oil price variation from 2003 to 2015, while OPEC explains about 17% of this variation. Saudi limit pricing led to a technology drive that more than halved initial fracking costs from over US $80 per barrel to about US $30 per barrel.

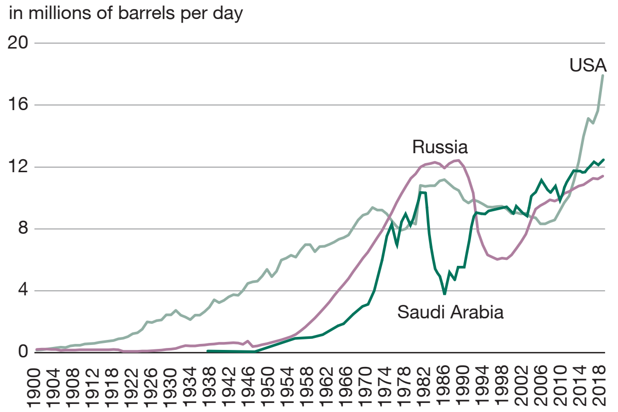
5 Studies supporting the resource curse include Sachs and Warner (1995), Collier and Goderis (2008), Sala-i-Martin and Subramanian (2013), and Dartey-Baah et al. (2012). Studies rejecting the resource curse include Stijns (2005), Brunnschweiler and Bulte (2008), Alexeev and Conrad (2011), Michaels (2011), James (2015). Welcome institutional reforms could, in fact, help turn the resource curse into a resource blessing (Humphreys et al., 2007).

Defossilisation and oil's path towards non-criticality

Since the 19th century, the temperature of the Earth has risen by 1.14 degrees Celsius, resulting in observable negative impacts on its ecosystems. Climatologists today can identify a highly likely (95%) causality between human activity and global warming (IPCC, 2014). If carbon dioxid net emissions do not decrease, further warming will cause irreversible damage to the environment. Compared to all anthropogenic greenhouse gas sources, fossil fuel combustion and industrial processes accounted for about 78% of total emissions from 1970 to 2010 (IPCC, 2014). Therefore, the necessity of limiting global warming through defossilisation gained political and social acceptance and led to the 2016 Paris Agreement. Its ultimate goal is to keep the rise in global temperatures in this century to well below two degrees Celsius above the pre-industrial level or even below 1.5 degrees Celsius. To meet this goal, the entire world must achieve zero net carbon emissions by around 2065, with the odds of reaching the target exceeding 66% (Rogelj et al., 2015). Recently, the German Constitutional Court ruled that government implementation programmes must reflect the environmental positions of younger generations, thus pressing for more realistic reduction plans (BVerfG, 2021). A district court in The Hague ruled that Shell must drastically cut its greenhouse gas emissions because international climate agreements are also binding to enterprises. All of this will put additional pressure on oil prices.

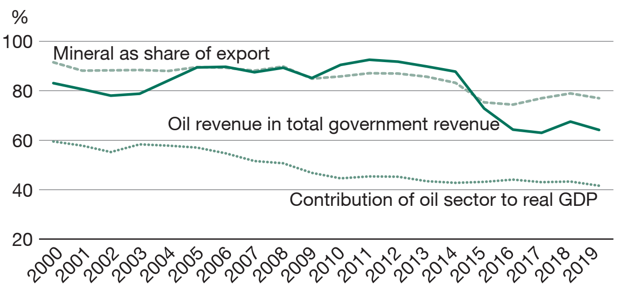
From another angle, the projected expansion of renewables mirrors a potentially sharp reduction in the market share of oil. During 2018 and 2020, renewable energy production grew at an annual rate of 6%. If the climate targets are met by 2050, the share of renewables in primary en-

Figure 2
Production of gasoline and other liquid derivatives



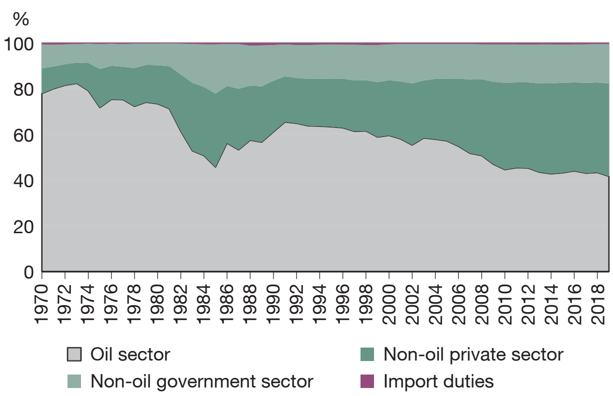
Sources: Etemadd & Luciani (1900-1980) and US EIA Historical Statistics (1981-2018), own illustration.

Figure 3
Saudi Arabia's oil vulnerability, 2000-2019



Source: Saudi Arabian Monetary Authority, own illustration.

Figure 4
Saudi Arabia's GDP by sector, 1970-2018



Source: Saudi Arabian Monetary Authority, own illustration.

ergy would increase from 4.7% to a value between 44.3% and 59.2% according to BP's Energy Outlook (2020). It further forecasts a 55% and 80% fall in oil demand in two intense decarbonisation scenarios, meeting the target of two and 1.5 degrees Celsius, respectively.[6] The report also conjectured that oil demand peaked already in 2018; henceforth, global oil demand would trend downward. Following the World Energy Outlook (IEA, 2020), its "net zero emissions by 2050" would lead to a fall in the present value of the world's oil sector by almost 50% by 2040 compared to 2019, and pre-COVID-19 consumption patterns would not be reached before 2023. Shocks may drive up the price, e.g. as OPEC+ chooses to curb supply or the Houthis attack Saudi facilities. However, for many oil-producing countries, oil prices may just oscillate around their fiscal breakeven oil prices (IMF, 2020).

Vulnerability and the Saudi Arabia's position

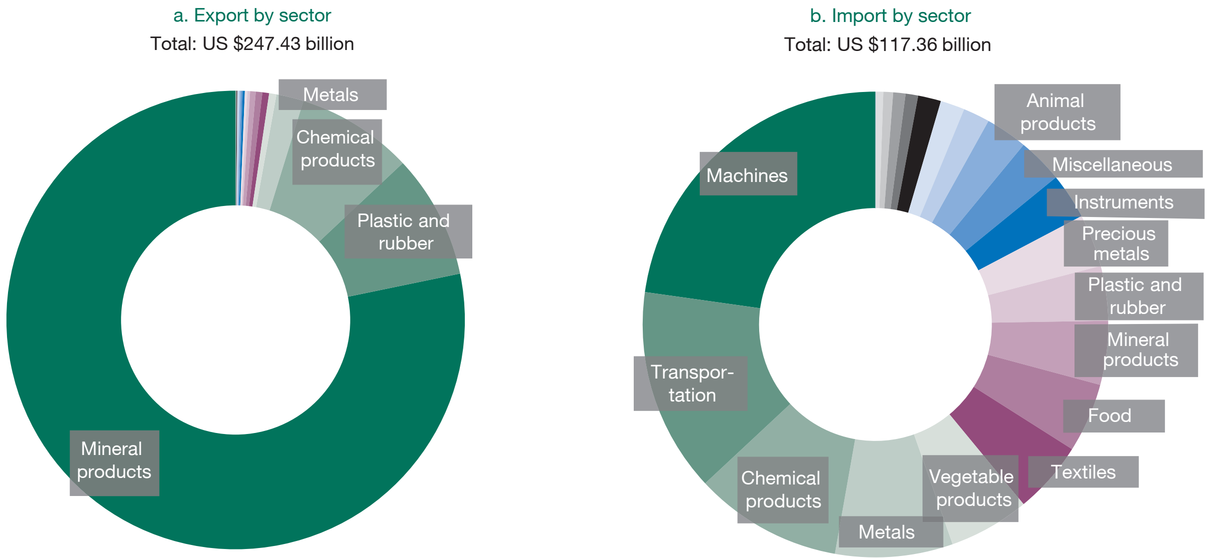
Saudi Arabia is typical of a country that has earned its national wealth from crude oil reserves. In the first decade of the new millennium, Saudi Arabia was the number one global oil supplier. Later, the United States overtook it and Russia with its fracking revolution. This is depicted in Figure 2. As a result, despite the absolute increase in its oil production, Saudi Arabia witnessed a shrinkage of its global oil share.

Saudi Arabia's oil revenues are substantial relative to its economic size, as different indicators in Figure 3 document. In the first two decades of the 21st century, the oil sector accounted for around 40% of Saudi Arabia's total GDP and contributed to about three-quarters of its governmental revenues. In 2019, oil revenues made up about 64.1% of its government's annual revenues, and the oil sector contributed over 40% to Saudi Arabia's real GDP. As a relatively small economy with little industrial diversification, Saudi Arabia has to sell most of its oil reserves to the rest of the world and is therefore intensively engaged in the oil trade. In the new millennium, Saudi Arabia's export-to-GDP ratio has averaged about 40%, 85% of which are mineral exports.

The high importance of oil in the composition of Saudi Arabia's GDP is also depicted in Figure 4. It shows the enduring problem of phasing out oil dependency, which is difficult because oil plays a major in fiscal stability. The IMF estimates that Saudi Arabia's external and fiscal breakeven oil prices in 2020 are US $45.3 and US $66 per barrel, respectively. Given the long-term price pro-

6 In absolute terms, oil consumption would decrease from 190 EJ to about 89 EJ and 42 EJ in the two scenarios.

Figure 5
Specialisation pattern of Saudi Arabia, 2018



Source: Simoes et al. (2011), own illustration.

jections, a depletion of Saudi Arabia's investment funds starts to become a reality.

Figure 5 shows Saudi Arabia's import and export structures in 2018 and is proof of an oil and oil-derivative dependent industry structure that finances a highly diversified import basket. In brief, Saudi Arabia is a highly specialised Ricardian country that thrives on its comparative advantage: oil. It exports resources in exchange for products that are knowledge, capital and labour intensive. Intra-industry trade, which is often observed in countries actively participating in global value chains (GVCs), is less discernible.

By producing first blue and later green hydrogen, Saudi Arabia could try to set up a new pillar for exports and use crude oil only as a material base for carbon-based products, e.g. plastics. Over and above the limitations already apparent in the export portfolio of oil-derivative commodities (Figure 5a), limits may emerge from the ability to absorb the necessary investments and geostrategic reliability. In fact, assuming a price of about US $1.5 per kg, exports would have to amount to some 128.67 billion kg.[7] More is needed if other specialised products should replace present exports like rubber or basic chemicals, such as ammonia. Investments in the necessary hydrogen production facility would amount to US $1,400 billion.

7 The data used here are taken from Dii Desert Energy and Roland Berger (2021), Fasihi and Breyer (2019), PwC (2021), Yates et al. (2021).

At least another US $400 billion should be added for the other third of export production, i.e. green steal, ammonia (as currently planned) or other chemicals. Over a period of 20 years, this would imply annual capital expenditures of some US $90 billion. They should be larger in the early years, i.e. the 2020s, and decline later. As Saudi Arabia would not be able to produce the necessary investment goods and supply the necessary labour, the current account balance would come under stress unless most of the investments are FDI financed. If historic budget surpluses and, thus, investment into overseas funds are reversed, the resulting impact on financial stability and on exports from manufacturing countries could have the potential to trigger a crisis.

Saudi Arabia's position in the global value chain

Intra-industry trade is one of the newly discovered stylised facts in the international trade pattern, particularly after the 1980s. It contradicts the premises of traditional trade theory (Inomata and Taglioni, 2019). In contrast to the Ricardian Saudi Arabia, the world economy has evolved into a brand new stage of global production fragmentation. This has allowed many economies, especially in Asia, to escape the poverty trap and develop a broad industry base – unlike Saudi Arabia.

A cross-country GVC analysis allows us to locate Saudi Arabia in the global production network and calculate the forward and backward production length of Saudi Arabia and other selected countries based on the methodology of Wang et al. (2017) and the OECD Inter-Country Input-Output (ICIO) data. We use the ratio of the forward and backward production length index to calculate Saudi Arabia's relative position in global value chains for 2005 and 2014 and show the dynamics.

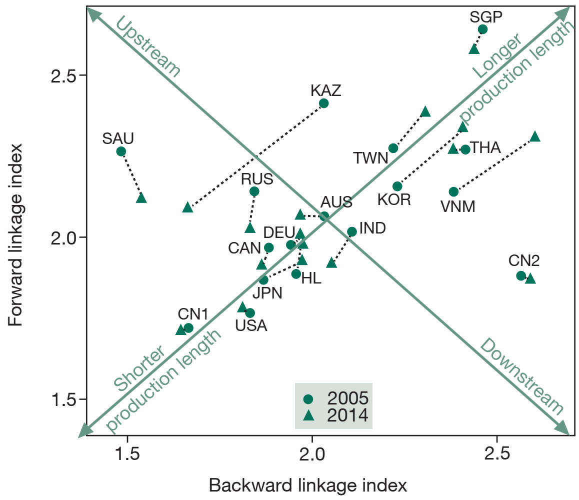
Figure 6 demonstrates the results. The x-axis and y-axis represent backward and forward production lengths, respectively. In this representation, the dots in the bottom left corner represent countries with the shortest average production chain lengths; as a dot moves towards the upper right, the total production chain it represents gets longer. From the other angle, dots in the bottom right represent countries positioned further downstream in the GVCs, with short forward linkages and long backward linkages. As a dot moves towards the upper left, the country it represents moves forward along the GVCs. This way of mapping forward and backward linkage length and GVC position is credited to Escaith and Inomata (2016).

As Figure 6 suggests, Saudi Arabia has an overall short GVC length and is positioned at the very upstream end. In 2014, its average forward and backward indices were 2.11 and 1.54. In the same year, the world's forward and backward indices are equal at 2.02. A shorter production chain length demonstrates less vertical specialisation on the sector level in the first approximation, indicating less industrial network complexity. Usually, the phenomenon of an increasing complexity of the production network accompanies industrial development. In this sense, the lower index can be explained by Saudi Arabia's weak industrial base, as its industrial complexity lies below the world average. When comparing 2014 to 2005, Saudi Arabia's total production length has dropped from 3.74 to 3.65, whereas the world average has increased from 3.90 to 4.04. Therefore, while the world has averaged a deeper vertical specialisation, Saudi Arabia has moved against this trend. In terms of its GVC position, Saudi Arabia is positioned far upstream, with no remarkable change from 2005 to 2014. This slight change corroborates the country's slow progress in shifting away from oil to a more industrialised economy.

In stark contrast, Asian countries, hotspots for global investment in recent decades, gather in the upper right quadrant. They share the common features of relatively long production chain lengths and a downstream GVC location. Due to the resource curse described above, Saudi Arabia's relatively high labour costs factor into its limited GVC participation. Without a substantial increase in labour productivity or a declining exchange rate, it is difficult for Saudi Arabia to compete for FDI against emerging economies with more favourable labour costs.

Figure 6

GVC analysis of Saudi Arabia and selected countries



Note: Data are presented for 64 countries (i.e. 36 OECD countries and 28 non-OECD economies), the rest of the world, and split tables for China and Mexico. Data on Mexico and China are split into MX1, MX2, and CN1, CN2, respectively. CN1 represents China's activities, excluding export processing; and CN2 represents its export processing activities. In the same vein, MX1 and MX2 represent Mexico's activities (excluding export processing) and its export processing activities, respectively.

Source: Authors' own calculations.

Investments in a hydrogen economy would most likely not change this basic pattern of international labour division.

Dutch disease as a factor in limiting Saudi Arabia's economic growth

Oil revenues have had an overall positive impact on Saudi Arabia's real GDP per capita (Alkhathlan, 2013). Anser et al. (2020) also conclude that Saudi Arabia's oil rent looked in fact like a "resource blessing". The reason is that, given its small population, the Kingdom has sufficient opportunities to successfully invest in industrialisation for the benefit of its entire population. From 1990 to 2014, Saudi Arabia experienced a year-on-year average growth rate of 9.35% on its industrialisation intensity index. However, its industrialisation process still lags behind emerging East Asian countries such as Vietnam, Indonesia and Thailand (UNIDO, 2020).

However, Dutch disease selectively hit Saudi Arabia after the oil boom (Looney, 1990; Parvin and Dezhbakhsh, 1988; Ahmad Bajwa et al., 2019). The Saudi riyal's real effective exchange rate remained appreciated for most of the 1970s. This made exporting expensive and importing cheap (Looney, 1990; Ahmad Bajwa et al., 2019), reduced industrial output, especially in major non-oil sectors

(Looney, 1990), increased local labour costs and impeded industrialisation. As a result, migrant workers constituted over two-thirds of the country's total labour market from 2005 to 2015. An investment bonanza into first blue and later green hydrogen in competition with other countries may, given the above-mentioned composition of the economy, overburden the absorptive capacity. We may take the transformation of East Germany as a reference case, as in both cases, a new economy had or has to be (re-)capitalised.[8] Compared to Saudi Arabia, it had 50% of the population and 60% of employment. Annual investments averaged 60 billion euros in the 1990s (30% plant and equipment, 50% housing, 20% infrastructure) and led to severe absorption problems. Assuming that, over and above the industrial investments, Saudi Arabia would also need investments into housing and infrastructure, severe macroeconomic adaptation problems will surely arise – from a revaluation of the currency to price hikes for local goods and the destruction of existing industries.

Countries with relatively weak industrial bases could in fact improve their productivity, know-how and export diversification by participating in the GVCs (Kowalski et al., 2015). However, the Dutch disease might have deprived the Saudis of their opportunity to adopt such an economic development strategy.

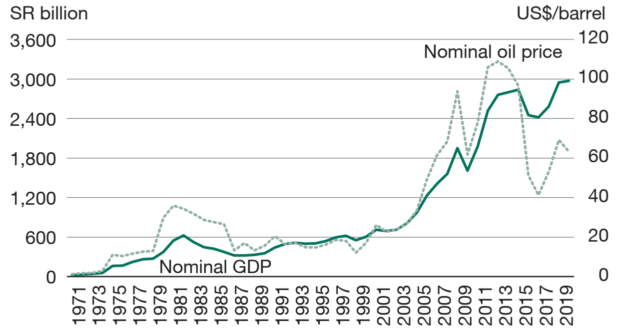
Challenges facing Saudi Arabia's economic transformation

Against the backdrop of the phasing out of oil, the Kingdom must decouple its economy from the potential downside risk of oil prices. In 2016, it adopted the most rigorous transformation strategy since the 1970s, the Saudi Vision 2030 (2016), aiming to invest in a more diversified and industrialised economy and ending its oil dependency before fading oil revenues exhaust its ability to finance domestic projects in the industrial, mining, energy and logistics sectors.

However, Vision 2030 faces political and economic challenges for rent-seeking reasons, especially interlocking interests and institutions opposing a decoupling from oil. Even if the recent oil price slump reduced such dissenting voices, they would always come back as soon as the oil price recovers and obstruct the transition (Moshashai et al., 2020). Figure 7 shows the dependency of the Saudi Arabia's GDP on oil. Oil prices have impacted the Iranian revolution, the Iran-Iraq war, the Gulf Wars and the global financial crisis of 2009. The oil price shocks in 2014 and now the COVID-19 pandemic have significantly hurt Saudi Arabia's real economy (Jawadi and Ftiti, 2019). According

Figure 7

Saudi Arabia's GDP and oil prices, 1970-2019



Sources: SAMA; and World Bank Commodity Price Data, own illustration.

to the IMF's estimation, the Saudi government's budget deficit for 2020 is estimated to be 12% of its GDP.

Furthermore, to finance the Saudi Vision 2030, the government announced a doubling down on oil production before the resource becomes valueless. Such a policy is in line with the green paradox hypothesis because the future lack of demand would generate even worse revenues (Sinn, 2008a; 2008b). However, overwhelming oil revenues are likely to come with the risk of being infected by the Dutch disease, which might jeopardise Saudi Arabia's diversification efforts and leave the Kingdom with an even stronger dependency on oil.

Several empirical studies have confirmed the close nexus of oil prices and Saudi Arabia's real economy. Algahtani (2016) uses VAR and VECM models to verify a significant and positive long-run relationship between oil prices and Saudi Arabia's GDP between 1970 and 2015. Aloui et al. (2018) use wavelet methodology to demonstrate strong but non-homogenous linkages between oil prices, riyal/US dollar exchange rates and real GDP. Jawadi and Ftiti (2019) identify nonlinearities and threshold effects. By regressing GDP and government revenues (per capita) to the oil price, Vandyck et al. (2018) estimate that the elasticities of the GDP and government revenues with respect to oil prices are 0.5 and 0.9, respectively. Using the estimation by Vandyck et al. (2018), a 30% fall in oil prices would cause Saudi GDP to contract by 15%, other things being equal. This rough calculation illuminates the vulnerability of the Saudi economy. And the prospects are bleak: Although financial reserves are high, financial markets have started to punish the country for its industry structure and oil dependency, which became visible when the IPO of Saudi-Aramco failed. Only a wise, import-led investment strategy into one's own diversified economic base could mitigate or even reverse such a trend and raise productivity (Adam and Bevan, 2006). Furthermore,

8 Data is taken from Blum et al. (2009a) and Blum et al. (2009b).

such a strategy might overcome the highly probable risk of a J-curve effect if a strong devaluation occurs as a result of an oil price crisis.

Policy outlook

A stabilisation strategy for the Saudi economy would have to harmonise the expected depletion of oil income, create the necessity to diversify its economy in time, and exploit locational advantages and new technologies in order to guarantee long-term competitiveness. From a global perspective, such a strategy should aim at stabilising, not disrupting world financial flows.

A future may emerge from the hydrogen economy: A transition path could start with blue (fossil-based) hydrogen and switch to green hydrogen based on solar and wind power alongside the development of a new "carbon culture". One principal export good would be hydrogen or methane, encompassing all the high-end research and industry functions that go with it and a "jump" into a new innovation cycle.[9] However, the required investments must be accelerated in order to offset possible declines in oil demand, which may run against efficiency and effectiveness and may be delayed by counter-effects through limits of economic absorption.

The same logic could apply to other oil-dependent countries with similar economic structures. In this case, the decriticalisation of oil would be as catastrophic for other oil-dependent regions as it would be for Saudi Arabia. The collapse of the exchange rate and currencies, such as the Saudi riyal, and the contamination of other oil-exporting countries' currencies might eventually threaten the stability of the highly interconnected global financial system.

9 In the case of Germany, the phasing out of atomic and coal energy may result in blackouts as the necessary electrification of the economy lags behind. To supply the Bavarian industry, the power link currently being built across the Bavarian border to Thuringia would have to be quadrupled, which is politically unfeasible. However, the existing gas grid and the newly built hydrogen grid could be perfect substitutes to supply existing or newly constructed, decentralised power plants.

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America's Polarized Politics of Climate Change

Winston Churchill described the Soviet Union and its actions toward Germany at the beginning of WWII as "A riddle wrapped in a mystery inside an enigma." The same might be said of the United States' actions concerning climate change (among other issues). To understand whether Americans view the outcomes of the Glasgow Climate Change Conference as successes or failures, it is important to remember how divided the American population is politically. Every issue is rapidly politicized. Almost 800,000 people have now died of COVID-19 in America. In the early months of the pandemic, Republicans saw a political advantage in a slow response because the virus was mostly affecting states that were predominantly Democratic. Now, the anti-vaccine movement largely follows party lines: Maps of vaccination rates resemble voting patterns, with Biden-voting counties getting vaccinated and Trump-voting counties getting sick. This politicization pattern even made its way into support for the US at last summer's Olympics. Donald Trump proclaimed that, were it not for "leftist maniacs," the US Women's National Soccer team would have won the gold medal.

If politics can divide a country over taking steps to avoid unnecessary deaths or whether to support its own athletes in the Olympics, how can it unite on addressing climate change? This year's Conference of the Parties (COP) to the UN Framework Convention on Climate Change (UNFCCC) was the first conference since the US withdrew from, and then reentered, the Paris Agreement. The COVID-19 pandemic postponed COP26 from 2020 to 2021, preventing a meeting during the United States' brief self-imposed exile. Several US negotiators said how relieved they were that they did not have to attend a COP during the year when the US was out of Paris, but it was clear that Americans remained divided over the decision to rejoin. Interestingly, the issue has not always been so divisive. In 2008, the Republican Newt Gingrich and Democrat Nancy Pelosi pledged to join forces and fight climate change together. In 2007, 71% of Americans believed burning fossil fuels would affect the climate. This share fell to 51% in 2009, and 44% in 2011.

The US has had an enigmatic role in climate negotiations from the beginning. It provided about 40% of the total funding for the Intergovernmental Panel on Climate Change, the UN body that conducts scientific assessments to inform decision-making around climate. This funding was cut in 2017 by the Trump Administration. The first George Bush Administration negotiated the UNFCCC at the Rio Summit, and the US is a major funder of the UNFCCC secretariat. Under President Bill Clinton, US negotiators played a significant role in shaping the Kyoto Protocol, the 1997 treaty to curb greenhouse gas emissions through a trading scheme modeled on market-based approaches to limiting the pollutants that cause acid rain. The US never ratified Kyoto because the Senate unanimously voted for the 1997 Byrd-Hagel Resolution, which declared that the US should not join a climate agreement that would create new commitments for developed countries if it did not also create commitments for developing countries, or would harm the US economy.

This divided government attitude is partly a reflection of the different electoral calculations of a president who can draw votes from across the country, versus individual senators and congress members who are elected by voters in their states, or in even smaller congressional districts. The voting of members of congress does not seem to reflect national at-

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titudes on climate. Just before COP26, a survey from the AP-NORC Center and the Energy Policy Institute at the University of Chicago showed that 75% of Americans believe climate change is happening, and 59% say it is accelerating. Fifty-five percent say they would pay a small surcharge on their electricity bills to fund more investment in renewable energy. While almost half the population would support requiring a transition to electric vehicles, the divide along political party lines helps explain why the polling does not translate into new laws: 61% of Democrats support such a requirement, while only 23% of Republicans do. The structure of our government means that America in 2021 is neither governed by averages nor, in some cases, by majorities.

So how will these attitudes make their way into practice? As with many issues in the US, the markets will drive action. US CO_2 emissions peaked in 2007 and have fallen by about 13% overall. Emissions from electricity generation have fallen by about one-third, due to a shift in fuel choice from coal to natural gas and renewables. As the cost of generating electricity from renewables and natural gas has fallen, electricity producers have shifted and cut emissions.

Emissions from transportation have only fallen slightly across the same period. The transportation sector is now the single biggest source of emissions in the country. To meet the Biden Administration's commitments to the world through the UNFCCC process, emissions from energy will have to continue to fall, and emissions from transportation will have to fall dramatically.

Americans are unlikely to give up their cars anytime soon, but the emissions from those cars can change. Teslas and other electric cars are increasingly popular. Cost and convenience are two factors that keep consumers from switching to electric cars, but the average retail cost of electric cars is expected to fall below that of gas-powered cars in the next few years. And the Democratic Party's second infrastructure bill, passed by the House of Representatives this November, contains a number of incentives and penalties to encourage a more rapid transition of the energy and transportation sectors including offering rebates for electric vehicle purchases of up to $12,000 per car and dramatically increasing the number of charging stations for electric cars. There are also tax credits for renewable energy production, investments in the electric grids so they can take in more power from renewables, as well as increased fees and penalties for fossil fuel extraction, use and pollution.

Americans lived through a summer of climate impacts in 2021, with drought and wildfires out west and storms and flooding in the east. The estimated cost of damages to property was close to $100 billion. The awareness that there are consequences for inaction is reflected in opinion surveys, in climate activism and in consumer behavior. Even Fox News seems to be shifting from denying climate change to arguing that it is good: several stories note that fewer people are dying from extreme cold. Will these changes in attitudes and behavior be enough for the United States to play the leadership role needed for the world to curb global emissions? Will economic carrots and sticks be enacted to allow American technological creativity to scale up solutions that the whole world could benefit from? That remains to be seen. The political divisions in the US pose formidable hurdles.

While progress at the national level is unsteady, we are seeing increasing commitments from the private sector and real dedication and leadership from cities and states. These efforts can support the actual implementation of the objectives of the Paris Agreement regardless of commitments of the federal government, while also acting as incentives to increase ambition at the federal level if included in the national effort. Another quote attributed to Winston Churchill offers some hope: "Americans can always be counted on to do the right thing, once they have exhausted all other possibilities."

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