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POLICY BRIEF

21-20 Climate Policy is Macroeconomic Policy, and the Implications Will Be Significant

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INTRODUCTION

The mitigation of climate change was long envisioned as a slow process for carbon-intensive economies to gradually reduce their emissions of greenhouse gases. Of the many questions this perspective raised, few were of a macroeconomic nature.

But decades of procrastination have turned the expected smooth transition into what is likely to be an abrupt one. Estimates by the Intergovernmental Panel on Climate Change (IPCC) of the United Nations indicate that emergency action is indispensable to limit catastrophic climate disruption.

The reality of the emergency is increasingly acknowledged and it is being translated into plans for a swift transition to carbon neutrality. According to the International Energy Agency (IEA 2021), countries representing 70 percent of global emissions and GDP, as well as a growing number of states, cities, and international companies, have committed to reaching net zero emissions by 2050 or 2060. Further commitments can be expected in the run-up to the 26th UN Climate Change Conference of the Parties (COP26)[1], which will assess progress made (or not) since the Paris accord of December 2015.

The European Commission (2021) recently introduced plans for cutting emissions by 55 percent by 2030 (with respect to 1990), instead of 40 percent as legislated in 2018. It plans to overhaul energy legislation, broaden the scope of the European cap-and-trade scheme, introduce a raft of new technical standards, and push through minimum carbon taxation at the national level. The consequences will be wide-ranging transformations for energy, transportation, housing, manufacturing, agriculture, and even services (European Commission 2020).

Not everything in this ambitious package will survive negotiations with the member states of the European Union. But European leaders have already

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1 COP26 will take place from October 31 to November 12, 2021, in Glasgow.

committed to carbon neutrality by 2050 and the Commission is essentially telling them that they now must align their actions with their words.

The new EU agenda changes the economic perspective. Because of the magnitude of the efforts involved and the pace of the transformation implied, the accelerated transition to a carbon-neutral economy is bound to have immediate economic implications. Some equipment will lose economic value. Some plants will have to close. Employees will have to be reallocated to other occupations. Investment will have to increase, to repair or rebuild the capital stock.

So far, however, these implications have not been addressed in a systematic manner. Too often the transition has been pictured, if not as pathways of roses, at least as a rather benign endeavor. Even now, while unveiling its "shock and awe" climate plan, the European Commission (2021) posits that "what is good for the planet is good for people and the economy." Simulations released as part of the impact assessment conclude that implementation of the EU plan should result in a very modest change in real 2030 GDP that is estimated to range between −0.7 percent and +0.55 percent, depending on the model and the policy setup (European Commission 2020, table 14).

Too often the transition to a carbon-neutral economy has been pictured as a rather benign endeavor.

But small aggregate changes at a 10-year horizon may conceal stronger disruption along the way. Because climate action involves an array of regulations, subsidies, incentives, border measures, government expenditures, and taxes, its macroeconomic consequences are admittedly hard to pin down. Fundamentally, however, decarbonization amounts to putting a price on a resource that used to be free. The pricing may be explicit (through taxation) or implicit (through regulation), but both types of measures have the same effect of triggering an accelerated obsolescence of existing capital stock. Decarbonization can thus be regarded as an adverse supply shock—very much like the oil shocks of the 1970s. In the short run at least, it is bound to affect potential output negatively.

This does not necessarily mean that growth will decline—unless the output gap was closed already—as the pricing of carbon will trigger research expenditures, new infrastructure spending, the accelerated renewal of equipment, and investment in the renewal of buildings. But the composition of growth will change, as more resources will be devoted to investment and less to consumption. Undoubtedly, consumers will be better off in the long run, as they will benefit from a preserved climate. But in the short run their welfare is likely to take a hit, at least in comparison to trend.

Public finances will also be affected. Because carbon taxation is regressive, many governments will probably attempt to cushion its impacts on the most vulnerable households.[2] Instead of providing the means to lower other taxes (and increase potential output correspondingly), revenues will have to finance transfers. Further transfers will also be needed to offset the consequences of tougher regulations (for cars, for example, or domestic heating systems). Public investment in research, infrastructure, and the renovation of buildings will be required. The net impact on government budgets is likely to be negative.

2 In recent years a growing proportion of governments has come to a more realistic appreciation of the political economy constraints of the green transition. For example, the European Commission (2021) proposes that 25 percent of the resources from the new EU-level Emissions Trading Scheme be allocated to a dedicated social fund, and that individual member states contribute an equivalent amount.

Moreover, from a political economy standpoint climate investment will provide a powerful argument for letting governments go into debt, because the usual intergenerational argument does not apply.

Reasonable optimism about the long-run effects of the transition to a carbon-neutral economy is no reason to overlook transition costs. These costs, while bearable, are likely to be significant. Rather than pretending that they are trivial, policymakers should face reality and design transition strategies accordingly.

This Policy Brief focuses on the nature and magnitude of the economic impact of climate action—not on the steady-state consequences of decarbonization, but on those of the transition. The longer-term debate is not addressed here—that is, the controversy between the techno-optimists who argue that if the right investments are made in time, climate-related disasters can be prevented without much change to living standards, and the techno-pessimists who maintain that life on Earth can be preserved only if societies break away from an economic model centered on the maximization of material well-being.

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More precisely, the argument presented here builds on the assumptions of the techno-optimists and assumes that, at a 30-year horizon, net zero can be achieved without a major decline in real income and standard of living.[3] If this hypothesis proves to be too optimistic, that will only strengthen the macro significance of decarbonization.

Section 1 discusses why the macroeconomic perspective has long been largely neglected. The nature and magnitude of the transition to net zero are assessed in section 2. Section 3 is devoted to implications for growth and welfare. Section 4 addresses impacts on public finances. Section 5 concludes.

1. THE MACROECONOMIC DIMENSIONS OF CLIMATE ACTION HAVE LARGELY BEEN OVERLOOKED

Environmental economics started developing five or six decades ago, drawing on older roots, but for a long time there was a near-complete disconnect between climate economics and macroeconomic policy. It is only very recently that economic policy reports—whether issued by international organizations such as the International Monetary Fund (IMF), Organization for Economic Cooperation and Development (OECD), and European Commission, by central banks, or by national treasury departments—have begun seriously addressing decarbonization.

There are intellectual and policy reasons for this long neglect. The intellectual reason is that, quite naturally, environmental economics initially developed in the framework of public economics rather than in a macro framework.[4] The (related) policy reason is that decarbonization was regarded as a topic for the longer term, of relevance only beyond the usual macroeconomic horizon.

True, integrated assessment models (IAMs) were developed to make the connection between climate policy and macroeconomics. But the macro questions they have mainly been used to address concern the optimal pace

3 For recent discussions in support of this optimistic outlook, see UK CCC (2020), Turner (2020), and Blanchard and Tirole (2021).

4 See, for example, Heal (2017).

of the transition and whether net zero will imply a *permanent* decline in GDP and standard of living. For growth, investment, inflation, or fiscal deficits, the consequences of managing the transition to climate neutrality within a fixed time frame have been addressed cursorily at best.[5]

Rather than through the lenses of intertemporal optimization, the transition to net zero must nowadays be approached as a finite-horizon challenge. Because necessary action has been repeatedly delayed, the carbon emissions budget (the total volume of emissions compatible with the avoidance of catastrophic climate change) is nearly exhausted. At pre-COVID emission levels, the atmospheric stock of greenhouse gases compatible with containing the rise in global temperature to 2 degrees Celsius will be reached in fewer than 25 years, and it will be attained in 7 years if the threshold is lowered to 1.5 degrees Celsius.[6] For these reasons, compliance with the COP21 objective of limiting the rise in temperature to 2 degrees Celsius requires precipitous action.

The transition to net zero will imply sizeable relative price changes, accelerated obsolescence of the existing capital stock, significant reallocation of labor, and a major investment push.

The consequence, as the European Systemic Risk Board pointed out five years ago, is that the transition to net zero is by now bound to be "too late and too sudden" (ESRB 2016). It will therefore imply sizeable relative price changes, accelerated obsolescence of the existing capital stock, significant reallocation of labor, and a major investment push. Such developments are by definition macroeconomic in nature.

The fate of the automotive industry provides a telling illustration of what is at stake for the whole economy. Until recently regulations in the European Union or the United States implied a gradual tightening of emission standards, leaving the long-term target uncertain. The message to industry was that steady incremental improvements would suffice. But the UK government has now announced that all new cars will need to be zero-emission by 2035, and the European Commission (2021) has proposed a similar timetable.

The implication is that the auto industry must plan to replace traditional combustion engine cars with vehicles based on entirely new technologies. Audi, the German manufacturer, has for example announced that it will stop releasing new vehicle models with combustion engines (including hybrids) by 2026 and stop selling them by 2033.[7] Other manufacturers have outlined similar plans. As a consequence, investment in the design of new combustion engine models will stop without delay. The corresponding stock of patents, skills, and equipment will lose value prematurely. Instead of being replaced at the end of its economic life, equipment will be discarded. Plants will close, especially those of specialized subcontractors. As noted, an abrupt transition is bound to result in the accelerated obsolescence of the existing physical and human capital stock.

Labor reallocation will also be rushed and widespread. Workers in combustion engine factories will need to be retrained and moved to other jobs and other firms. Because the labor content of an electric vehicle is significantly lower than that of a combustion engine vehicle, many will need to train for

5 See Stern and Stiglitz (2021) for a discussion on the use of IAMs in the context of irreversibility and catastrophic risks.

6 Update by the Mercator Research Institute on Global Commons and Climate Change, which is based on IPCC (2018).

7 Motor Authority, June 24, 2021.

and move to other industries. Such creative destruction may eventually boost productivity and end up being a positive for growth. But the transition is bound to involve frictions.

Macroeconomic mainstreaming of the economics of the net zero transition is under way. But much remains to be done before the economic impacts of decarbonization strategies have been fully assessed. Even financial supervisors, who started earlier, do not yet know what the implications will be of the greening of financial assets and credit channels. Macroeconomists must catch up with a fast-changing reality.

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2. THE TRANSITION TO NET ZERO INVOLVES A LARGE NEGATIVE SUPPLY SHOCK

Presenting the EU climate agenda in December 2019, European Commission president Ursula von der Leyen declared that the European Green Deal was Europe's "new growth strategy."[8] Green Deal advocates claim that, because of the investment involved, the transition to climate neutrality will unleash a Keynesian boost and create more and better jobs (see, e.g., Ocasio-Cortez 2019 and IEA 2021).

But their claims do not consider potential roadblocks such as lack of spare capacity, adverse impacts of decarbonization on the supply side, and difficulties with labor reallocation. They deserve credit for taking account of the macroeconomic dimension, but not for the quality of their assessment. There is no guarantee that the transition to carbon neutrality will be good for growth.

Analysis of the issue is easily obscured by a number of technicalities. Policy instruments combine carbon prices, technical regulations, subsidies, and direct government expenditures. Because they need to represent the energy system in great detail, models are generally complex and mechanisms at work are hardly tractable. To understand the nature of the transition, it is preferable to start from simplifying assumptions.

Assume therefore a policy setup in which carbon taxation is set at a level consistent with the shadow price of carbon derived from the net zero objective; this assumption is clearly a simplification, but it helps provide a quantitative measure of the magnitude of the expected effort. Let us also assume that the proceeds from carbon taxation are entirely redistributed through lump sum transfers (e.g., carbon dividends); this again is a shortcut, but it neutralizes the fiscal impact of the policy action. Finally, assume that all countries implement the same policy and that there is thus a single price for carbon at the global level; this highly hypothetical assumption makes it possible to consider the global economy as a single economy, abstracting for the moment from the impact of differences in the pace of decarbonization.

In 2019 global CO_2 emissions amounted to 36.4 gigatons, carbon pricing schemes (taxes and quota allowances) generated $48 billion in receipts at the global level, and the average price of carbon was $1.3/ton.[9] An IMF estimate puts that price slightly higher, at $3/ton (Gaspar 2021). A more elaborate assessment that considers other forms of carbon taxation, as well as subsidies,

8 Op-ed by President von der Leyen, December 11, 2019.

9 See appendix A.

puts the "comprehensive" price of carbon at $12.9/ton in 2019 for 25 countries representing 82 percent of total CO_2 emissions (Carhart et al. 2020). Knowing that countries outside the sample often do not price carbon (or price it negatively by providing fossil fuel subsidies), the actual comprehensive price of carbon is probably close to $10/ton globally.

This is to be compared with estimates of the price level consistent with the goal of remaining within the carbon budget and limiting the rise in temperature to 2 degrees Celsius. The Stiglitz-Stern High-Level Commission on Carbon Prices estimated it to be "at least" $40–$80/ton in 2020 and $50–$100/ton in 2030 (Carbon Pricing Leadership Coalition 2017). These estimates cannot be considered particularly ambitious: For example, the more recent Network for Greening the Financial System report (NGFS 2021) puts the global price of carbon consistent with a net zero scenario at $160/ton in 2030 and around $350/ton in 2040. A French official report sets for 2030 a €250/ton shadow price of carbon (Quinet 2019). The "early action scenario" of the Bank of England (2021) is in the same ballpark, putting the price of carbon at $300/ton in 2030.[10]

The actual comprehensive price of carbon is probably close to $10/ton globally. To be consistent with the goal of remaining within the carbon budget and limiting the rise in temperature to 2 degrees Celsius it should be at least $40-$80/ton.

Reaching the midpoint of the Stiglitz-Stern estimate would imply raising immediately the price of carbon from around $10/ton to $60/ton, and increasing it further to $75/ton in 2030, a price also recommended by the IMF (Gaspar 2021). But what sort of economic effects would this entail?

In macroeconomic terms, the sudden pricing of a negative externality that was overlooked in production decisions amounts to an adverse supply shock. The impact of such a shock is familiar because it resembles the oil shocks of the 1970s, when a previously underpriced resource was suddenly revalued. Now, as contributions to the depletion of a resource must be priced, effects are likely to be similar: As noted, part of the capital stock (in the energy, transportation, manufacturing, and building sectors, especially) will be made economically obsolete by relative price changes and will have to be discarded before having reached the end of its economic life; potential output will therefore decline in the short term; downward price rigidity will complicate relative price adjustment and involve inflationary consequences; and labor will need to be reallocated to different jobs and different places, which will inevitably entail frictions.[11]

The oil and climate transition shocks are also roughly similar in terms of size. If priced at $75/ton the aggregate value of the 36.4 gigatons of carbon emissions of 2019 would amount to 3.1 percentage points of 2019 world GDP, an increase of 2.7 percentage points over the status quo. Priced at $100/ton it would amount to 4.1 percentage points, or 3.7 percentage points above the status quo. In comparison, the 1974 oil shock resulted in the repricing of 19.7 billion barrels of oil from $3.3 to $11.6/barrel; the corresponding shock amounted to 3.6 percentage points of the 1973 global GDP.[12]

The 1974 shock was of the same order of magnitude as the one that is bound to be triggered by efforts to cut emissions in the decade ahead. At the time, it caused a significant slowdown of world GDP and a sharp recession in advanced

10 Longer-term calculations generally forecast further increases in the price of carbon, but these depend on highly uncertain assumptions about future abatement costs.

11 This would not be true if proceeds from carbon taxation were used to finance a lowering of distortionary taxes on labor and capital. I discuss this hypothesis in section 4.

12 See details and sources for this calculation in appendix A.

economies. It ushered in a struggle between workers and employers for the distribution of a diminished surplus. It led to stagflation, which confronted policymakers with the hard choice between warding off recession and fighting inflation. Growth was subdued for several years. Should the same be expected with the climate transition?

There are likely to be several mitigating factors. First, a global price of carbon is not a realistic expectation. So far, carbon pricing has been adopted by a few individual countries only. Even if the European Union implements its plan in full, the bulk of global emissions is unlikely to be priced in the short term. What is probable is a gradual evolution in this direction, possibly together with the linking of national or regional emissions trading schemes.

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Second, the oil shock was much more sudden and unexpected than anything realistically anticipated for carbon pricing. The slower the rise in the price of carbon, the less capital will be discarded before it reaches the end of its economic life. It is furthermore likely that the global economy has become more flexible and learned to live with and adapt to sharp changes in the price of energy.[13]

Third, the oil shocks and decarbonization differ in terms of their likely demand-side effects. The former redistributed income to oil exporters, whose marginal propensity to consume was lower than that of the oil importers, adding to the contractionary impact. In contrast, carbon pricing is likely to be neutral initially and could even support demand if carbon dividends are distributed on a per capita basis.

Fourth, carbon price increases, or regulatory equivalents, are far from unexpected. Even in the United States under Donald Trump, the use of internal carbon prices by private firms was not insignificant.

Finally, some positive effects can be expected. As emphasized early on by Michael Porter and Claas van der Linde (1995) and later formalized by Daron Acemoglu and colleagues (2012), a change in relative prices and a tightening of emission standards are bound to unleash a new wave of technological progress. Evidence has confirmed that the cost of decarbonization could fall dramatically once endogenous technological change is considered. Abatement cost curves have already shifted downward spectacularly.

So the comparison should not be taken at face value. What it reveals is not that the experience of oil shocks will be repeated, but that the regime change implied by the net zero transition involves a deadweight loss that is potentially macro-significant and could trigger adverse developments.

Policymakers are caught between a rock and a hard place. If too gradual in the years to come, the transition is likely to prompt precipitous adjustments later, as illustrated by the NGFS (2021) scenarios. If too swift it is bound to entail large losses resulting from the accelerated obsolescence of the existing capital stock and the limited availability of cost-reducing innovations. Procrastination has reduced the chances of engineering an orderly transition.

13 In the first decade of this century the global economy experienced a rise in oil prices from \$25/barrel in 2002–03 to nearly \$100 in 2008. There is no evidence that this rise triggered recessionary consequences, but this is perhaps because any such impact was eclipsed by that of the global financial crisis.

These conclusions apply whatever the policy levers used to foster the change to carbon-neutral technologies. If triggered by regulations rather than price, the change may not have the same inflationary consequences, but because a quantity constraint is nothing but the dual of a price, the macro effects are unlikely to be fundamentally different. And if undertaken faster by an individual country, the change is likely to result in additional adverse effects from the offshoring of carbon-intensive industries (unless an effective border adjustment mechanism is put in place) and real exchange rate depreciation.

One way or another, the global economy is bound to be confronted with an accelerated transition—unless the temperature target is missed altogether and the world suffers much more significant damages down the road.

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3. THE TRANSITION WILL TRIGGER AN INVESTMENT BOOM BUT REDUCE CONSUMPTION

The shock is only one aspect of the regime change implied by achieving net zero. Another is the response to it. As mentioned, the transition to a carbon-neutral economy will require significant investment to replace or adapt the old, carbon-positive capital stock. A major macroeconomic question is how much additional investment this replacement will entail.

The literature does not provide an unambiguous answer to this question. Estimates of investment needs often focus only on some sectors (especially energy). They may also label certain investments as green without distinguishing those that would have taken place anyway.[14] Nonetheless, a degree of consensus emerges from the available estimates.

The IEA (2021) estimates that a global transition to net zero by 2050 would imply increasing global investment in energy from 2.5 percent of world GDP in 2016–20 to 4.5 percent by 2030, after which it would gradually return to 2.5 percent by 2050. As not all sectors are included in this figure (it omits agriculture and services), the *net* increase should therefore amount to at least 2 percentage points of GDP in 2030. Gross investment in the transition would be significantly higher, as part of the current investment in fossil fuel extraction, transportation, and transformation would be reallocated to green energy investment.

Estimates by the European Commission are broadly similar. The latest impact assessment of the 2030 climate plan (European Commission 2020) anticipates a rise in the investment-to-GDP ratio (including transportation) by 1.5–1.8 percentage points in 2021–30 in comparison to 2011–20. As in the IEA scenarios, energy system investment (excluding transportation) is expected to peak in 2030 at 3 percent of GDP, or 2 percentage points above the 2010 level. The UK Climate Change Committee (UK CCC 2020) also forecasts a rise in investment by about 2 percent of GDP in 2030. It calculates that this additional effort will be offset by operational cost savings, but only in the long run. The IMF (2021) surveys available estimates and also concludes that annual additional investment should amount to 2 percent of GDP between 2030 and 2040.[15]

14 See Ledez and Hainaut (2021) for an application to the French case.

15 Estimates of the GDP impact of the transition to net zero vary significantly, however: from 4 percent in 2030 (IEA 2021, for the global economy) to 2 percent (UK CCC 2020, for Britain) to a roughly neutral impact (European Commission 2021, for the EU) and a small decrease (NGFS 2019, for the global economy). These discrepancies are indicative of the lack of consensus on the macroeconomics of climate action.

An increase of 2 percentage points in the investment-to-GDP ratio would be far from negligible macroeconomically. Assuming again that the transition would take place at the global level, it would more than reverse the decline in the world investment ratio from 25.7 percent in 1980–89 to 24.3 percent in 2010–19. Even if limited to the advanced economies, such an investment surge would likely materially affect the equilibrium real interest rate and could help counter secular stagnation.

A significant effort to replace the existing capital stock will also impact welfare. The net zero transition is likely to have positive side-effects on current consumer satisfaction in the long run—because of, say, upgraded transportation infrastructure, cleaner air, or better insulation of houses—but its first-order immediate effect on consumption will be negative. Assuming (an admittedly rough assumption) that the investment surge would translate into a greening of capital stock but ultimately leave potential output unchanged, by 2030 10 percent of GDP (1 percent on average over 10 years) will have been subtracted from consumption to turn unsustainable output into sustainable output. If matched by a parallel decline in personal consumption expenditure (a natural assumption in the context of a closed economy), the toll on annual consumption will reach 3 percent in 2030, a significant number in a low-growth context.[16]

An increase of 2 percentage points in the investment-to-GDP ratio would more than reverse the decline in the world investment ratio between 1980–89 and 2010–19.

These calculations are admittedly pessimistic in that they disregard the possibility that the investment surge will trigger an increase in GDP, either in the short run, by stimulating aggregate demand, or in the medium run, by triggering productivity increases. But they illustrate an unavoidable trade-off between current consumption and future well-being. In a way, investment in the transition to net zero is not unlike military spending: Its primary effect is to divert resources from immediate welfare-enhancing expenditures to spending that contributes to maintaining citizens' welfare in the long run. Such a program may have a positive impact on GDP, and spillovers from related research and innovation may improve potential output in the long run, but this should not obscure the basic arithmetic.

In addition, it should be noted that such calculations err on the optimistic side by neglecting the costs of adaptation to climate change. These are significant and separate from mitigation costs in a realistic scenario where the rise in global temperature reaches—or perhaps even exceeds—2 degrees Celsius. Back-of-the envelope calculations also indicate that the magnitude of the investment effort involved and the corresponding welfare implications are bound to be macro-significant.

4. THE NET ZERO TRANSITION WILL LIKELY PUSH PUBLIC FINANCES FURTHER INTO DEBT

Early analyses of the public finance consequences of decarbonization assessed it as positive or neutral. The expected proceeds from Pigouvian taxation were forecast as a windfall that could be either saved or recycled through the lowering of other taxes. The strong form of the "double dividend" hypothesis posited that a revenue-neutral substitution of a carbon tax to existing distortionary taxes would yield both an environmental and an economic benefit, which would translate to a higher level of output and higher tax revenues (Goulder 1995).

16 Assuming personal consumption expenditures amount to two-thirds of GDP.

This approach has increasingly been questioned for overlooking the fact that decarbonization entails significant distributional consequences. Carbon taxation is regressive and often affects residents of some areas disproportionally. This is because relatively low income and a carbon-intensive lifestyle make the suburban middle class vulnerable to a rise in the price of carbon; in contrast, affluent residents of metropolitan centers are largely spared.

This reality (and the corresponding discontent, vividly illustrated by the French Yellow Vests movement) has led governments to reconsider plans for carbon taxation. Whereas it was viewed a few years ago as a potential source of revenue or an opportunity to substitute for other taxes (according to the "double dividend" hypothesis), there is growing recognition that revenue from carbon taxation or the auctioning of tradable permits must largely be redistributed in order to neutralize their income effects, at least for the bottom half of the income distribution.

Politically, a commitment to redistribute the proceeds from taxation dollar for dollar may be indispensable to dispel suspicions that carbon pricing is just a convenient pretext for increasing taxes (Akerlof et al. 2019). This would rule out the possibility of offsetting adverse supply-side effects from carbon taxation through the reduction of distortionary taxes on labor or capital. Even the less ambitious version recommended by the European Commission (2021)—a Social Climate Fund endowed with half of the revenues from the sale of new transport and housing emission permits—would draw significantly on new revenues.

Because redistribution may be insufficient to quell complaints about carbon taxation, governments in the United States and Europe are contemplating strategies that combine regulation, subsidies (e.g., for renewable energy, electric vehicles, housing renovation, and research and development), and direct expenditures (e.g., on research, green infrastructure, and renovation of public buildings). But they must also plan for investment in adaptation—a potentially costly program. Instead of providing new government revenues, the transition to net zero is thus increasingly likely to entail significant public cost (Zenios 2021).

Some recent developments are indicative of this approach. In the European Union, debt-finance recovery and resilience plans adopted in the post-COVID joint economic initiative allocate at least 37 percent to climate-related expenditures. However, US legislation, still pending, includes infrastructure investment and subsidies, but carbon pricing is not expected to be on the agenda.

To what extent climate-related public expenditures will be financed by debt remains to be settled. Discussions are still in early stages. What is clear is that climate investment is a powerful argument for letting governments go into debt, because the usual intergenerational objection does not apply. Future generations may well be better off inheriting a preserved climate and financial debt rather than preserved public finances and permanent damage to the environment. In the end, governments may choose to go into financial debt to be able to pay down climate debt.

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5. CONCLUSIONS

Accelerated decarbonization efforts are indispensable and urgent. Longer term, the emergence of cost-effective low- or zero-carbon technologies provides good reasons for informed optimism about their economic consequences. Though not certain, it is increasingly likely that, if collective action challenges are overcome, the transition to net zero can be achieved in the long run without a major decline in real incomes and standards of living.

Techno-optimism is no reason for overlooking transition costs, however. Comparison with past experiences, and the amount of investment needed in the decade ahead (and beyond), suggest that these costs, while bearable, are likely to be significant.

Because of the accelerated pace of climate change and the magnitude of the effort involved in decarbonizing the economy, while at the same time investing in adaptation, the transition to net zero is likely to involve, over a 30-year period, major shifts in growth patterns. Effects will include a significant negative supply shock, an investment surge sizable enough to affect the global equilibrium interest rate, large adverse consumer welfare effects, distributional shifts, and substantial pressure on public finances.

Leaving aside many dimensions of the issue—such as stranded assets and the trade and exchange rate consequences of decarbonization—a simple exploration of the essential mechanisms at work suggests that the transition to net zero will confront policymakers with serious *macroeconomic* difficulties. This transition is unlikely to be benign and policymakers should get ready for tough choices.

A precise analysis of policy challenges and options requires much more than the rough first pass attempted in this Policy Brief. Preparation of quantitative scenarios, such as those released by policy institutions, is probably the best way to map out the considerable uncertainty that lies ahead.

The main message from a simple analysis is that while discussions of the relative roles of innovation and investment, or the desirable combination of price signals and regulation, remain important, it is high time to realize that climate policy is also macro policy. A better, more precise discussion on the macroeconomics of climate action is urgently needed.

In this context, debates should focus more on identifying the mechanisms and choices involved in what is bound to be a challenging transition. It is not by minimizing the challenges ahead that concerned analysts and policy experts will convince politicians and the public to step up decarbonization efforts, but rather by addressing them thoroughly.

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APPENDIX A
SOURCES FOR CALCULATIONS

- Net zero commitments: United Nations
- Global CO_2 emissions: Our World in Data
- Revenues from carbon pricing schemes: Institute for Climate Economics (emissions do not include other greenhouse gases)
- Comprehensive global price of carbon for a sample of 25 countries in 2019 = $12.9/ton (update by Kepos Capital of estimate by Carhart et al. 2020 for a sample of large emitters)
- Annual world oil production in 1973: 33.4 terawatt-hours or 19.7 billion barrels (Our World in Data via BP Statistical Review of World Energy and the Shift Project Data Portal)
- Global crude oil price in 1973: $3.3/barrel; oil price in 1974: $11.6/barrel (Our World in Data via BP Statistical Review of World Energy and the Shift Project Data Portal)
- Global GDP (current US dollars): $4.6 trillion in 1973; $87.6 trillion in 2019 (World Bank)
- Global investment-to-GDP ratio: World Bank