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A Net-Zero Target Compels a Backwards Induction Approach to Climate Policy

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Abstract

Jurisdictions around the world increasingly affirm their contributions to the 2015 Paris Agreement by pledging net zero targets. We argue that delivering on a net-zero target compels a backward induction approach to climate policy, which differs from the prevailing approach by stipulating that the objective for designing policy pathways must change from minimizing the cost of the policy to maximizing its credibility. Our argument rests on the premise that private investments play a key role for net zero, and to align them with net zero, *getting expectations right* is more relevant than *getting the prices right*. Backward induction compels a dynamically consistent pathway that can overcome the problem that emitters may expect the rules and targets of climate policy as open for constant political renegotiation. We furthermore sketch the main elements for a regulatory strategy to put this approach into action that builds on instilling commitment.

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1. Introduction

Jurisdictions around the world increasingly affirm their contributions to the 2015 Paris Agreement by pledging net zero emission targets. Specifically, governments have issued statements (Japan), submitted legislative proposals (Canada, European Union), or enacted laws (United Kingdom, New Zealand) to reach net zero emissions by midcentury (Hale et al. 2021), as suggested by the IPCC special report on the impacts of global warming of 1.5C above pre-industrial levels (IPCC, 2018). This goal is underpinned by the notion that achieving a specific warming objective requires a commitment to a set carbon budget (Drouet et al. 2021). Yet net-zero targets limit policymakers' ability to alter the emissions reduction target (timing and quantity) in light of new information about the parameters (i.e., net benefits) of the climate problem or changing political and economic circumstances. This inflexibility may raise total abatement costs. What, then, could justify the adoption of net-zero targets?

In this paper, we argue that the value of net-zero targets lies in emphasizing credible commitment to increasingly stringent climate policy, for the following reason: the primary motivation for net zero – besides meeting the goal of the Paris Agreement – is to reinforce the sense of urgency of the climate problem (Goulder 2020) by stipulating that it must be approached as a finite horizon challenge (Pisani-Ferry 2021). However, to be a rational goal, in the sense of inducing appropriate action by private investors (Edvardsson and Hansson 2005), it must be perceived as credible (Victor et al. 2022). Credibility is a precondition to shaping expectations so that investment and operational decisions align with the goal, thereby lowering the intertemporal costs and making its achievement increasingly likely. And a requirement for credibility is the dynamic consistency of the policy pathway (Kydland and Prescott 1977).[1]

A new approach to policy is needed to satisfy the credibility requirement. We call it *backward induction,* in analogy to the mathematical approach for identifying solution strategies in finite games, from which we draw insights. Backward induction as used here describes a planning process that begins by identifying an endpoint and works backward to find pathways to that outcome. It enables policy design that centers on credibility and stipulates a shift in emphasis from *getting the prices right* to *getting expectations right* by making commitment, which affects expectations, a core aim of policy pathway design.

This approach would deviate from the prevailing approach to climate policymaking and may better induce action. We refer to the prevailing policy approach as *open-ended incremental.*[2] Its defining characteristic is that climate targets and related

[1] Since we view dynamic consistency as a necessary condition of credibility, we do not view these two concepts as equivalent. However, since this paper focuses on dynamic consistency as a determinant of credibility, we will use credibility and dynamic consistency interchangeably.

[2] Throughout this paper, we hold recursive updating and reoptimization in mind as the instance of open-ended incremental policy development.

policies are chosen and revised every time a new government comes into power. Its main shortcoming is that it arguably delays action, since emitters can interpret the rules of the game as open for constant political renegotiation (Cullenward and Victor 2020). Consequently, it may lead to underinvestment in present abatement and research activities if firms expect that long-term emissions goals will not be binding.[3] This, in turn, raises future policy costs, increasing the likelihood of policy delay or reversal, thus becoming a self-fulfilling prophecy.

The backward induction approach addresses that problem by putting dynamic consistency at the forefront of policy pathway design—that is, making the goal and policies nonrenegotiable and shaping expectations accordingly. Importantly, this implies a departure from least-cost policy pathways, which according to economic theory are not time consistent (Petit 1990). Regulators may therefore need to consider new economic instruments or new rankings of known ones (Vogt-Schilb et al. 2018; Goulder 2020). The first principle of backward induction is to give precedence to policy choices that can generate commitment by future policymakers—that is, choices that create the conditions under which ever more stringent climate policy can be implemented. Examples include investments in infrastructure and incentives to accelerate private sector investments. In fact, the US Infrastructure, Investment and Jobs Act (2021) and Inflation Reduction Act (2022) and the EU Green Deal (2021) reflect many of the characteristics of backward induction in that each of them – intentionally or not – includes aspects that enhance long-term commitment.

To the best of our knowledge, there is no literature that investigates the rationality of net zero and its policy design implications from the angle of credibility and expectations. Fankhauser et al. (2021) identify seven attributes for achieving net zero but do not focus on policy choice and regulatory strategies. Other work looks at how to make climate policies more credible (Brunner et al. 2012) or assesses targets and commitments on the international level (Nemet et. al. 2017; Victor et al. 2022) but does not focus on long-term policy pathways or the specifics of net zero. Though related to that research, our work is rooted in the extensive literature on credibility and commitment in policymaking (Kydland and Prescott 1977; Dellas and Tavlas 2022; Cukierman and Meltzer 1986, 6; Blinder 1999, 64–65) and policy sequencing to ratchet up stringency (Meckling et al. 2017; Pahle et al. 2018). Moreover, we integrate an emerging literature on the trade-off between cost-effectiveness and the capacity of environmental policies to create commitment (Fuest and Meier 2022).

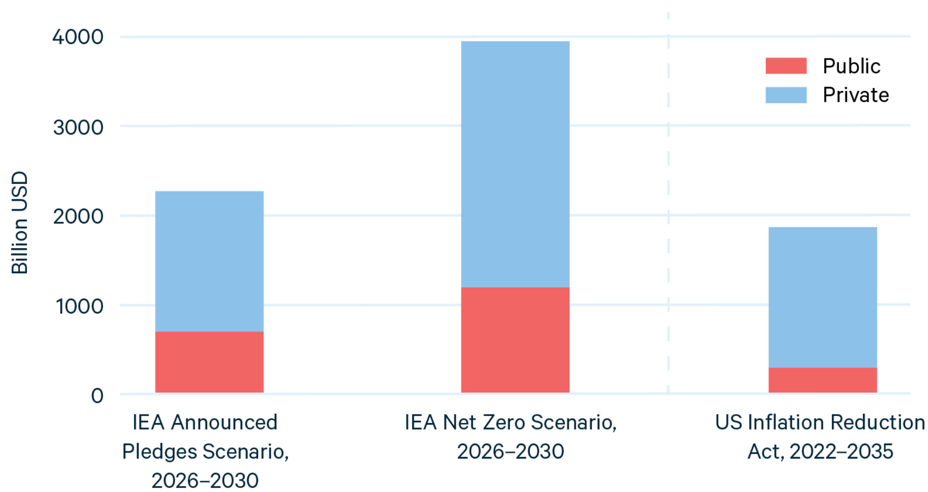
[3] A more extreme view suggests that industries engage in dynamic regulatory capture (Di Chiara and Schwarz 2021). That is, they underinvest in green (i.e., carbon-free) assets to strengthen their case for weaker emissions reduction targets—or higher compensation—in future periods. This is similar to Harstad (2016), who argues that when countries anticipate future negotiations, they may underinvest in green capital for fear of being required to achieve higher emissions reductions. At the firm level, and in the context of permit markets, Harstad and Eskeland (2010) argue that firms, anticipating that high-cost firms will receive more permits in the future, could purchase excessive amounts of permits to signal high cost.

The remainder of this paper is organized as follows. Section 2 establishes the role of expectations and how they affect policy credibility. Section 3 presents the backward induction approach to climate policy. Section 4 describes a regulatory strategy to implement backward induction. Section 5 concludes.

2. Investors' Expectations and Climate Policy Credibility

Credibility is tied to the role of expectations for private investment decisions. To put the world on an emissions reduction path to net-zero emissions by 2050, very substantial mobilization of private capital is required. The International Energy Agency suggests that almost $4 trillion a year is needed for clean energy financing (IEA 2021) (Figure 1), and the Global Financial Alliance for Net Zero places the multisectoral investment needs at $125 trillion through 2050 (Race to Zero 2021). This suggests that about 70 percent of the financing needs will have to be provided by the private sector, with public funding playing a catalyzing role.

Figure 1. Annual Average Clean Energy Financing by Sources in Announced Pledges and Net-Zero Scenarios, 2016–2030



Note: The differentiation of private vs. public investment in different studies emphasizes the key role of private investments. Figures to the left of the dashed vertical line are from IEA (2021) and refer to *annual world* investment (in 2020 USD) required over the period 2026-2030 under two different emissions reduction scenarios. The figure to the right of the vertical dashed line is from Wood Mackenzie (2022) and represents *cumulative* expected investment in the *United States* over the period 2022-2035 (in 2022 USD) as a result of the Inflation Reduction Act.

The long lifetimes and irreversibility of capital investments make investment decisions highly sensitive to expectations about future policies, implying that "getting expectations right" is the key to achieving net zero (Box 1). Unless emissions-intensive capital is retired before the end of its economically valuable lifetime (IEA 2021), investment decisions made in this decade will play a large part in determining countries' emissions pathways through 2050. Thus, to stimulate the requisite private sector investment in emissions-free (or emissions-abating) technologies, regulators need to take actions, introduce policies (or more broadly, climate policy pathways), and use other means (e.g., narratives) to anchor long-term private sector expectations around an ever more stringent climate policy path. In other words, regulators must align private investors' expectations about the policy outcome with the stated long-term goal.[4]

Box 1. Policy Credibility

Formally, policy pathway credibility (h_t) at any time t can thus be defined as the difference between the chosen policy *target* ($\bar{e}_T$) and the *expected* ($\mathbb{E}[e_T]$) emissions level in the target year T[1]:

$$h_t = \bar{e}_T - \mathbb{E}_t[e_T]$$

where, for all t, $\mathbb{E}_t[e_T] = e_t + \mathbb{E}(\sum_{t+1}^{T} e_{i+1} - e_i)$ and $e \equiv z(p)$, with p denoting policy stringency and $z(.)$ being a mapping from policy stringency to emissions. Assuming $e \in [0, \infty)$, credibility, h_t, is decreasing in $\mathbb{E}_t[e_T]$ and comprised in $(-\infty, \bar{e}_T]$. For example, credibility would be undermined if emissions in $T-1$ were not on a plausible pathway to achieve the emissions level in T. In addition, note that $e_{i+1} - e_i$ for $i = t+1, \dots, T$ is the sequence of emissions reductions.

Importantly, the expected level of emissions in the target year (T) depends on the sequence of expected emissions reduction ($e_{i+1} - e_i, for\ i = t+1, \dots, T$) between time t and T. This suggests that to affect expected emissions over the relevant time horizon, policymakers are compelled to specify, at time $t = 0$, a *credible* sequence of policies (i.e., a policy pathway) leading to net-zero emissions.

Getting expectations right requires a policy pathway that investors perceive as credible in terms of delivering net-zero emissions—and that future policymakers will stick with. In other words, investors need to move beyond viewing the net zero goal as just an imagination of the future (Beckert 2016), but instead expect to actually materialize. How can such a credible pathway be designed? The monetary policy literature on the "rules vs. discretion debate" (Dellas and Tavlas 2022) stresses that policymakers have an inherent incentive to deviate from a previously announced policy because in general it is optimal to do so, but if the path is dynamically consistent and thus credible, it is economically suboptimal (Petit 1990, 271). Hence there is a trade-off between dynamic consistency (credibility) and optimality.

[4] This requirement is compounded by the fact that those objectives imply investments of a momentous scale and result from the choices of millions of independent decisionmakers.

However, the literature concludes that dynamic consistency is warranted because the optimal path is unlikely to materialize: private actors would anticipate a future policy deviation and thus not act in accordance with the current policy.

Ensuring dynamic consistency requires dedicated commitment mechanisms, and the case for them is even stronger in climate policy. The credibility problem in monetary policy differs from the credibility problem that net zero aims to address, in two important ways. First, in the traditional monetary policy setting, firms are policy takers, in the sense that they only react to policy announcements. In climate policy, one could expect firms to be policy setters, in the sense that they are politically powerful enough to trigger future policy renegotiation (Victor and Cullenward 2020). Second, the traditional monetary policy setting does not account for different generations of policymakers (subsequent administrations), which may have different political priorities. This is a well-known challenge for long-term policies in democracies (Jacobs 2016). Relatedly, a net-zero target compels policymakers to refrain from evading action by saying there is no need to be stringent now because we can always make things more stringent in policy adjustments later on. Since policymakers cannot make irrevocable commitments to the target (Brunner et al. 2012), dedicated mechanisms (i.e., instructions and incentives) must be used to bind future policymakers. These mechanisms need to be integral elements of the policy pathway. The monetary literature policy recommends policy rules to that end, but it is unclear what these rules would be in the case of net zero and how to derive them. This conundrum is what we turn to next.

3. The Main Policy Rule for Net Zero: Getting Expectations Right

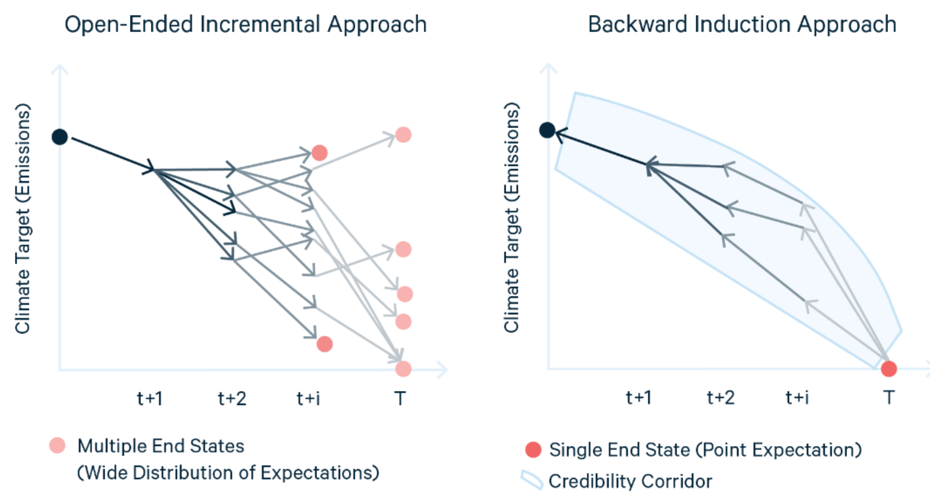
Our interest lies in identifying the high-level rule or rules that generate and govern policies and related institutions along the pathway to net zero. We draw on insights from dynamic optimization theory, first establishing the characteristics of the formal solution of the prevailing open-ended incremental approach,[5] and then contrasting it with the specification of the problem as required by net zero.

The open-ended incremental approach derives policies starting from the present (status quo) and periodically adjusts these policies (climate goal and instruments) as new information arrives and the cost-benefit calculation changes. Historically, the high uncertainty about climate change damages made it challenging to identify and narrow the distribution of optimal long-term goals. Although the approach provides flexibility to adjust the emissions target and policy mix in light of new

[5] In economic terms, the former approach can be characterized as cost-benefit analysis with both costs and benefits being (highly) uncertain; the latter approach can be characterized as cost-benefit analysis where uncertainty in benefits is deemed to have low relevance to policy decisions and optimization should be primarily subjected to reducing cost uncertainty.

information, it ensures attainment of only the initial steps toward achieving the emissions target in the short term, until the goal is reevaluated. But as pointed out above, reevaluations might reflect not just new information but also the strategic behavior of firms and future governments. Private investors may come to expect a wide distribution of possible long-term policy goals, $\bar{e}_T$ (Figure 2, left panel), and the corresponding uncertainty implies that abatement investments are delayed or not made at all. Hence, the open-ended approach precludes the design of a dynamically consistent policy pathway to net-zero emissions.

Figure 2. Open-Ended Incremental and Backward Induction Approaches



Note: This figure illustrates the contrast between policy pathways under the open-ended incremental (left panel) and the backward induction (right panel) approaches. Under the open-ended incremental approach, policy pathways are constantly adjusted to minimize cost from the adjustment period onwards. But the underlying climate policy rules of the game are also open for constant renegotiation and thus lead to a broad distribution of expected emissions outcome. Net zero can narrow expectations to a specific end state, but then credibility becomes the key concern. The backward induction approach addresses it by stipulating that maximizing credibility must be the objective for designing policy pathways. This requires ensuring dynamic consistency in the sense that adjustments by future administrations stays within a certain corridor, i.e. ultimately a much narrower range of policy pathways.

Net Zero aims to address that problem by making the cumulative emissions goal rigid, thus shifting the focus toward policy mixes that can incrementally strengthen commitment to a policy pathway while progressing along it—that is, it identifies the sequence of policy mixes that lead to net zero while satisfying the condition of dynamic consistency (see Figure 2, right panel). A net-zero target enables such an approach because it sets a clear endpoint, which reduces the dimensionality of the problem, thereby constraining the space for political negotiation and, therefore, private actors' expectations.

But how does Net Zero change the high-level rules that govern the design of the policy pathway? Our starting point is the realization that net zero converts the climate policy problem from an open-ended optimal choice problem to a finite dynamic game. To understand the implications, we seek guidance from theory by turning to the formal approach that can be used to solve both problems: backward induction by means of the Bellman principle (Box 2). Its core idea is to search backward in time for the system states (x_t) and policies (a_t) at each time that have the highest value in achieving the policy objective.

Box 2. The Bellman Foundation in a Net-Zero Climate Policy Context

$$V(x) = \max_{a \in \Gamma(x)} \{F(x,a) + \beta V(T(x,a))\}$$

where V is the value function, F is the objective function (total climate policy cost), x is the state of the system (technological, social, infrastructure, etc.), a is the policy function; $\Gamma(x)$ is the set of possible actions given the current state, and β is a discount factor representing a preference for payoffs achieved in the near term. Note that in this framework, net-zero emission is introduced as a transversality condition.

The value function describes the best possible value of the objective, given the current state x. It is the expectation that if the system is in state x_i at time t_i, the transversality condition is met (i.e., the policy is credible). The lower the value of a system's state at a given point of time (i.e., the more costly it is to achieve the objective), the lower the credibility of the pathway.

In the open-ended approach, the main high-level policy rules are to "get the prices right" and pursue the least-cost options first. From an economic point of view, the objective is to minimize costs over a potentially infinite time horizon. This implies the following two rules. First, because the problem is open ended, the solution to the Bellman equation is not a rule that defines a unique policy pathway, but just a rule for what policy is optimal from period to period (den Haan 2022). Correspondingly, policy should create incentives to take the least-cost options first. Second, cost minimization implies that getting the prices right (in the current period) is the main criterion. However, the cost-optimal solution of the Bellman equation is not dynamically consistent because it ignores firms' expectations that future governments may not follow through on the current plans (Petit 1990, 271).

By contrast, in the approach implied by net zero, the main high-level policy rules are "getting expectations right" and pursuing options that enhance credibility over time. The first rule derives from the fact that net zero turns the open-ended problem into a finite problem. This implies that the solution of the Bellman equation is a unique policy pathway characterized by the state of the system at the final period T (transversality condition = net-zero goal). This, in turn, implies that expectations must be right, in the sense of aligning with this pathway. Furthermore, the objective of minimizing costs does not lead to dynamic consistency (see above). Consequently, to achieve net-zero emissions, the objective function must change from minimizing the cost of the policy to maximizing its credibility—implying a dynamically consistent pathway—with cost being integral to policy credibility. These policy rules compel an approach that is similar in spirit to formal backward induction.

Table 1 summarizes the contrast between the two approaches.

Table 1. Open-Ended Incremental and Backward Induction Approaches, Compared

	Open-Ended Incremental	Backward Induction
Long-Term Goal	Flexible	Rigid
Corresponding Formal Problem	Optimal recursive control problem	Finite Dynamic Game
High-Level Policy Rule	Efficiently, *getting the prices right*	Commitment to ensure dynamic consistency, *getting expectations right*
Policy Cost Consideration	Pursue least-cost options first while learning over time	Reduce (long-term) marginal cost through systemic change
Private Sector Expectations	Implied: Future is uncertain, investment risk inherent	Managed: "getting expectations right"
Quality of Policy Pathway	(Cost) optimal but time inconsistent	Time consistent but (cost) suboptimal

The reorientation of the objective has important implications for policymaking. First, the main criterion for policy choice (a_t) becomes changing the system to make the pathway more credible in the long run. That is, it calls for implementing (near-term) policies that will enable long-run system change. Some policies may have high upfront cost and lead to modest emissions reduction in the short run, but they change the future marginal cost of certain abatement options (Vogt-Schilb et al. 2018). Second, the policy pathway must prevent deviations from the emissions trajectory, which therefore must be specified at time zero (Figure 2). This can be done through compliance institutions that ensure that the system change takes the right direction and pace to remain on track for the emissions reduction goal. In the following section, we discuss implementation of net zero in a regulatory strategy.

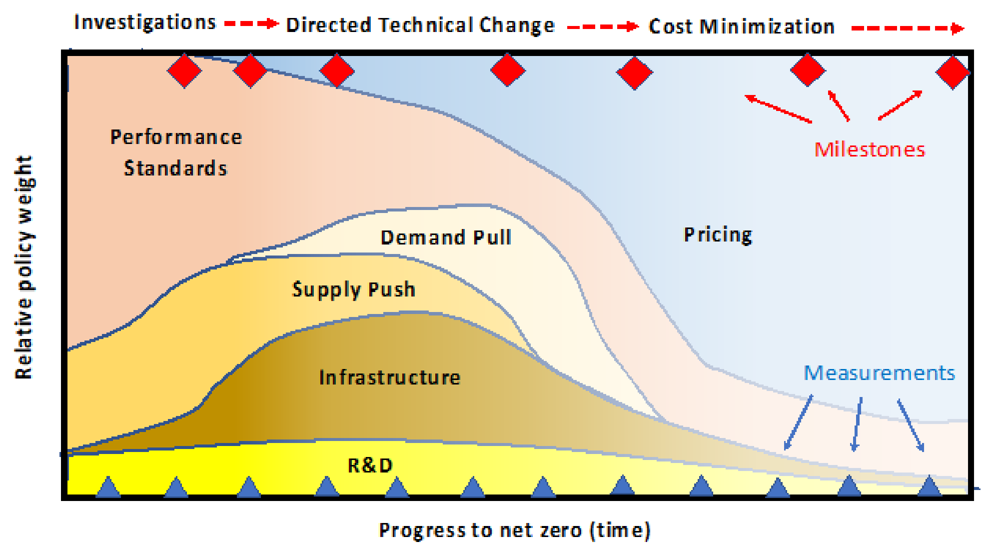
4. Implementing Backward Induction in a Regulatory Strategy

A regulatory strategy implementing the backward induction approach has two basic components: (i) policy instruments that advance system change by creating (pre)commitment for higher stringency in the future; and (ii) compliance institutions that act on deviations from the set emissions pathway. Additional aspects that can enhance credibility include design of rules, transparency and trust, political economy considerations, and policy robustness (Nemet et al. 2017).

Policy instruments. Policies to advance system change can both constrain (Acemoglu et al. 2012) and expand (Meckling et al. 2015; Pahle et al. 2018) the incentives and choices of future policymakers. To discourage decisions to deviate from the pathway and enable decisions to adhere to it, policies are best designed with a phase-in and phase-out logic. Phase-in policies address low-carbon technologies and institutions to ensure (i) a reduction in their long-term costs of abatement; and (ii) change in the structure of capital assets (i.e., stock). For example, regulators could use sustainable finance policy—even though it is economically inefficient—that would continue to induce stricter environmental measures despite a possible change in administration (Fuest and Meier 2022). Phase-outs, intended to wring carbon-intensive technologies and institutions out of the system, could take the form of bans or increasingly stringent performance standards. Such policies may be cost-ineffective but they arguably are hard to revoke and thus can anchor the expectation that carbon-intensive technology is ending—similar to the effect of net zero for emissions overall. They are particularly hard to revoke if they unlock private sector investments to develop new technology, triggering accelerated reductions in cost of the technology and eventually making the ban nonbinding.

The identification of phase-in and phase-out as (pre)commitment devices raises questions about the timing and sequence of the policy instruments. Much depends on the circumstances of the policy settings and the jurisdiction, requiring analysis that would go beyond the scope of this work. Here we provide an example comprising three stages (Figure 3), beginning with multidisciplinary investigations, moving through directed technological change, and increasingly focusing on (short-run) cost minimization once an emissions-free technology pathway is established. Economists' first-best instrument, carbon pricing, is still deployed, but its timing and role would change. Introduced at a later stage of the policy pathway, it could prove extremely valuable for improving the static efficiency of emissions reductions and driving further emissions reductions. Furthermore, and equally important in this context, given the high political costs of implementing carbon pricing, governments can signal that they are committed to net zero.

Figure 3. Illustrative Dynamically Consistent Policy Pathway to Net Zero



Note: The vertical axis denotes the share of the policy portfolio. Backward induction identifies a policy portfolio and sector-specific technology, cost, and emissions milestones. The portfolio shapes expectations about the net-zero goal and motivates and coordinates private sector investments. Further adjustments to the portfolio, and potentially to the timing of milestones, may occur based on scheduled evaluations, but the net-zero goal remains firm.

Instruments other than carbon pricing would kick in earlier. The first is public investment in infrastructure or subsidies for private investment in green capital (Harstad 2020), which change the structure of (physical) capital assets and alter the incentives and rewards inherited by future policymakers (Gerlagh and Liski 2018; Dengler et al. 2018). For example, to unlock the full potential of the US Inflation Reduction Act early investments in electricity transmission infrastructure are key (Jenkins et al. 2022). Relatedly, bonds that finance such investments commit future governments to continued payment for them. Second are regulatory designs that force technological innovation and strategies that grow supportive constituencies to sustain commitment by future policymakers. For instance, priority given to ancillary benefits such as clean air and environmental justice builds coalitions and supply-push policies develop infant industries that advocate for their interests (Grey 2018). Performance standards induce private sector investments that lock in technological tipping points.

Compliance institutions. This component of the backward induction approach institutionalizes the goal (e.g., through legal recognition) as well as progress control (e.g., milestones) and policy feedback mechanisms (i.e., processes that make progress in emissions reductions and system change transparent and actionable). In principle compliance could be ensured through a cap-and-trade program that caps emissions at the necessary level. However, if carbon prices rise too steeply and become politically unacceptable, they might lead to a softening of the cap (Pahle et al. 2022). This is where milestones come into play: they ultimately reinforce the cap by ensuring that costs will be kept at a sufficiently modest level, thus enhancing its credibility.

To the end of reinforcing the credibility of the cap, milestones fulfil two purposes. First, they provide a clear metric to measure progress and to hold the public authority accountable—for example, through judicial review. But sometimes, emissions reductions are due not to policy but to economic downturns. Accordingly, progress should be measured more broadly, on the level of systemic change. This requires identifying technology and institutional milestones that are in line with system transformation that drive down long-run abatement costs, increasing credibility. Milestones could be defined as attainment of salient indicators (e.g., technology cost, regulatory frameworks, nth of a kind deployment, infrastructure, green financing for the developing world), along with emissions targets, and be differentiated across sectors (Figure 3). The (non)achievement of milestones would serve as an early-warning system if jurisdictions lag in long-term systemic change (Fietze et al. 2021).

In fact, in some jurisdictions that have adopted ambitious net-zero targets, progress measures and remedies for nonattainment are gaining traction. For instance, in the EU proposals have recently been made how to measure the progress towards net zero (Duwe et al. 2022), and the EU's Scientific Advisory Board on Climate Change now aims to "develop a methodology to assess progress of the EU and its Member States towards the objectives of the European Climate Law, ensuring to avoid duplication with the work of other organisations" (EEA 2022). Furthermore, to reach net-zero emissions, Germany's climate law defines annual emissions targets for all sectors through 2045. If the targets are not met, ministries must propose immediate action programs to close the gap. While this particular institutional approach has a number of shortcomings that need to be addressed (German Council of Experts on Climate Change 2022), reacting to insufficient progress is an important complement to the measurement of progress.

Milestones' second purpose is to trigger a transition to the next phase of the policy pathway. Future policies may evolve in response to progress in achieving milestones (e.g., the less definitive vision of the policy instruments to be employed later in time in Figure 3). For instance, Sivaram et al. (2021) suggest to resort to different demand-pull policies according to stages of technology development. By tying policy change and reform to the attainment of milestones, policymakers could lay out a plan for long-term policy evaluation. Future policymakers could deviate from that plan and delay the introduction of more stringent instruments, but the deviation from the policy pathway would be transparent and allow for accountability.

What if a milestone is delayed because of new information—for example, about technology costs—that calls into question the basis for the policy? A credible regulatory strategy must be adjustable in light of new knowledge. Two observations can be made. First is whether adjustment occurs through defined institutional processes (rules) or regulatory discretion. Rules-based mechanisms, which could be embedded in the policy instruments themselves, are typically quicker than discretionary administrative processes; agents know the policy rules and can form expectations based on them, and their automatic nature builds credibility.[6] It is possible to envisage policy instruments with built-in adjustment mechanisms: a declining feed-in-tariff or a declining renewable energy credit price if emissions targets are met, for example, or a rising carbon tax if they are not. Similarly, the supply of allowances in carbon markets can be automatically and instantaneously adjusted in response to the effectiveness of companion policies and changes in costs (Burtraw et al. 2022) in order to avoid the time-inconsistency problem inherent in carbon pricing (Gollier & Tirole 2015). Paradoxically perhaps, adjustability enhances the durability of policies in light of scientific, technological, and economic discoveries over time (Carlson and Burtraw 2019).[7] Furthermore, overlapping policies provide a different type of automatic mechanism. For instance, if a relatively cost-effective flexible policy fails to reach a milestone, a coincident and more prescriptive mechanism—for example, an increasingly stringent and less flexible emissions standard—becomes the operational influence driving systemic change.

5. Conclusion

The adoption of net-zero emissions goals by more and more jurisdictions to meet the Paris climate goal has shifted the credibility issue form the goal to the policy pathways required to achieve it. We argue that net zero pathways require a different approach to climate policymaking than the open-ended incremental approach used so far. We propose a new approach, backward induction, which explicitly accounts for this condition. Importantly, this approach is enabled by a specific target like net zero. It leads us to consider dimensions of the policy landscape and instruments that have been undervalued in the conventional open-ended incremental approach, which has justified, on normative grounds, a portfolio of second-best instruments that cannot be politically achieved and may not be efficient when the goal is subject to reexamination and updating (Stern 2018). Furthermore, it shifts emphasis from policy design to policy implementation and governance, in particular for aspects conducive to commitment like accountability, transparency, delegation, and the robustness of rules.

The backward induction approach invites additional research on the policy formation process, credibility, implementation in the climate context, and learning. Most policy analysts in fact aim to solve the dynamic problem, but they often slight the potential for time inconsistency and thus give too little weight to investments in durable (irreversible) capital and technological change. We conjecture that with a set goal like net zero and a backward induction approach to climate policy, social learning would occur more quickly than under incremental goals. As a result, early revisions to the

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[6] Aldy et al. (2017) argue for "structured discretion" on the part of the regulator.
[7] For instance, China has a centralized target-setting and monitoring approach; the alignment of the UK government's climate policies with its stated emissions target is monitored by the Climate Change Committee (Dubash and Joseph 2016); Sweden's Climate Policy Council offers a comprehensive annual report to parliament to evaluate progress in achieving national policy goals.

policy mix could prevent us from taking a policy path that fails to reach the goal—and thus from revising the goal itself.

Our work also has implications for the evaluation of long-term policy packages, such as the recent EU Fit-for-55 package and the US Inflation Reduction Act. It defines a benchmark—a reference point—for determining whether these packages can achieve net zero. For instance, the EU package contains several elements of the net-zero regulatory strategy we describe, notably phase-outs of carbon-intensive technologies (e.g., internal combustion engines by 2035) and the phase-in of carbon pricing for buildings and transportations sectors by 2027 (features of stage 2 in the illustrative policy pathway, Figure 2 above). The US package is less advanced but has several elements that promise evolution in the right direction, notably "sticky" tax credits that can induce major system change in the electricity sector. The complexity of both packages requires in-depth analysis—research that could also be used for refining expert elicitations of the credibility of climate commitments (Victor et al. 2022).

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