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Article

Emissions Lock-in, Capacity, and Public Opinion: How Insights From Political Science Can Inform Climate Modeling Efforts

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Abstract
The implementation of ambitious climate policies consistent with the goals of the Paris Agreement is fundamentally influenced by political dynamics. Yet, thus far, climate mitigation pathways developed by integrated assessment models (IAMs) have devoted limited attention to the political drivers of climate policymaking. Bringing together insights from the political science and socio-technical transitions literature, we summarize evidence on how emissions lock-in, capacity, and public opinion can shape climate policy ambition. We employ a set of indicators to describe how these three factors vary across countries and regions, highlighting context-specific challenges and enablers of climate policy ambition. We outline existing studies that incorporate political factors in IAMs and propose a framework to employ empirical data to build climate mitigation scenarios that incorporate political dynamics. Our findings show that there is substantial heterogeneity in key political drivers of climate policy ambition within IAM regions, calling for a more disaggregated regional grouping within models. Importantly, we highlight that the political challenges and enablers of climate policy ambition considerably vary across regions, suggesting that future modeling efforts incorporating political dynamics can significantly increase the realism of IAM scenarios.

Keywords
climate policy ambition; climate modeling; climate policymaking; climate politics; emissions lock-in; integrated assessment models; Paris Agreement; public opinion; public support; state capacity

Issue
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1. Introduction

The international scientific community asserts clearly that rapid and substantial reductions in greenhouse gas (GHG) emissions are required to avert irreversible damages to the earth's climate and limit the most adverse environmental and economic impacts of climate change (Intergovernmental Panel on Climate Change [IPCC], 2021). More than 190 countries have signed the 2015 Paris Agreement, whose long-term goal is to keep the global average temperature increase to well below 2 °C compared to pre-industrial levels and to pursue efforts to keep it below 1.5 °C. Reaching this goal will require implementing ambitious climate mitigation policies. Research in different disciplines investigates the strategies that can contribute effectively to climate mitigation efforts. In this context, integrated assessment models (IAMs) are important tools that feature prominently in the reports of the IPCC. IAMs model the economic, energy, land, and climate systems and can be used to study the implications of countries' climate mitigation policies and pledges or to identify pathways that allow reaching climate mitigation goals (Bosetti, 2021). IAMs are very sophisticated in their incorporation of geophysical, technological, and economic factors. However, the academic community is increasingly paying attention to how IAM scenarios compare to real-world conditions (Brutschin, Pianta, et al., 2021; Cherp et al., in press; Jewell & Cherp, 2020; O'Neill et al., 2020; Trutnevyte et al., 2019; van Sluisveld et al., 2015; Vinichenko et al., 2021; Wilson & Grubler, 2011). In particular, IAMs have been criticized for not incorporating important social, political, and behavioral elements that fundamentally shape the low-carbon transition (Turnheim & Nykvist, 2019; Victor, 2015). This is because IAMs were originally designed to identify mitigation pathways that minimize overall mitigation costs (Żebrowski et al., 2022), which often leads them to produce scenarios where considerable mitigation effort is present in developing regions, where mitigation is less costly. In these regions, however, mitigation might be more challenging because of social or political factors, such as a lack of capacity or political support to prioritize climate mitigation goals. Incorporating political factors into IAMs can allow producing scenarios that might more closely mirror mitigation potential across regions and contribute to identifying context-specific enablers of more ambitious climate action in different countries and regions. Considering the substantial policy impact of the IAM scenarios featured in the IPCC reports, which are used by policymakers to set long-term climate mitigation goals—such as the so-called "net zero" commitments undertaken by the European Union, China, and other countries (Rogelj et al., 2021; van Beek et al., 2020)—it is essential to incorporate social and political dynamics into future IAM modelling efforts.

Climate policymaking, like other policy domains, is crucially determined by domestic political dynamics (Aklin & Mildenberger, 2020; Geels et al., 2017; Mildenberger, 2020). However, it is only recently that the climate modeling community has started to incorporate insights from political science (Dasgupta & De Cian, 2018; Peng, Iyer, Binsted, et al., 2021; Shen, 2021) and the mainstream political science literature is starting to pay more attention to the politics of climate change (Green & Hale, 2017; Javeline, 2014; Keohane, 2015). Political science research highlights how factors like state capacity, the influence of interest groups, and the role of public opinion can affect climate policy ambition. The configuration of these factors in different countries and contexts can produce different challenges for the implementation of ambitious climate policies (Bailey & Compston, 2012; VanDeveer et al., 2022).

In this article, we bring together key insights from political science and socio-technical transitions research on the challenges and enablers of ambitious climate mitigation policy and suggest how they can be incorporated into integrated assessment modeling efforts. We focus here on climate mitigation policies, defined, in line with the IPCC reports (IPCC, 2018; Roelfsema et al., 2022) as policies that aim to reduce or prevent GHG emissions, thus contributing to reaching the goals of the Paris Agreement.

We build on and extend past efforts to highlight key constraints affecting climate policy stringency and ambition (Lamb & Minx, 2020; Tørstad et al., 2020). Our goal is to provide a relatively simple framework that focuses on the drivers of policy outputs and outcomes about which there is a broader agreement in the literature. Our framework can be employed to highlight the main potential bottlenecks across countries and regions. We focus on three key factors driving climate policymaking at the domestic level: emissions lock-in, capacity, and public opinion. We do not argue that these three factors are key drivers of climate policy ambition in each context, but we stress that their incorporation in IAMs modeling efforts can allow the production of scenarios that more closely mirror likely real-world mitigation trajectories.

A first key factor shaping the speed of the low-carbon transition is the degree of entrenchment of economic systems in emission-intensive structures, usually referred to as carbon lock-in (Seto et al., 2016; Unruh, 2000), and the consequent opposition of vested interests—economic, social, or political actors who benefit from the current system and have strong incentives to oppose reforms that would alter the status quo (T. M. Moe, 2015). In energy transition research, carbon lock-in and vested interests are often proxied by measuring the entrenchment of fossil sources in the electricity and industrial sector (Erickson et al., 2015; Lamb & Minx, 2020). However, achieving climate mitigation goals will also require transformations of the agriculture, forestry, and land-use sectors. We, therefore, propose to expand the focus from carbon lock-in to the broader concept of "emissions lock-in."

A second key enabler of climate policy ambition identified by the literature is state capacity (Hanson & Sigman, 2021; Meckling & Nahm, 2021). Capacity can be operationalized through different types of capabilities. We argue that in the context of climate policy, three types of capabilities play a fundamental role in mitigation: governance capabilities, which refer to the general ability of the state to implement goals and policies (Cingolani, 2013); economic capabilities, which refer to the economic resources and market environment that can enable investments in the transition; and technological capabilities, that can enable technological innovation and the diffusion of low-carbon technologies (Brutschin, Cherp, et al., 2021; Eskander & Fankhauser, 2020).

Finally, public support for climate policies can create significant incentives for policymakers to implement ambitious climate action. A broad political science literature has shown that public opinion has an impact on policy decisions (Burstein, 2003; Wlezien & Soroka, 2012), and research on the impact of public opinion on climate policymaking is gaining more attention (Bakaki et al., 2020; Schaffer et al., 2021). We argue that public opinion is a third key factor whose role should be better incorporated into modeling efforts (Peng, Iyer, Binsted et al., 2021), importantly taking into account the differentiated impact of public opinion in democratic and non-democratic settings.

We propose a simple operationalization of these three concepts based on a selection of indicators and explore their variation across countries to identify context-specific challenges and enablers of climate policy ambition. Table 1 summarizes the selected indicators for each of the three concepts (see Table S1 in the Supplementary Material for details on the indicators and their sources). Different arguments can be made to motivate the selection of the key political determinants of climate policy ambition and the indicators that should be employed to measure them. Our selection is based on a review of the relevant literature and made for descriptive purposes. As our objective is to highlight how these factors can be incorporated in IAMs, we have striven to develop a simple framework that allows us to assess variation in political environments across and within IAM modeling regions (see a map of the most common regional aggregation of global IAMs in Figure 1 and the classification of countries in the five regions in Table S3 in the Supplementary Material).

The remainder of this article is organized as follows. Sections 2 to 4 focus on the conceptualization and operationalization of emissions lock-in, capacity, and public opinion, providing descriptive evidence on the variation of these factors across countries and regions. Section 5 summarizes evidence of the variation of these three factors across the five IAM modeling regions. Section 6 reflects on how these insights from political science can be incorporated into IAMs, and Section 7 concludes, highlighting the main insights from the article and calling for more empirical work that can lead to improvements in the assumptions adopted by IAMs. The link to access the article's replication package is made available in the Supplementary Material.

2. Emissions Lock-In

A key aspect shaping countries' likelihood of implementing ambitious climate policies is their current emission levels. In this context, Unruh (2000) has coined the term "carbon lock-in" to describe how technological systems and institutional factors have coevolved to lock industrial economies into fossil-dependent pathways. Vested interests (economic, social, or political actors who benefit from the current system and have strong incentives to oppose reforms that would alter the status quo) and the dependence on emitting sectors and technologies have been shown to have a fundamental impact on energy and climate policy decisions (Cherp et al., 2018; E. Moe, 2016). Most of the existing literature on the role of carbon lock-in and vested interests focuses on the challenges to reduce carbon dioxide emissions from fossil sources (Erickson et al., 2015; Lamb & Minx,

Table 1. Summary of the concepts and indicators that we propose to use to assess cross-country and cross-regional variation of political drivers of climate policy ambition.

Concept	Guiding question	Indicators
Emissions lock-in	What type of *resistance* to reducing emissions can be expected in a country, both on the *production* side (interest-based opposition) and on the *consumption* side (resistance to shifting consumption patterns)?	Carbon lock-in: • CO_2 emissions (consumption) • Fossil rents (production) Methane lock-in: • Per capita methane emissions in the agriculture, forestry, and other land use (AFOLU) sector (consumption) • Share of agriculture in GDP (production)
Capacity	Does a country have the *capabilities* to implement ambitious climate policies and develop and scale-up new low-carbon technologies?	Governance capabilities: • Government effectiveness • Rule of law Economic capabilities: • GDP per capita • Ease of doing business Technological capabilities: • R&D as % of GDP • STEM graduates as % of total graduates
Public Support	How likely is it that in a country there will be sufficient *public support* to implement ambitious climate policies?	Environmental attitudes Postmaterialist values

Note: Details on the indicators and their sources are provided in Table S1 of the Supplementary Material.

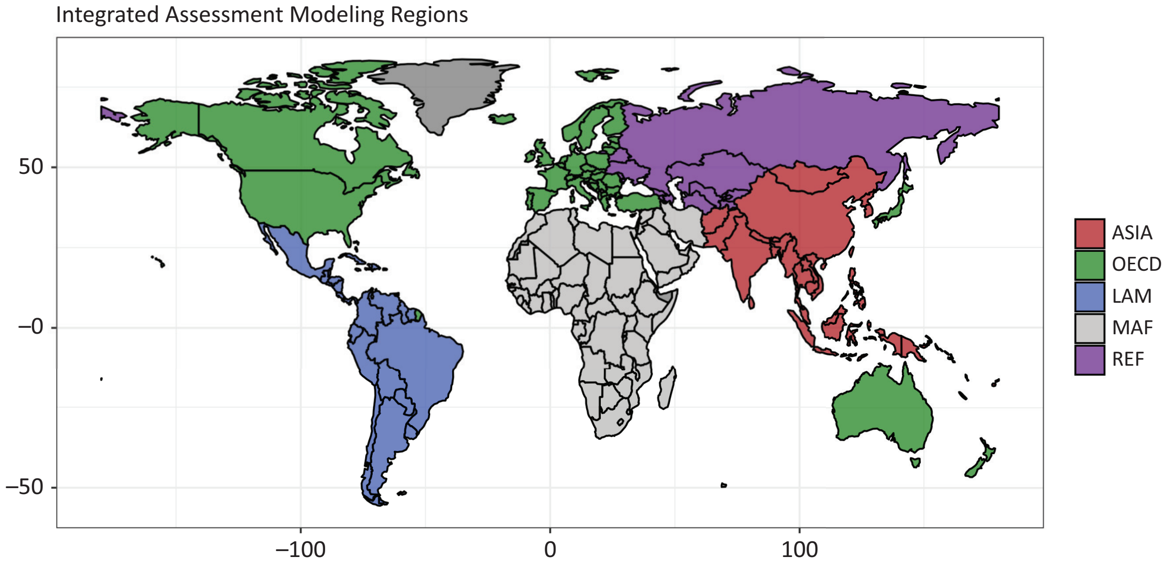

Figure 1. The most common regional aggregation of global IAMs, employed in the *5th IPCC Assessment Report*. Notes: The five regions are OECD, REF (reforming economies, or former Soviet Union countries), LAM (Latin and Central America), MAF (Middle East and Africa), and ASIA (Asian countries, excluding the Middle East, Japan, Korea, and former Soviet Union countries).

2020). However, emissions of other GHGs significantly contribute to global warming, with methane accounting for about 40% of the contribution of GHGs to short-term global warming (Cain et al., 2022; Höglund-Isaksson et al., 2020; IPCC, 2014; Saunois et al., 2020; Shindell et al., 2017). Mitigation will therefore require important changes also in the agricultural sector (Fesenfeld et al., 2018), raising different challenges and potential opposition from different interest groups, in particular in countries whose economies are more dependent on agriculture. Moreover, lock-in dynamics are present both on the production and on the consumption side. It is therefore important to incorporate both the power of producers in incumbent sectors and the dependence on emitting sources on the consumption side, linked for instance to the resistance to shifting consumption patterns.

To provide a comprehensive picture, we propose to measure emissions lock-in by employing four indicators, covering both the production and the consumption side not only in the energy and industry sectors, which are responsible for most carbon emissions, but also in the agricultural sector, which is responsible for most methane emissions. To proxy the carbon lock-in in the energy and industry sectors, we use (a) the share of fossil fuels in electricity generation (for the consumption side) and (b) fossil rent as a share of GDP (for the production side); to proxy the methane lock-in in the agricultural sector, we use (c) per capita methane emissions in the AFOLU sector (for the consumption side) and (d) the share of agriculture in GDP (for the production side).

Figure 2 visualizes the geographical variation in emissions lock-in across countries. There is significant variation in the level and type of emissions lock-in across regions, with very high carbon lock-in in the MAF, ASIA, REF, and OECD regions, and high methane lock-in in the LAM and MAF regions, and in a few OECD countries.

3. Capacity

A second key element shaping climate policy ambition is capacity, which refers to the ability of the state to implement goals and policies (Cingolani, 2013). It refers to capabilities, including material resources and organizational competencies, that the state possesses and can employ to reach policy goals. The political science literature shows that capacity exerts considerable influence on a broad set of policy outcomes such as economic development, civil conflict, democratic consolidation, and international security (Hanson & Sigman, 2021). Capacity has also been shown to be a key driver of climate and energy policy (Aklin & Urpelainen, 2013; Eskander & Fankhauser, 2020; Jewell et al., 2019; Levi et al., 2020). Different capabilities are relevant to different functions of the state. Building on a broad low-carbon transition literature, we argue that three categories of capabilities are relevant for climate policy implementation: (a) governance capabilities, (b) economic capabilities, and (c) technological capabilities.

3.1. Governance Capabilities

Governance capacity, defined as the ability to make and enforce policy decisions, is the first key element shaping the ability of a country to reach policy goals. Countries with high governance capacity have been shown to be more likely to phase out coal (Jewell et al., 2019), have higher deployment rates of renewable energy (Aklin & Urpelainen, 2013), have higher levels of carbon prices

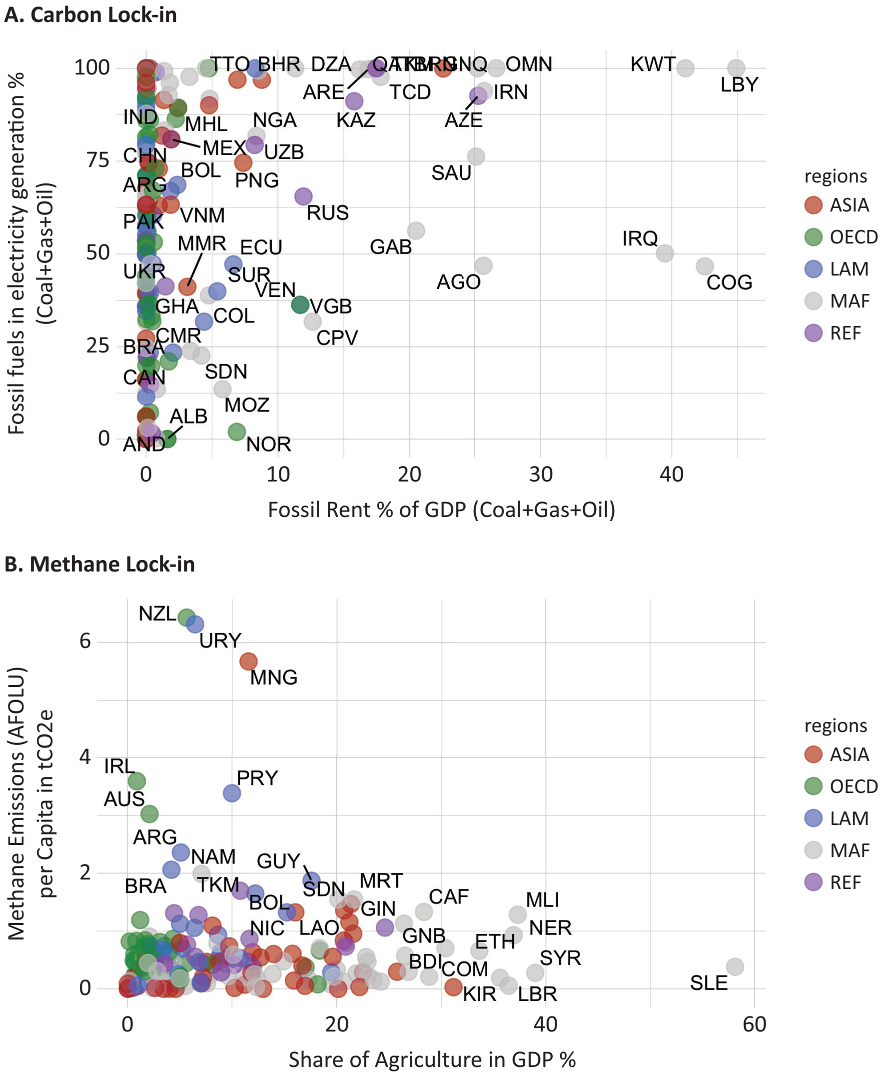

Figure 2. Geographical variation in emissions lock-in. Notes: Panel A includes a scatterplot of countries with the share of fossil fuels in electricity generation on the y-axis and fossil rent as a share of GDP on the x-axis; panel B focuses on methane lock-in in the agricultural sector, with per capita methane emissions in the AFOLU sector on the y-axis and the share of agriculture in GDP on the x-axis; values are from 2019; Table S1 in the Supplementary Material provides details on all the data sources.

(Levi et al., 2020), be better at implementing climate laws (Eskander & Fankhauser, 2020), and have better air quality (Danish et al., 2019; Halkos, 2013).

The most widely used measures of governance capacity are the World Bank Worldwide Governance Indicators (Kraay et al., 2010). We propose to employ two indicators, measuring (a) government effectiveness, defined as the ability of the government to provide public services and to formulate and implement public policies, and (b) the rule of law, defined as the extent to which agents have confidence in and abide by the rules of society. Figure 3 visualizes the geographical variation in governance capabilities across countries belonging to different IAM regions. There is significant cross- and within-regional variation in governance capabilities. OECD countries generally score highest on both indicators, followed by countries in the ASIA region. Governance capacity can be a key enabler of mitigation in these regions; in other regions, capacity building can contribute to increasing the likelihood of more ambitious climate action.

3.2. Economic Capabilities

Economic capacity can also be a key enabler of climate mitigation action. A systematic and robust relationship has been identified between GDP per capita and the deployment of new technologies—or the phasing-out of old ones (Aguirre & Ibikunle, 2014; Brutschin, Cherp, et al., 2021; Halkos, 2013; Jewell et al., 2019). Achieving ambitious climate mitigation goals will also require major domestic and foreign investments in low-carbon technologies. Investment environments can be key enablers of the diffusion of low-carbon technologies, in particular in countries that are not frontrunners. For example, a

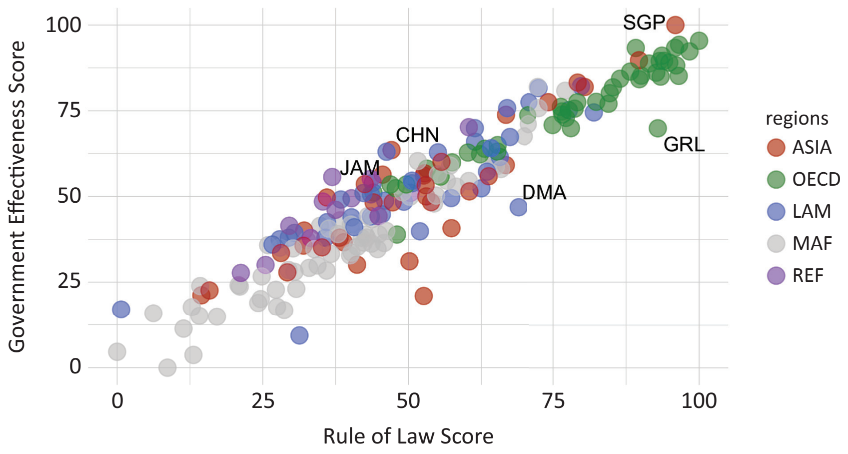

Figure 3. Geographical variation in governance capabilities. Notes: Scatterplot of countries with the World Bank Government Effectiveness and Rule of Law indicators on the y- and x-axis, respectively; the indicators are rescaled to a range from 0 to 100; values are from 2019; Table S1 in the Supplementary Material provides details on the data source.

major increase in global trade flows of solar photovoltaic technologies has been observed over recent years, with a key role played by China. We measure economic capabilities by employing two indicators: (a) GDP per capita, as a proxy of the overall domestic economic structure, and (b) the measure of "ease of doing business" developed by the World Bank, as a proxy of countries' investment environment.

Figure 4 shows the geographical variation in economic capabilities across countries. Predictably, OECD countries are well-positioned in terms of GDP per capita and market environment. On the whole, the Middle East and African countries scale low on both proxies of economic capacity, suggesting that achieving mitigation in this region might require substantial financial support from other countries. Some low-income African countries have an open investment environment, which might facilitate the diffusion of low-carbon technologies.

3.3. Technological Capabilities

Reaching ambitious climate goals will also require significant efforts in terms of technological innovation and diffusion. Technological capacity will be crucial in particular for the mitigation of emissions in the energy sector and the industrial sector. Historically, new energy technologies were often developed in OECD countries and subsequently diffused to other regions (Brutschin, Cherp, et al., 2021; Cherp et al., in press), and countries that were able to support new technologies through R&D were able to achieve higher shares of renewable energy (Aklin & Urpelainen, 2013). Substantial technological resources have been shown to be necessary, especially for the scaling up of complex and "lumpy" technologies, such as nuclear energy technologies (Brutschin & Jewell, 2018; Wilson et al., 2020). However, technological innovation and diffusion can be also key enablers of demand-side

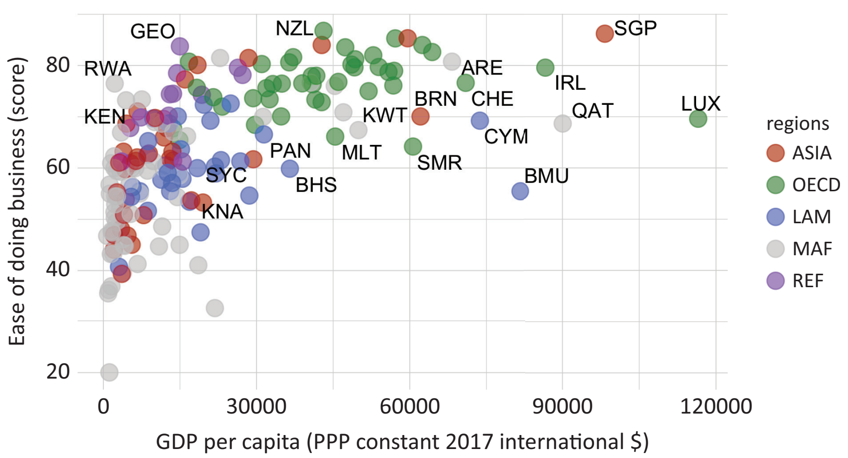

Figure 4. Geographical variation in economic capabilities. Notes: Scatterplot of countries with the World Bank Ease of Doing Business index on the y-axis and GDP per capita on the x-axis; values are from 2019; Table S1 in the Supplementary Material provides details on the data sources.

mitigation in the building and transportation sectors, facilitating the scaling up of energy efficiency technologies and low-carbon infrastructure construction.

Technological capabilities can therefore be key enablers of more ambitious climate policies. We employ two indicators to measure technological capabilities: (a) R&D investments as a share of GDP, and (b) the share of graduates in science and engineering over total graduates. Combining these two indicators allows us to identify countries and regions that are not traditionally considered global leaders in technological innovation but have a high level of human capital that can facilitate the diffusion of new low-carbon technologies. Figure 5 shows the geographical variation in technological capabilities across countries. There is substantial variation within regions. On average, not only OECD but also Asian and former Soviet countries possess high levels of technological capacity, which, in the presence of political decisions to undertake ambitious mitigation strategies, could significantly facilitate the scaling up of low-carbon technologies.

4. Public Support

Public opinion has been shown to have a significant impact on policy decisions (Adams et al., 2004; Burstein, 2003; Caughey & Warshaw, 2018; Wlezien & Soroka, 2012), also in the climate policy domain (Bakaki et al., 2020; Bromley-Trujillo & Poe, 2020; Schaffer et al., 2021; Vandeweerdt et al., 2016). Public support and opposition to different energy technologies can be important determinants of the development and diffusion of different low-carbon technologies (Boudet, 2019; Devine-Wright, 2006). Supportive public opinion can enable the implementation of ambitious climate policies, in particular in democratic countries.

A broad interdisciplinary literature has investigated the drivers of climate change belief, attention, concern, and public support for climate policies. Inglehart's post-materialist theory argues that the achievement of physical and economic security produces a shift from concerns for material security to post-materialist values, including belonging, self-expression, quality of life, and an increased concern for environmental protection (Inglehart, 1981). Indeed, different studies have documented the impact of the country's economic performance and of personal economic conditions on environmental attitudes (Duijndam & van Beukering, 2021; Scruggs & Benegal, 2012).

Unfortunately, we have no access to survey data measuring climate-specific attitudes in a broad set of countries with good coverage of all continents. We are aware that Gallup collected climate opinion data across 143 countries from 2007 to 2010 and that a second wave was collected in the past few years, but we do not have access to those datasets. The freely available dataset with the broadest geographical coverage containing information on environmental attitudes across a broad set of countries is the Integrated Values Survey (IVS), which combines the European Values Study and the World Values Survey (European Values Study & World Values Survey, 2021). We employ IVS data on environmental attitudes and post-materialist values to map cross-country and cross-regional variation in attitudes that can enable ambitious climate action. Future studies could employ climate-specific public opinion data to assess such variation more accurately.

Figure 6 displays the geographical variation in environmental attitudes—measured as the preference between environmental protection and economic growth—and post-materialist values across countries (details of survey questions are provided in Table S2 of the Supplementary Material). It is evident that OECD countries are the ones where attitudes supportive of climate policies are most prevalent, providing further evidence that it is the region where most climate mitigation

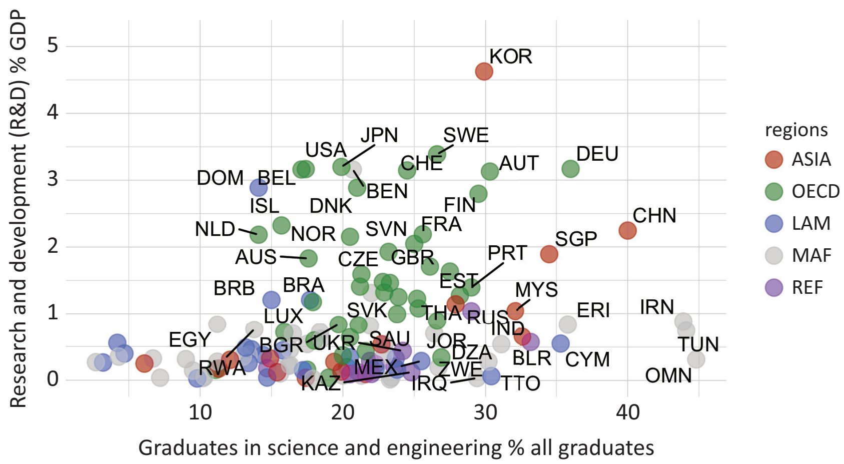

Figure 5. Geographical variation in technological capabilities. Notes: Scatterplot of countries with R&D investment as a percentage of GDP on the y-axis and the percentage of graduates in science and engineering over total graduates on the x-axis; values are from 2019; Table S1 in the Supplementary Material provides details on the data sources.

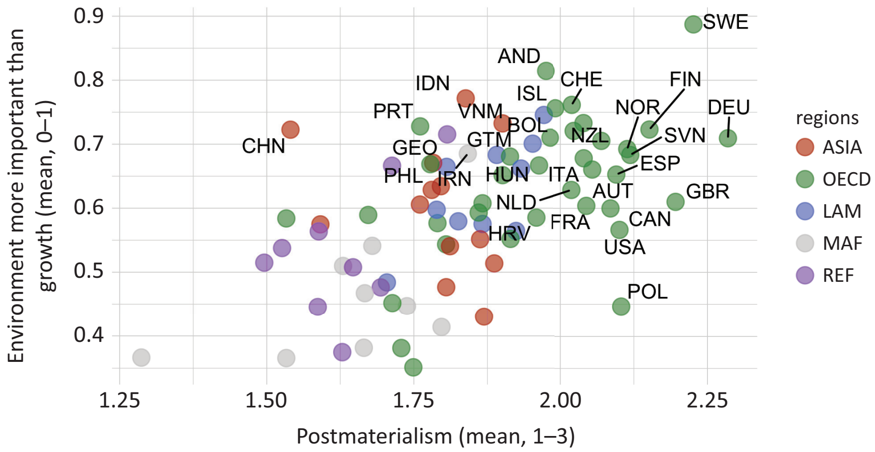

Figure 6. Geographical variation in public opinion across countries. Notes: Scatterplot of countries, with the average values of Inglehart's post-materialism index on the x-axis (country-level averages ranging from 1 to 3) and the average of a measure of preferences between environmental protection and economic growth on the y-axis (country-level averages ranging from 0 to 1); data from the last IVS wave (2017–2020); details on the measures are provided in Table S1 and S2 in the Supplementary Material.

efforts could be concentrated. Public opinion in countries of the LAM and ASIA regions could be relatively supportive of climate action, but there is considerable variation within regions. The MAF and REF regions are those whose population is potentially the least supportive of climate action.

5. An Overview of Emissions Lock-in, Capacity, and Public Support Across Integrated Assessment Modeling Regions

The purpose of this article is to give an overview of how political factors might pose challenges or act as enablers of climate policy ambition and suggest how they can be better incorporated in modeling exercises. The importance of these factors will vary across different countries and specific policy output and outcomes. To make a broad assessment of the regional heterogeneity across key enablers and constraints, we develop aggregate regional indices and report some descriptive statistics. To build these indices, we employ the following aggregation procedure: (a) we standardize each country-level indicator from 0 to 100, (b) we aggregate relevant indicators to build country-level indices for each dimension by computing their mean, and (c) we compute the population-weighted regional average of the country-level aggregate indicators.

Figure 7 illustrates aggregated regional indices for carbon lock-in, methane lock-in, governance, economic and technological capabilities, and public support. Looking at these statistics, we can see that in the OECD region, despite a high carbon lock-in, a broad set of political

Regions	Carbon lock-in	Agricultural lock-in	Governance capabilities	Economic capabilities	Technological capabilities	Public support
OECD	43.2	6	82.2	61.3	47	62.3
ASIA	44.3	13.6	51.8	39.8	47.8	49
LAM	27.5	13.5	45	38.3	26.4	53.3
MAF	35	17.6	36.6	30.9	24.4	29.5
REF	44.7	10.9	43.4	46	34.3	29.3

Figure 7. Regionally population-weighted aggregated standardized indices for key dimensions, with yellow signaling possible challenges and green signaling possible enablers. Notes: These indices are based on standardization of each of the indicators described in the article on a 0 to 100 scale, a mean-based aggregation of the indicators relevant to each dimension to build dimension-specific country-level indices, and a population-weighted regional mean-based aggregation; these values are reported for illustrative purposes and do not have mathematical meaning; the colors are assigned based on the median values of the distribution of the standardized indices in the country level data.

factors might act as enablers of climate policy ambition. In the ASIA region, lock-in is still high, but governance and technological capabilities might act as enablers of more ambitious climate policy. The LAM region faces relatively low carbon lock-in but a high lock-in of its agricultural sector and might face some challenges linked to governance, economic, and technological capabilities. In the MAF region, capacity and public support are not high, but carbon lock-in is low, and the transition might face fewer challenges, especially if there is a direct shift to a low-carbon development pathway. The REF region has high carbon lock-in and very low public support for climate mitigation. However, in the presence of political decisions aimed at ambitious mitigation, it might have technological and economic capabilities that could act as key enablers of the low-carbon transition.

6. A Framework to Incorporate Insights from Political Science in Integrated Assessment Models

There is now a general agreement in the climate mitigation literature that the social sciences should play a bigger role in shaping the development of new climate mitigation scenarios (Anderson & Jewell, 2019; Beckage et al., 2020; De Cian et al., 2020; Peng, Iyer, Bosetti, et al., 2021). Disregarding key insights from political science might lead to overestimating or underestimating mitigation potential in different countries or regions. Including such insights can help develop a more accurate understanding of the risks and enablers of ambitious mitigation pathways (Brutschin, Pianta, et al., 2021). There are some existing efforts to model social and political dynamics in the context of climate mitigation, such as studies of the linkages between human behavior and climate models (Beckage et al., 2018; Moore et al., 2022) and the international futures model (Hughes, 2016). So far, those efforts have not been applied to larger-scale process-based IAMs (such as MESSAGE, REMIND, WITCH, or IMAGE), which have a very detailed representation of different types of technologies. We present a simple framework to include insights from political science in IAMs based on the imposition of empirically motivated constraints on some of the key parameters in IAMs. A key limitation of our framework is that it does not incorporate feedback dynamics among the key drivers and the main outcomes of interest. Such an approach could in the future be extended to include a more direct coupling to a social system model. However, the incorporation of such feedback dynamics would exponentially increase the complexity of the model and require even stronger assumptions on the relationships between all drivers and outcomes.

The proposed approach, summarized in Figure 8, follows the logic of imposing exogenous constraints on

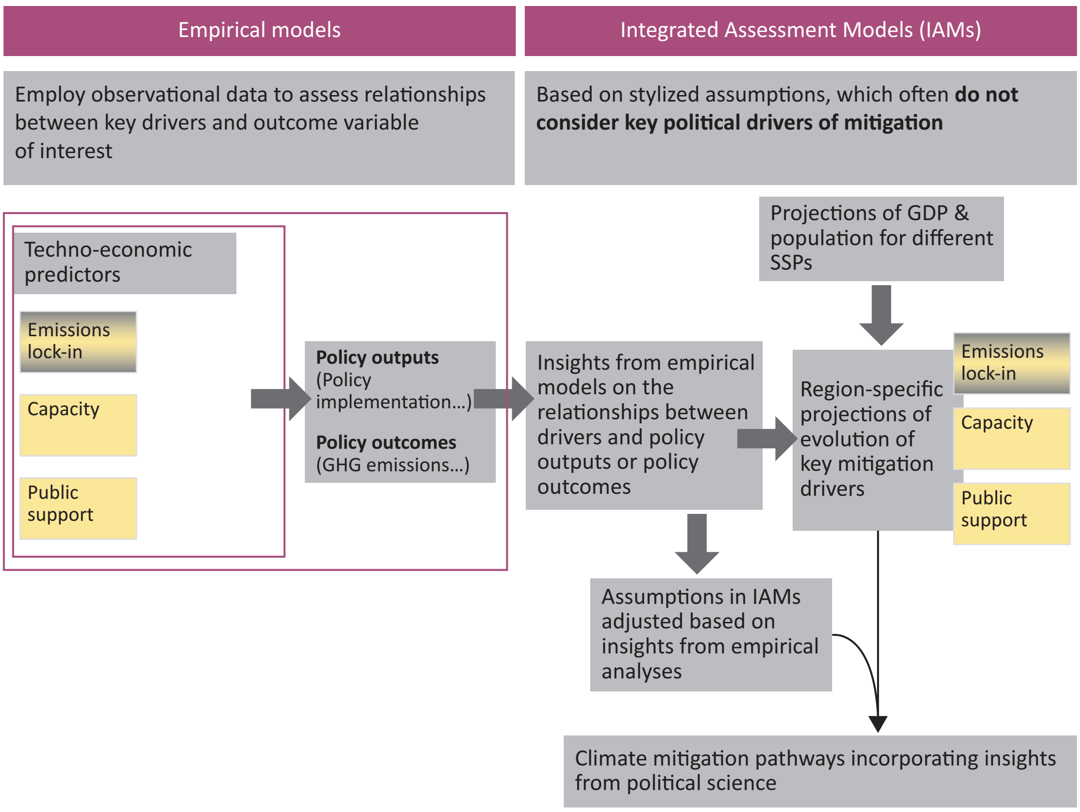

Figure 8. Overview of the framework to incorporate insights from empirical analyses on the political drivers of climate mitigation into IAMs. Notes: This approach is based on past literature and frameworks presented in Andrijevic et al. (2020), Cherp et al. (2018), and Lamb and Minx (2020); emissions lock-in is marked with a different color to signal that this variable might be proxied directly from the model outputs.

existing model parameters based on insights from empirical research. Examples of existing applications using a similar approach include the qualitative narratives of the shared socio-economic pathways (SSPs; Riahi et al., 2017), an exercise to impose constraints on the level of investments depending on institutional quality (Iyer et al., 2015), or, in the context of the US, assuming state-level variation in carbon prices that is reflective of state-level variation in public support for climate policy (Peng, Iyer, Binsted et al., 2021).

The proposed framework aims at improving some of the key assumptions adopted in IAMs, rather than proposing a forecast-based model or assuming any strong causal links between key drivers and the main outputs of interest. The linkage between empirical models and IAMs is based on the following key elements: (a) Both empirical models and IAM include some of the key variables/parameters that measure either policy outputs (such as carbon prices) or policy outcomes (such as GHG emissions); (b) it is possible to employ empirical analyses to identify correlations between the key drivers that we identified in our overview and policy output/outcomes; and (c) it is possible to develop country-level and regional-level projections that incorporate the geographical variation in such drivers. As many global IAMs divide the world into macro-regions that include many countries, careful reflection should be devoted to how much insights from empirical work, which is often done at the country level, can be extended to the regional level.

Some first attempts to explore how IAMs react to regionally differentiated socio-economic constraints might start with relatively simple set-ups where regional emissions or carbon prices (depending on the type of IAM) are constrained based on historically observed correlations with the political drivers of mitigation that we identify in this article. A more complex approach could focus on specific sectors or technologies. For example, the so-called technology learning curves could be calibrated based on their historical relationships with political variables. By varying key input assumptions of IAMs, we could explore more systematically in which regions the major bottlenecks are and what type of enablers might contribute most to reaching more ambitious climate targets in different regions and contexts. Further empirical research is essential to translate these insights into IAMs, as the effect of different political factors might vary substantially across countries, regions, and specific climate policy actions.

7. Conclusion

This article brings together insights from political science and socio-technical transitions research to highlight three key political factors that can fundamentally shape climate policy ambition: emissions lock-in, state capacity, and public opinion. We propose an operationalization of these factors based on a selection of indicators to assess their variation across countries and regions and suggest how they can be incorporated into climate modeling efforts by the IAM community. This can contribute to improving the incorporation of political dynamics in climate scenarios, which have a considerable impact on global and national climate policy discussions and decisions but have so far taken into account social and political dynamics only to a very limited extent. We argue that the incorporation of such insights in future modelling efforts is crucial, given that political factors are likely to be much more powerful drivers of future climate mitigation action compared to techno-economic constraints.

We explore the variation in emissions lock-in, state capacity, and public opinion across countries and regions, documenting significant cross-regional and within-regional heterogeneity. We highlight how OECD countries have the highest potential for mitigation, which contrasts with most IAM scenarios, which often shift mitigation efforts to other regions due to cost-effectiveness considerations. Some countries, including the Russian Federation, are well equipped to develop and adopt new technologies but have low governance capacity and public support for climate action. To identify levers of climate policy ambition in these contexts, it is essential to understand under what conditions the institutional landscape and public opinion could change or how soon technological diffusion will create economic incentives to mitigate. Latin American countries face a different set of challenges, related to the prominence of an agricultural sector with high methane emissions and to limited state capacity. Importantly, there is often considerable variation in emissions lock-in, capacity, and public support within regions. A substantial cross-country heterogeneity makes it difficult to provide a comprehensive assessment of the region including the Middle East and African countries. This within-region heterogeneity is also reflected for instance in important differences between European countries and the US, highlighting the importance of a more disaggregated regional aggregation in IAMs. We do not argue that all political factors we focus on in this article are key drivers of climate policy ambition in all contexts, but we stress how assessing their distribution can contribute to shedding light on potential challenges and enablers of mitigation action across contexts.

A limited number of studies have attempted to include political dynamics in IAMs, but a systematic approach to incorporate political factors is so far missing. We describe a framework to build new scenarios that incorporate political drivers of climate mitigation. Building on empirical analyses of existing relationships between key political factors and climate policy outputs and outcomes, we can develop assumptions on the relationships between input and output variables for new IAM scenarios that are more transparently grounded in empirical data. However, more research on the size of the effects of lock-in dynamics, capacity, and public opinion on different policy outputs and outcomes will be essential to inform future research endeavors in this direction.

Further investigating the interplay between these factors will permit an assessment of where major mitigation bottlenecks or virtuous cycles might arise.

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Conflict of Interests

The authors declare no conflict of interests.

Supplementary Material

Supplementary material for this article is available online in the format provided by the author (unedited).

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