Pricing Carbon: Evidence from Expert Recommendations

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We study the variation of carbon price recommendations and their determinants using survey evidence from more than 400 experts across almost 40 countries. We quantify the extent of disagreement and reveal that a majority of experts can agree on short- and medium-term global carbon price levels, and on unilateral carbon price levels in most countries. The majority of recommendations do not exhibit a “free-riding” pattern of lower unilateral than global carbon prices. Furthermore, border carbon adjustment facilitates higher unilateral price recommendations. We show how recommendations vary with additional survey responses, and with country and expert characteristics. (JEL Q54, H43)

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1. Introduction

A carbon price is widely seen as a key ingredient of any effective climate policy mix. This has been highlighted by recent high-level statements, such as the “Economists’ Statement on Carbon Dividends” (Wall Street Journal, 2019) and the “Economists’ Statement on Carbon Pricing” (EAERE, 2019), signed by more than 5000 economists in combination. According to the World Bank (2022), carbon prices—by means of a carbon tax or a cap-and-trade scheme—have been implemented in 46 national jurisdictions covering around 23 percent of global greenhouse gas emissions, with prices ranging from a few cents to more than 100 US dollars per (metric) ton of CO₂. The large variety in implemented carbon prices mirrors a heated academic debate, with estimates for appropriate carbon prices, or the related concept of the “social cost of carbon” (SCC), ranging from negative values to several hundred US dollars (e.g. Dietz and Stern, 2015; Hänsel et al., 2020; Nordhaus, 2019; Pindyck, 2019; Tol, 2018). While numerous political obstacles stand in the way of enacting climate policies, the seemingly substantial disagreement among experts is often regarded as an impediment to climate action in itself.

We report evidence on carbon pricing, based on the largest-to-date global survey among experts who have published on this topic. Our goal is to provide a systematic and representative understanding of the range of appropriate carbon prices. To this end, we ask experts directly for their recommendations on carbon pricing. Expert elicitation has become more common to inform climate policy and its determinants (e.g., Christensen et al., 2018; Drupp et al., 2018; Howard and Sylvain, 2020; Nordhaus, 1994; Pindyck, 2019) and in eliciting information on key economic aspects (e.g., Andre et al., 2022; DellaVigna and Pope, 2018; Sapienza and Zingales, 2013), but has not been applied to carbon pricing directly.¹

¹ Two previous surveys contain responses on the social cost of carbon (SCC) but not on carbon prices directly. Schauer (1995) surveyed 16 experts to calibrate a pre-curser to analytic integrated climate-economy assessment models (IAMs). Howard and Sylvain (2015) elicited views on whether a SCC of $37 is a likely estimate, too high or too low. 55 percent of
Determining appropriate carbon prices is often informed by integrated climate-economy assessment models (IAM) at the global level, such as the DICE model by Nordhaus (2019), or by computable general equilibrium models at a country-level (e.g., Chen and Hafstead, 2019). IAMs are criticized as being very sensitive to crucial modeling and parameter choices, such as on climate damages and discount rates, some of which are left to judgement calls by modelers (e.g., Pindyck, 2013; Stern and Stiglitz, 2022). Numerous recent studies provide more empirically grounded estimates, relying on much finer grained data to update estimates of the economic damages from climate change (e.g., Carleton et al., 2022; Kalkuhl and Wenz, 2020; Hsiang et al., 2017; Moore and Diaz, 2015; Rennert et al. 2022; Rode et al. 2021). Other studies translate a range of expert views on key parameters, such as on discount rates and climate damages, into optimal carbon prices or the SCC within specific models (Drupp and Hänsel, 2021; Hänsel et al., 2020; Howard and Sylvain, 2020; Jaakkola and Millner, 2022; Nesje et al., 2022; Pindyck, 2019). However, there is no way to judge whether an expert holding specific views on input parameters, such as on discount rates or climate damages (e.g., Hänsel et al., 2020; Pindyck, 2019), would also find carbon prices that result from, say, an IAM run agreeable, as input parameters are channeled through a corset of functional assumptions (e.g., Weitzman, 2010). The crucial question of how representative, and thus robust to alternative well-founded views, recommendations derived in the literature are of a broader expert population remains unanswered.

Our approach gives experts full flexibility in determining carbon price recommendations, without having to rely on a specific model or definition of social welfare, etc. This has the benefit that experts are neither confined to a certain IAM structure, nor disallowed from drawing on it (Metcalf and Stock, respondents thought that the SCC should be higher than $37. Among other differences, an optimal carbon price is typically computed along an optimized path, whereas the SCC often quantifies the global welfare cost of an additional ton of CO2 under a business-as-usual path (e.g., Nordhaus, 2019). Likewise, country-level SCC estimates (e.g., Ricke et al., 2018) may differ from appropriate country-level carbon prices for multiple reasons.
2017). Instead, they can build on their own “mental model” of the climate-economy, which may be informed by a mix of quantitative modelling, empirical evidence, and fact-based intuition.² This flexibility is important as subjective models of the macroeconomy are very heterogeneous (Andre et al., 2022), which will naturally extend to coupled climate-macroeconomy models. It is important to note that experts’ responses to our survey not only reflect positive but also normative views that are, among other things, inherently linked to balancing the well-being of individuals across generations (e.g., Dennig et al., 2020; Groom et al., 2022; Howard and Sylvan, 2020; Millner and Heal, 2023). As such, heterogeneity in expert responses stems from differences in views not only about positive aspects but also normative choices. Our succinct survey is not designed to characterize experts’ “mental models”, but using additional data, we are able to test and illustrate how selected positive and normative determinants relate to carbon price recommendations.

Our sample includes 445 responses on carbon price recommendations from a population of 2106 invited scholars. The survey elicited recommendations on carbon prices across three scenarios that are stylized to capture key features of the academic and policy debate and allow testing key hypotheses on carbon pricing. In the first scenario, experts were asked to give a recommendation to a hypothetical world government that plans to implement a uniform carbon price globally. In the second scenario, experts were asked to give a recommendation to the government in their country, if the government were to implement a carbon price unilaterally, under the assumption that competitiveness concerns can be addressed with the help of a border carbon adjustment (BCA) scheme. In the third scenario, we again asked for the unilateral carbon price, but without BCA. The difference between unilateral carbon prices with and without BCA provides an indication of competitiveness.

² This is echoed in qualitative remarks by experts, e.g.: “[A]ll of the answers are grounded at least as much in fact-based intuition as in formal modeling, as I’m not sure how far formal modeling gets us to any of them”.

and leakage concerns hampering carbon pricing. In each scenario, we asked for experts’ recommendations on carbon prices for the short term (2020) and the medium term (2030). In the global scenario, we also asked for a long-term recommendation (2050). Furthermore, we asked for ranges of carbon prices that respondents would still feel comfortable with recommending to examine spaces for agreement among experts on carbon price levels.

We find that the distributions of carbon price recommendations are highly dispersed and skewed towards high prices. In Section 3, we first scrutinize global carbon price recommendations. We find average (median) global carbon prices of $50 ($40) in 2020, $92 ($70) in 2030, and $224 ($100) in 2050 per ton of CO₂. The interquartile ranges are $25 to $50 in 2020, $50 to $100 in 2030, and $75 to $250 in 2050. Our first result is, thus, that there is a strong consensus among experts that a uniform global carbon price should be higher than the existing global average price, estimated to be less than $3 (Dolphin, 2022). Indeed, CO₂ prices of $3 (or lower) are recommended by fewer than two percent of experts and are contained in acceptable ranges of fewer than three percent. Based on these acceptable ranges, we further show that a majority can agree on global carbon prices of $30-35, $40, or $50 in 2020, and $50 or $60 in 2030. Our second result summarizes that—despite sizeable heterogeneity in point recommendations—a majority of experts can agree on some short- and medium-term global carbon price levels.

Examining experts’ unilateral carbon price recommendations, we find that these vary substantially across countries, such as from $13 ($41) in India to $99 ($171) in Switzerland in 2020 (2030) for the case without BCA. Across scenarios, unilateral carbon price recommendations with BCA are, on average, significantly higher than global carbon price recommendations. This pattern of experts’ recommendations does not exhibit the standard notion of free-riding.³

³ Free-riding means to benefit from the efforts of others, while contributing little to the provision of a public good (such as climate stability) yourself to avoid individual costs, when the marginal cost of providing the public good exceeds the (individual) marginal benefit. Due to the free-rider incentive, unilateral carbon prices would be expected to be lower, and emissions higher,
Free-riding is widely seen as an impediment to tackling climate change (e.g., Barrett, 1994; Nordhaus, 2015), but we find evidence of free-riding only in 16 percent of recommendations, while unilateral carbon price recommendations with BCA exceed global recommendations in twice as many expert responses. Yet, there is a clear income-dependency, as the latter effect is strongest for experts from the richest countries, and insignificant for those from the poorest countries. The result suggests that experts take impacts of non-domestic citizens into account when recommending unilateral policies, thus factoring in altruistic motives. The lack of evidence for a free-riding pattern in experts’ aggregate carbon price recommendations establishes our third result.

Moreover, we compare unilateral price recommendations with and without BCA and find that prices with BCA are on average at least 30 percent higher than those without BCA, pointing towards sizable competitiveness and leakage concerns. Nevertheless, even when these concerns are not addressed, i.e., in the absence of BCA, we find a broad consensus among experts for significantly higher carbon prices than currently implemented in most countries.\(^4\) Our fourth result thus establishes that BCA facilitates higher unilateral carbon price recommendations, yet that there is strong consensus among experts that existing carbon prices are too low even in the absence of BCA. We further study the space for agreement based on unilateral carbon price ranges at the country level. We find that spaces for agreement and majority agreement on unilateral carbon prices tend to be larger with BCA as compared to without BCA, suggesting that the introduction of BCA tends to facilitate higher agreement on unilateral carbon prices.

In Section 4, we draw on additional data to uncover determinants of experts’ recommendations. Using survey data on policy design issues, we, for

\(^4\) We find that 94 (88) percent of experts’ 2020 unilateral recommendations with (without) BCA are larger than the weighted existing carbon prices in the respective countries, while 89 (83) percent of acceptable ranges lie strictly above, extending our first result to the country level.
instance, find that experts who favor carbon taxes recommend carbon prices that are more than 30 percent higher than those by experts who prefer cap-and-trade. Furthermore, we find that experts recommending more stringent emissions reduction targets recommend higher carbon prices, and that higher utility discounting is associated with lower prices, both suggesting that experts’ normative views play an important role. Moving on to the analysis of country characteristics, we find that experts from Europe, from countries with higher GDP per capita, with higher mean world governance indicator rank score, or more knowledge about climate change recommend higher carbon prices. By contrast, experts from Asia and from countries with a higher share of fossil fuel energy consumption recommend lower carbon prices. This is broadly in line with the literature on existing carbon prices (e.g., Levi et al., 2020; Best and Zhang, 2020; Levi, 2021). Regarding experts’ observable characteristics, we find, for instance, that there are no (significant) differences in price recommendations between those experts who have published on IAMs, or on the SCC, and all others. Using various combinations of determinants, we find a major share of unexplained heterogeneity in recommendations, pointing at strong idiosyncratic components in experts’ views on carbon pricing.

It is important to emphasize that expert elicitation (such as our survey) is not meant to replace other research methods, including methods for determining suitable carbon prices. Instead, it builds on and is complementary to the theoretical, computational, and empirical literature. Indeed, experts participating in our survey have actively contributed to, or have been informed by various approaches to determining carbon prices in the literature, such as estimates generated by IAMs. It is thus likely that expert recommendations to some degree reflect—individually adjusted—recollections of existing results from the literature. We discuss this, along with other merits and limitations of our research method, in more detail in Section 5. We conclude in Section 6.
2. Survey design and expert selection

2.1 Survey design

Our survey instructs experts to have in mind a setting where they give advice on hypothetical carbon pricing policies for CO$_2$ emissions covering all sectors of the economy (the full survey text is available in the Appendix).

We first ask for recommendations on global uniform carbon pricing. Precisely, we ask them to suppose that a “world government” exists, which seeks to maximize the well-being of all present and future people and plans to implement a uniform global carbon price (measured in real US dollars per ton of CO$_2$). While a uniform global carbon price may be required to achieve a (theoretical) first best outcome, such a unified and fully cooperative approach to climate policy may not be feasible in practice for various political reasons. Reflecting these real-world constraints on countries’ climate policy, we asked each expert to provide carbon price recommendations also at the unilateral country-level. We, therefore, also included a question that elicits which country each expert would feel most ready to advice on carbon pricing.\(^5\)

Unilateral carbon pricing comes with a number of additional challenges. First of all, when each country sets its own targets, the free-rider problem can have a detrimental effect upon countries’ climate policy ambitions (e.g., Barrett, 1994; Nordhaus, 2015). Competitiveness concerns, among others, can also play a major role under unilateral carbon pricing, motivating the use of BCA (Böhringer et al., 2022). If a country establishes a higher price unilaterally, firms located in this country may suffer losses in international competitiveness. Apart from potential job losses (e.g., due to firm relocation), this may also lead to leakage of emissions to countries with less stringent environmental policies.

Taking these issues into consideration, we asked experts to provide their recommendations on unilateral carbon pricing and on acceptable ranges of carbon prices across two different scenarios. In the first scenario (“unilateral

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\(^5\) Whereas we asked for recommendations for 2020, 2030, and 2050 in the global scenario, we restricted the set to 2020 and 2030 in the unilateral scenarios to make the survey more succinct.
with BCA”), we asked each expert to assume that “any competitive disadvantages are neutralized by border carbon adjustment, exempting exports from the carbon price and pricing the carbon content of imports at the domestic rate”. The idea is that with the help of this BCA-scenario, we are able to disentangle any effects that are related with competitiveness and leakage concerns from other concerns that may determine experts’ views on unilateral carbon prices. In the second scenario (“unilateral without BCA”), we asked each expert to consider the same case without BCA.

When analyzing the results, we compare experts’ recommendations across these three scenarios (global, unilateral with BCA, and unilateral without BCA). The difference in the price recommendation of an expert between the global and the unilateral scenario with BCA (“Glocal-wedge”) serves as a proxy for the expert’s view on the issue of free-riding, where the term “Glocal” captures “both local and global considerations” (Lexico, 2021). Similarly, the difference between the price recommendation of an expert in the unilateral scenario with BCA and the one without BCA (“BCA-wedge”) helps us to quantify each expert’s views on competitiveness and leakage concerns. If such concerns play a major role, then we would expect that carbon prices in the unilateral scenario with BCA are substantially higher than in the scenario without BCA. In practice, governments enact some measures to address competitiveness concerns, such as allocating part of their allowances in emissions trading schemes for free (e.g., Schmidt and Heitzig, 2014), or partially exempting certain industries, but these measures may be insufficient to fully eliminate competitiveness concerns.

We further analyze possible determinants of carbon price recommendations by drawing on four types of additional data. First, we elicit experts’ recommendations on key carbon pricing policy design issues, analyzed in detail in Nesje et al. (2023). This includes a question on instrument choice, i.e. whether unilateral carbon pricing should be implemented with the help of a carbon tax, or via a cap-and-trade scheme, or some other instrument(s). We
further asked if experts strongly recommend introducing BCA, and how they recommend to use the revenue from carbon pricing, a key determinant of carbon pricing acceptance (e.g., Carratini et al., 2019; Klenert et al., 2018).

Second, we elicited each expert’s views on selected determinants of carbon pricing that are typically featured in IAMs. These include experts’ views on global emission reduction targets, reduction costs, expected climate damages, and discounting. These are plausible positive and normative “ingredients” that experts may utilize when forming recommendations on appropriate carbon prices.

Third, we gathered country-level information, such as GDP per capita, “good governance” indicators, and existing carbon prices, among other things, based on the countries experts indicated to feel most comfortable with recommending on carbon pricing. A number of these (potential) explanatory variables have been shown to correlate with existing (weighted) carbon prices at the national level (e.g., Levi et al., 2020; Best and Zhang, 2020; Levi, 2021).

Fourth, we further asked each expert if they are willing to provide their identity. For those experts who did, we gathered additional information. This includes the number of publications and citations, the number of publications in SCOPUS’s economics category, and data on whether an expert’s publications are concerned with the SCC, IAMs, or different carbon pricing instruments that we obtained via a keyword-based analysis of the abstracts. We further gathered data on an expert’s country of main affiliation and gender via online search.

2.2 Expert selection, survey dissemination, data
Determining carbon prices is a complex matter. We restricted our sample to scholars who are involved with these complex issues and who have, as judged

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6 To preserve the anonymity of our respondents, we only report results of aggregated data that makes use of these expert characteristics and we do not provide this data linked to individual survey responses. For linked country-level data, we set the threshold at a minimum of 5 potential experts from a country within the full population of 2106 potential experts. We report data on carbon pricing at a country-level when at least three experts from a given country responded.
by colleagues via cited publications, made relevant contributions to pricing carbon. Specifically, we consider a scholar to be a potential expert if they are a (co-)author of at least two pertinent and cited publications on the topic since the year 2000. We constructed our population of experts by defining suitable keywords, including “carbon tax”, “cap-and-trade”, and a number of equivalent terms and combinations of terms (Online Appendix A.2.1 provides the search-string), and conducting an automated search in the literature database SCOPUS to identify authors of pertinent peer-reviewed papers. To define a potential expert on carbon pricing, we narrowed down this pool to those authors who had at least two publications since the year 2000 that had been cited at least once, and for whom we could obtain a workable e-mail address. This search strategy provided us with a population of 2106 potential experts.

Starting in June 2019, we sent out a link to the online survey via email to all potential experts (Online Appendix A.2.2 provides the invitation e-mail). We used four reminders and closed the survey end of November 2019. We received 574 responses out of a pool of 2106 potential experts, with 445 experts providing carbon price recommendations. The response rate of around 25 percent compares well with other large-scale online surveys with experts (e.g., Drupp et al., 2018; Howard and Sylvain, 2015, 2020; Pindyck, 2019). The sample contains responses from all major continents, and represented countries cover more than 80 percent of global CO2 emissions.

7 Table A.2 in Online Appendix A.3 provides an overview of key descriptive statistics on response numbers, carbon price recommendations, and determinants. Throughout, we winsorize the carbon price data to deal with extreme outliers by replacing the highest two price recommendations by the third highest recommendation for each carbon price question, including their ranges, and follow the same procedure for the lowest prices. See Online Appendix A.3 for details on data cleaning and winsorizing.
3. Results

3.1 Global carbon price recommendations

Figure 1 shows global price recommendations for the years 2020, 2030, and 2050 in raincloud plots. Figure 1 showcases substantial heterogeneity in experts’ price recommendations and skewness towards higher carbon prices. Recommendations range from $0 to $500 in 2020 and 2030, and up to $4000 in 2050, with considerable bunching at focal points at $10 or $50 step-intervals.

Figure 1: Global carbon price recommendations

Notes: Raincloud plots of global carbon price recommendations for the years 2020 (orange), 2030 (green), and 2050 (velvet), cropped at $300, and raincloud plot for 2050, cropped at $1000. Raincloud plots include kernel density plot violin and box plots, in which the black line represents the median recommendation, the multiplier sign the mean, and the boxes interquartile ranges. Visually cropped values in the raincloud plots in Panel A are the 1 (2) [17] percent highest prices for 2020 (2030) [2050], and less than one percent in Panel B.

The mean (median) recommended carbon prices at the global level are $50 ($40) for a ton of CO$_2$ in 2020, and increase over time to $92 ($70) in 2030,
respectively $224 ($100) in 2050. The interquartile ranges extend from $25 to $50 for 2020, from $50 to $100 in 2030, and from $75 to $250 in 2050, and 90 percent of recommendations range from $10 to $100 in 2020 and $20 to $250 in 2030, for instance. Overall, we find that more than 98 percent of experts recommend a 2020 global carbon price that exceeds the globally prevailing emission-weighted carbon price in 2020, estimated at below $3 (cf., Dolphin, 2022), suggesting a strong consensus within this expert sample on more ambitious carbon pricing. We summarize this finding as:

**Result 1:** There is a strong consensus among experts that a uniform global carbon price should be higher than the existing global average carbon price.

This result is further strengthened by our data on ranges of prices that experts would feel comfortable with recommending. This allows us to quantify the potential degree of agreement among experts on carbon price levels. It is natural to assume that those experts who indicated ranges that comprise a given price can jointly agree on such a price recommendation. Figure 2 quantifies this “space for agreement”, i.e. the fraction of all experts whose price ranges comprise a given price level. When examining experts’ acceptable price ranges for 2020, the overlap of which are shown as orange bars in Panel A, we find that 97 percent of experts recommend carbon prices for 2020 that lie above the existing emissions-weighted global carbon price of (around) $3.

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8 Values are rounded to integers in the main text. Tests etc. are based on the full numbers.
9 In Online Appendix C, we discuss potential non-response bias, using the population of potential experts as the comparison group, strategic response bias, and non-representation bias by drawing on various measures of global averages, such as in terms of GDP per capita. We find no evidence for non-response or strategic response bias, but document non-representation bias, as experts are—unsurprisingly—sourced disproportionally from the richer half of the global income distribution. We furthermore compare our results with those from IAMs.
Figure 2: Spaces for agreement on global carbon prices

Notes: Proportion of experts for whom a certain carbon price level, varied on the horizontal axis, is contained within their acceptable range of global carbon prices for 2020 (orange, panel A), 2030 (green, Panel B), and 2050 (velvet, Panel C). For instance, a global carbon price of $150 per ton of CO$_2$ in 2020 (2030) [2050] is contained in the acceptable ranges of 13% (30%) [41%] of experts. Carbon prices are capped at $300 for expositional purposes. No carbon price beyond $300 yields support of more than 25 percent of experts.

By contrast, a majority of all experts (more than 60 percent) indicated ranges that comprise a carbon price of $30 for 2020. Carbon prices of $40 and of $50 and prices between $30 and $35 can also gain a majority support.\textsuperscript{10} Hence, despite the large variation in experts’ price recommendations, our data suggests that there is nevertheless space for majority agreement on certain price levels among experts. Also for the year 2030 (Panel B in Figure 2), we find that majority support for certain global carbon price levels is possible, since at least half of all experts indicate ranges that comprise carbon prices of $50 and $60

\textsuperscript{10} That prices between $40 and $50, or between $35 and $40 do not gain a majority support is likely due to rounding, as most experts recommend prices that are multiples of $5 or $10.
per ton of CO₂, while still around 48 percent of experts could agree on a price level of $100. Only for 2050 (Panel C), we find that experts’ recommendations are so divergent that no single carbon price level is supported by a majority. Still, 48 percent of experts could agree on a price of $100, and more than 40 percent could agree on a price of $150. We summarize these findings as:

**Result 2:** Despite substantial heterogeneity in recommendations, experts can agree on some short- and medium-term global carbon prices.

### 3.2 Unilateral carbon price recommendations

We next examine differences between global and unilateral carbon price recommendations of all experts in the scenario with BCA (see top row ‘All’ and Panel A of Figure 3), and compute the difference as the “Glocal-wedge” (Panel B). On average, unilateral price recommendations with BCA tend to be higher than global price recommendations, with means of $55 versus $50 for 2020, and $104 versus $92 for 2030 (two-sided t-tests: p<0.165 and p<0.043), with negative Glocal-wedges on average (t-tests: p<0.000 and p<0.000).¹¹ This contrasts with the ubiquitous notion of “free-riding” (e.g., Barrett, 1994), according to which one might expect unilateral prices (with BCA) to be lower than the global carbon price. Overall, we find patterns pointing at free-riding, i.e. lower unilateral with BCA than global carbon prices, in only 16 percent of recommendations. In contrast, twice as many expert responses exhibit higher unilateral with BCA than global carbon prices (32 percent for 2020 carbon prices, and 34 percent for 2030). This finding is summarized as:

**Result 3:** The majority of experts’ carbon price recommendations do not exhibit a pattern of free-riding. Instead, unilateral price recommendations with BCA are, on average, higher than global price recommendations.

¹¹ We report two-sided tests throughout and therefore omit this qualification in the following.
Figure 3: Unilateral and global carbon pricing and the “Glocal-wedge”

Notes: Panel A shows mean unilateral with border carbon adjustment (BCA) (in blue) and global (green) carbon price recommendations for 2020 (transparent circle) and 2030 (dot), for all countries or groups of countries with at least three observations in all scenarios. Within each continental group, countries are ordered by their rank in terms of GDP per capita. Panel B shows bar plot with differences in means for 2020 and 2030 between global and unilateral with BCA carbon price recommendations (“Glocal-wedge”), with standard errors.

We, next, examine how Result 3 varies across countries. Panel A of Figure 3 shows average unilateral with BCA (in blue) and global (green) carbon price recommendations (in green) for 2020 (circles) and 2030 (dots) also at a country or country-group level. Individual countries per continental group are ordered in terms of GDP per capita. Panel B of Figure 3 also highlights the difference between global and unilateral with BCA carbon price recommendations

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12 As stated above, we here consider countries (or groups) with at least 3 observations for both scenarios across all analyses, and keep these 20 “countries” depicted in Figure 3 for subsequent analyses. Besides individual countries, we consider “Other European”, “Other Asian”, and “Africa and South America” as their individual countries have a low number of respondents.
“Glocal-wedge”) at a continental level. The first observation is that effects for the Glocal-wedge are heterogeneous across countries and continents: While the Glocal-wedge for 2030 is insignificantly positive for Africa and South America ($8; t-test: p=0.692) and Asia ($2; t-test: p=0.773), it is significantly negative for Europe (-$19; t-test: p<0.000) and Oceania (-$8; t-test: p=0.059), and insignificantly so for North America (-$12; t-test: p=0.185). Consistently, however, unilateral carbon prices with BCA tend to increase with GDP per capita relative to global carbon price recommendations. As experts are sourced disproportionally from countries in the richer half of the global income distribution, this helps to explain why, on average, unilateral with BCA carbon price recommendations are higher than for the global level.

Next, we examine unilateral carbon price recommendations with and without BCA to shed light on the size of competitiveness or leakage concerns. Panel A of Figure 4 depicts unilateral carbon price recommendations for 2020 and 2030 across countries, while Panel B shows the BCA-wedge on a continental level. On average, unilateral price recommendations without BCA are lower than those with BCA for 2020, with means of $55 versus $41, and for 2030, with means of $105 versus $78 (t-tests: p<0.000 and p<0.000). BCA thus increases unilateral carbon price recommendations in 2020 (2030) by 34 (35) percent, indicating sizable competitiveness concerns.

The finding of sizable competitiveness concerns generalizes across all countries except “Other Asian” (see Panel A of Figure 4). Yet, unilateral carbon price recommendations are very heterogenous. In 2020 (2030), carbon prices without BCA vary from $10 ($39) in “Africa and South America” or $13 ($41) in India to $99 ($171) in Switzerland, with corresponding carbon prices in the scenario with BCA of $18 ($53), respectively $124 ($209).

13 While differences in how experts converted local currencies into US$ may confound our finding, we obtain the same results on the absence of a free-riding pattern for US respondents only (2030 Glocal wedge: -$10; t-test: p=0.331).
14 We discuss potential explanations for why unilateral carbon price recommendations with BCA may be higher (or lower) than for global prices in Section 5.2.
Figure 4: Unilateral carbon pricing and the BCA-wedge

Notes: Panel A shows the mean unilateral carbon price recommendations with (in blue) and without (brown) border carbon adjustment (BCA) for 2020 (transparent circle) and 2030 (dot), for all countries or groups of countries with at least five observations. Within each continental group, countries are ordered by their rank in terms of GDP per capita. Panel B shows bar plots with differences in means for 2020 and 2030 between unilateral with BCA and without BCA carbon price recommendations (“BCA-wedge”), with standard errors.

Comparing experts’ unilateral carbon price recommendations with emission-weighted existing carbon prices, we find that 94 (88) percent of experts’ 2020 unilateral carbon price recommendations with (without) BCA are larger than the existing carbon prices in their respective countries.\(^{15}\) This mirrors our results from the global level and suggests a strong consensus for unilateral

\(^{15}\) Likewise, the acceptable ranges of 89 (83) percent of experts in the unilateral scenario with (without) BCA lie strictly above the existing carbon price in their respective country.
carbon prices that exceed prevailing emission-weighted unilateral carbon prices, even in the absence of BCA.\textsuperscript{16} We summarize:

**Result 4:** The introduction of border carbon adjustment facilitates higher unilateral carbon price recommendations. Yet, even in the absence of border carbon adjustment, there is a broad consensus among experts for substantially higher carbon prices than currently implemented in most countries.

We next focus on unilateral price ranges that experts recommend. Figure 5 depicts the “space for agreement”, i.e. the fraction of experts whose price ranges comprise a given price, for 2030 unilateral carbon prices with (blue) and without BCA (brown) for the 20 countries. We find that majority agreement on some unilateral carbon price with BCA is possible for 15 out of 20 of the countries in 2030 shown in Figure 5, while these frequencies are reduced to 11 without BCA. Furthermore, the extent of majority agreement for 2030 prices\textsuperscript{17} is higher in 13 countries with BCA as compared to without BCA, while it is lower in only 4 countries. Thus, majority agreement on 2030 unilateral carbon prices tends to occur somewhat, but not significantly, more frequently with BCA (chi-squared test: p=0.185), while the “BCA-wedge” in majority agreement tends to be positive (t-test: p=0.056). We also consider the overall space for agreement by computing the interval covered by all overlapping ranges of at least two experts (i.e. the full blue or brown areas) and find that the space for agreement on 2030 unilateral carbon prices tends to be larger with BCA than without BCA (t-test: p=0.146; linear regression with countries weighted by the number of experts: p=0.108), while the “BCA-wedge” in overall agreement is positive (t-test: p=0.005). Taken together, this findings suggests that the introduction of BCA

\textsuperscript{16} Figure B.5 in Online Appendix B.2 illustrates this unilateral carbon pricing gap using mean values across countries, while B.6 shows the percentage share of experts within individual countries whose acceptable ranges for unilateral carbon prices in 2020 lie strictly above the existing emission-weighted prices. Across all countries—expect for Sweden and Finland—a majority of acceptable ranges for 2020 unilateral carbon prices lie above existing carbon prices.

\textsuperscript{17} This is the integral over all agreement levels exceeding 50 percent.
not only leads to higher unilateral carbon price recommendations, but that BCA also tends to facilitate more *agreement* on unilateral carbon prices.

**Figure 5:** Spaces for country-level agreement on unilateral carbon prices

**Notes:** Proportion of experts for whom a certain carbon price level, varied on the horizontal axis, is contained within their acceptable range of 2030 unilateral carbon prices with (in blue) and without (brown) border carbon adjustment (BCA). The red dotted line plots existing emission-weighted unilateral carbon price. Prices are capped at $300 for expositional purposes.
4. Analysis: Determinants of expert recommendations

We now analyze potential determinants to investigate reasons for the substantial variation in carbon price recommendations along the four additional data sources introduced in Section 2.1. We focus primarily on determinants directly elicited as part of our survey, only summarizing the results on country- and expert characteristics that we cover in detail in the Online Appendix.

4.1 Survey questions on policy design issues

Figure 6 examines relations between experts’ carbon price recommendations and their views on the policy design issues. We find that almost twice as many experts favor a carbon tax compared to a cap-and-trade scheme, with almost 20 percent favoring some “other instrument or mix of instruments”. Around three-quarters strongly recommend the usage of BCA, while views on revenue use are very heterogeneous (cf. Nesje et al., 2023).

As illustrated in Figure 6, experts who recommend the usage of carbon taxes recommend global carbon prices that, on average, exceed those by experts who prefer cap-and-trade by 33 percent in 2020 ($53 vs. $40; t-test: p=0.015), by 37 percent in 2030 ($100 vs. $73; t-test: p=0.002), and by 60 percent in 2050 ($236 vs. $148; t-test: p=0.007). It is intriguing why carbon price recommendations differ so much between experts favoring carbon taxes versus cap-and-trade. Consistent with lower carbon price recommendations, those who recommend using cap-and-trade also recommend a less stringent global emission reduction target. This result remains when we control for significant explanatory variables of cap-and-trade support in multivariate regressions.

18 Qualitatively, we find the same in multivariate analyses (Table B.1 in Online Appendix B.3) and also for univariate analyses on unilateral prices, e.g. experts recommending taxes instead of cap-and-trade recommend prices that are, on average, higher by 37 and 47 percent in 2030 ($114 vs. $77 with BCA; t-test: p=0.001, and $83 vs. $60 without BCA; t-test: p=0.004).

19 We have no clear explanations for this striking finding. One potential explanation could be that experts who believe that a swift and stable price signal is necessary to adequately tackle climate change may favor a carbon tax over cap-and-trade. The observation that experts favoring a carbon tax recommend more stringent emission reduction targets seems consistent with this. We leave delineating drivers of this empirical finding to future work.
Figure 6: Relation between carbon prices and policy design recommendations

Notes: All panels depict relations of policy design recommendations and 2030 carbon prices, with means and standard errors. Panel A depicts how 2030 carbon price recommendations across all three scenarios—global (green) as well as unilateral with (blue) and without (brown) border carbon adjustment (BCA)—vary between those recommending the use of a carbon tax versus a cap-and-trade scheme (in more transparent bars). Panel B shows the equivalent for those that strongly recommend the use of BCA or not, and Panel C depicts how 2030 global carbon price recommendations vary with recommendations on revenue use.

Also regarding experts’ views on BCA, we find that experts who strongly support the introduction of BCA recommend higher global carbon prices in 2020 ($54; t-test vs. $41: p=0.029) and in 2030 ($97 vs. $81; t-test: p=0.085). For 2030, this is illustrated in Panel B of Figure 6. We find qualitatively the same for unilateral carbon price recommendations with BCA (e.g., $110 vs. $89 in 2030; t-test: p=0.066), but find no difference in recommendations on unilateral carbon prices without BCA for those who strongly support the introduction of BCA or not ($77 vs. $81 in 2030; t-test: p=0.635). This is also supported qualitatively by multivariate analyses (Table B.1 in Online Appendix B.3). Relatedly, we find that the BCA-wedge is substantially larger for those who strongly recommend the usage of BCA as compared to those who do not (34$ vs. 10$ in 2030; t-test: p=0.002). This is indeed expected, as experts who express a strong preference for implementing
BCA are probably more concerned about competitiveness issues and, thus, less likely to recommend high carbon prices in a unilateral scenario without BCA relative to the case with BCA. Overall, our results point towards an important role of BCA for shaping experts’ carbon price recommendations.

We further investigate the relation between experts’ recommendations regarding the usage of the revenues from carbon pricing and carbon price recommendations. Based on frequencies of eleven pre-specified revenue usage options, where each expert could select several types of usage, we group responses in four categories (see Online Appendix A.4 for details): Using the revenues for (1) transfers to households, (2) transfers to firms or tax reductions, (3) governmental spending, and (4) international transfers. Panel C of Figure 6 depicts how 2030 global carbon price recommendations vary with recommendations on revenue use (Figure B.7 in Online Appendix B.3 shows the equivalent for the two unilateral cases providing qualitatively similar insights). Experts who recommend using some revenue for transfers to households tend to recommend somewhat higher 2030 global carbon prices ($97 vs. $83, p=0.102). Experts who recommend using some revenue for transfers to firms or tax reductions recommend considerably lower carbon prices ($82 vs. $108; p<0.001), while those who recommend using some revenue for international transfers recommend higher carbon prices ($107 vs. $85; p=0.009). A possible interpretation is that experts concerned about distributional issues within and across countries also favor more ambitious climate policy. By contrast, experts more concerned about firms and profits are likely more “laissez-faire” oriented, and recommend lower carbon prices.

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20 There are no differences in carbon prices between those recommending the usage of revenues for governmental spending or not ($93 vs. $92; t-test: p=0.911). The prior literature (e.g., Maestre-Andrés et al., 2021) has shown that revenue use for climate projects or for investments in environmental public goods matters for public acceptability of carbon prices. Zooming in on this sub-category, we confirm that this revenue category is not associated with higher 2030 global carbon price recommendations (t-test: p=0.332) but with higher 2030 unilateral carbon price recommendations with and without BCA (t-tests: p=0.063 and p=0.039).
4.2 Survey questions on “determinants”

Our final survey question asked for experts’ (rough) views on likely determinants of price recommendations. More than half of the experts expect catastrophic damages of at least 20 percent of GDP by 2070 to occur with a probability of at least 20 percent under business-as-usual, while more than half expect mitigation costs to be less than one percent of GDP annually for an 80 percent global emission reduction by 2050. These two observations already point towards a majority view among experts regarding the need of stringent climate policy, and we indeed find that a majority of experts (57 percent) recommend global emission reductions of at least 80 percent by 2050.

Table 1: Global carbon price recommendations and determinants

<table>
<thead>
<tr>
<th></th>
<th>(1) ERT</th>
<th>(2) Global price 2020</th>
<th>(3) Global price 2020</th>
<th>(4) Global price 2030</th>
<th>(5) Global price 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission reduction target (ERT)</td>
<td>0.54</td>
<td>0.75</td>
<td>0.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abatement costs</td>
<td>-0.66</td>
<td>-0.14</td>
<td>-0.02</td>
<td>-0.06</td>
<td>-0.13</td>
</tr>
<tr>
<td>Probability of 20% of GDP damages</td>
<td>0.18</td>
<td>0.11</td>
<td>0.07</td>
<td>0.09</td>
<td>0.07</td>
</tr>
<tr>
<td>Mean damages</td>
<td>0.42</td>
<td>-0.11</td>
<td>-0.21</td>
<td>-0.20</td>
<td>-0.13</td>
</tr>
<tr>
<td>Utility discount factor</td>
<td>0.18</td>
<td>0.27</td>
<td>0.24</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Observations</td>
<td>399</td>
<td>388</td>
<td>388</td>
<td>388</td>
<td>387</td>
</tr>
<tr>
<td>Pseudo R-squared</td>
<td>0.08</td>
<td>0.01</td>
<td>0.02</td>
<td>0.03</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Notes: Robust standard errors in parentheses. Multivariate regressions are estimated by ordered logit to account for categorical dependent variables.

Table 1 shows how estimates of abatement costs, damages, and views on discounting are associated with the overall emission reduction target (ERT), and how all determinants are associated with global carbon price recommendations by means of ordered logit regressions. We find that both higher damages and a higher discount factor are positively correlated with ERT, while higher abatement costs are associated with a less stringent ERT.
Disregarding the ERT, only the utility discount factor is significantly positively associated with global carbon price recommendations in 2020. When we consider all five determinants, only ERT and the utility discount factor are consistently significant (positive) correlating variables of global carbon prices across all years (columns 3-5 in Table 1). This is in line with the importance of utility discounting in both cost-benefit analyses and in cost-effectiveness frameworks (e.g. Emmerling et al. 2019; Hänsel et al. 2020; Nordhaus 2019; Traeger 2022). Furthermore, based on ordered logit regressions, the variation in price recommendations is more strongly driven by differences in determinants exhibiting normative content (ERT and utility discounting; Pseudo R-squared=0.029) than by differences in determinants relating to descriptive content (mitigation costs and damages; Pseudo R-squared=0.005).

Figure 7 illustrates 2030 carbon price recommendations across scenarios for subgroups of experts who selected the same global emission reduction target (ERT) by 2050 (Panel A), and for the utility discount factor in 2070 (Panel B).

Figure 7: Key determinants and carbon price recommendations

Notes: Boxplots of 2030 carbon price recommendations for the global (green) as well as unilateral with (blue) and without (brown) border carbon adjustment (BCA) scenarios. Boxes represent interquartile ranges, the black horizontal lines represent median recommendations and the multiplier signs depict mean carbon prices.
We find that carbon price recommendations increase strongly with the stringency of the ERT (also when controlling for answers to the other “determinants” survey questions, cf. Table B.3 in Online Appendix B.3). For instance, 2030 global carbon price recommendations are considerably lower (higher) for those who recommend the lowest (highest) emission reduction target ($29 vs. $128; t-test: p<0.000). The views on damages (see Figure B.1 in Online Appendix B.1), and the utility discount factor (Panel B of Figure 7) also relate to carbon price recommendations in expected ways.

Regarding utility discounting, we find that 2030 global carbon price recommendations are considerably lower for those recommending the lowest weight on the utility of future generations as compared to the highest weight ($82 vs. $118; t-test: p=0.028). Interestingly, we find that carbon price recommendations are considerably less sensitive to utility discount rate ranges as compared to results from prominent IAMs. For instance, while carbon price recommendations for the utility discount ranges that encompass a prominent focal assumption on the utility discount rate by Nordhaus tend to be lower as compared to the one by Stern, we do not find that these differences are statistically significant ($81 vs. $96 in 2030; t-test: p=0.196). For 2050 global carbon prices, this relative insensitivity to utility discounting—as compared to ERT—becomes more pronounced: While there is a large difference in terms of carbon price recommendations between those recommending less than 20 percent (equal to 100 percent or more) global emission reductions by 2050 ($44 vs. $289; t-test: p<0.000), global carbon recommendations do not differ among those recommending end points in the range of the utility discount factor ($273 vs. $308; t-test: p=0.733).

21 In contrast, using the 2016 version of DICE would suggest 2030 global carbon prices according to the utility discount rates by Nordhaus and Stern of $49 and $382 (Nordhaus, 2018). Nordhaus’ choice of a utility discount rate of 1.5% yields a utility discount factor in the year 2070 of 47%, Stern’s choice of 0.1% yields a utility discount factor of 95%. 
4.3 Country and expert characteristics

We next summarize how carbon price recommendations relate to country and expert characteristics, and report detailed results in Online Appendix B.3. In terms of country characteristics, we find that experts from Europe, from countries with higher GDP per capita, with higher mean world governance indicator rank score, or more knowledge about climate change recommend higher carbon prices across all scenarios. By contrast, experts from Asia and from countries with a higher share of fossil fuel energy consumption recommend lower prices. This is broadly in line with the literature on existing carbon prices (e.g., Levi et al., 2020; Best and Zhang, 2020; Levi, 2021).

We further utilize experts’ observable characteristics, including gender and what experts published on as sourced from our pertinent paper selection based on the abstracts from SCOPUS, to study how this relates to variation in carbon price recommendations. We find that expert characteristics exhibit only a very limited correlation with carbon price recommendations. Notably, carbon price recommendations are not different among those publishing in economics journals, or among those experts who have published on IAMs or the SCC.

4.4 The data in combination

We finally consider multivariate regressions that combine all explanatory variables. We find that a full model can explain up to 19 (25) percent of the variation in the global (unilateral) carbon price recommendations. We also undertake a closer inspection of the combined data when keeping only those explanatory variables that we have found to be significantly correlated with carbon price recommendations in systematic ways. This core model can only

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22 When examining how much of the variation in carbon price recommendations each pillar of data can explain individually, we find that experts’ recommendations on key policy design issues combined can explain up to 7 (9) percent of the variation in global (unilateral) carbon price recommendations, depending on the year (and unilateral scenario). Survey questions on “determinants” combined can explain a slightly lower amount of variation of up to 4 percent. Country characteristics combined can explain up to 5 (10) percent of the variation in the global (unilateral) price recommendations, while expert characteristics can explain only up to 1 (3) percent of the variation, respectively. We report all detailed results in Online Appendix B.3.
explain up to 14 (20) percent of the variation in global (unilateral) carbon price recommendations. This additional analysis confirms that the main findings from Sections 4.1–4.3 carry over. Yet, while several of the explanatory variables have predictive power on experts’ price recommendations, and many consistently so across different regression models, at least around 75 percent of the variation in the data remain unexplained. By contrast, we find that carbon price recommendations are strongly correlated across scenarios: Unilateral carbon price recommendations with (without) BCA can explain 64 (60) percent of the variation in global price recommendations in 2030. This points at strong idiosyncratic or subjective elements in the mental climate-economy models used by experts to arrive at their carbon price recommendations.

5. Discussion

5.1 Interpretation of carbon price recommendations

A key advantage of our approach is to give experts full flexibility in determining their recommendations. With this flexibility, aspects that experts consider important, but that are hard to quantify or to capture in a formal model, may be reflected in their recommendations alongside established insights or evidence (see the expert quote in footnote 2).23 Our flexible approach—ideally—allows arriving at a broader and more representative view. Yet, although we can quantify the amount of heterogeneity and (dis-)agreement in experts’ carbon price recommendations, we can only partially explain these. While concerns, such as those relating to non-response or non-representation biases, can be partially accounted for (Online Appendix C), others are more difficult to pinpoint. In the following, we discuss a number of such issues of interpretation.

23 These may relate, for instance, to issues such as “loss of habitat or biodiversity”, concerns regarding “trade conflicts”, or complex political economy considerations involving “political feasibility”, to name just a few examples given by experts that may be hard to capture formally.
First, when interpreting our results, it is important to be aware that experts’ responses reflect a mix of positive and normative considerations. That normative considerations affect carbon prices is not special to our survey. Every IAM or attempt to quantify the SCC has to rely on normative choices on how to balance well-being within and across generations. IAMs differ in the intensity to which they reflect how normative choices drive results. Oftentimes, they vary ‘‘key normative parameters’’ within Discounted Utilitarianism (Nordhaus, 2008: 188), but rarely explore robustness against other ethical approaches. By contrast, our flexible design cannot be explicit about how specific normative parameters drive recommendations, as ethical approaches employed by experts can be very diverse. Besides drawing on variants of Utilitarianism, experts were also free to draw on deontological ethics, such as rights and or duties, or procedural justice considerations, such as non-discriminatory procedures.

Making decisions on normative issues contains “an irremediably democratic element” (Dasgupta, 2008: 158). One respondent, for instance, calls for a “citizen jury” approach. In the absence of a world government to which one can relegate making these thorny normative choices, we did not want to impose a specific normative corset on our diverse set of experts. As a consequence, we are not able to fully disentangle the role of different normative drivers of experts’ recommendations. However, we study and illustrate how recommendations vary along key normative considerations in cost-benefit and cost-effectiveness analysis in Section 4.2: utility discounting, and the global emission reduction target (ERT). Thus, policy-makers and analysts can, to some degree, select subsets of expert recommendations tailored for their respective purposes. For instance, they may only consider carbon price recommendations for a specific utility discounting interval in line with their policy guidance, or select carbon price recommendations in line with reaching net-zero in 2050.

24 Some respondents state their views on selected normative issues. One respondent notes that s/he views discounting as an “ethical issue” but damages estimates as “hard numbers”.
A related limitation of our flexible and succinct survey is that experts likely not only had different normative frameworks in mind, but also different scenarios about behavioral and strategic reactions of various agents in their mental climate-economy models. For example, in the questions on unilateral carbon pricing, our survey did not provide assumptions about the behavior of other countries. Hence, some experts may have had in mind a business-as-usual scenario for policy choices of the other countries. Other experts may have considered strategic interactions or policy changes in the other countries, potentially induced by unilateral leadership (Mideksa, 2022), or that countries coordinate on a cooperative path in line with the Paris Agreement.

We deliberately designed our survey in this way to limit its complexity and length, and to approximate real-world situations where governments seek advice from experts on policy issues. In such situations, there are typically also no exact definitions of social welfare, or precisely defined scenarios for the likely behavior of households, firms, and foreign governments. Furthermore, imposing more assumptions does not fully eliminate the problem that experts may still have different scenarios in mind. By contrast, providing a full set of definitions and assumptions would ultimately amount to establishing a formal model of the climate-economy, thereby severely limiting respondents’ discretion in how to form their recommendations. Forcing experts into a corset of precise definitions and functional form assumptions would eventually invalidate our research approach that tries to elicit experts’ recommendations on carbon pricing directly. Our approach is thus complementary to attempts that

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25 While the preamble and survey questions fix some normative and positive aspects, numerous issues were left for experts to decide on. These include, among others, the form and arguments of utility functions, the specification of the normative framework and its specifics, such as Pareto weights in a standard social welfare function, behavioral reactions of households, and strategic reactions of firms and countries. While this design is deliberate and has been piloted, it is an open issue how to best aggregate “mental models” with heterogeneity in both normative and positive aspects. We therefore report a number of summary statistics beyond the mean.

26 One expert notes, for example: “The questions about optimal unilateral actions depend upon whether other countries will follow my country, particularly by 2030.” Another notes: “For the US, I put the same values for the questions 1, 3, and 4 because my belief is that if the US unilaterally imposed those carbon taxes, a large number of other countries would too.”
calibrate formal climate-economy models (e.g., Hänsel et al., 2020; Jaakkola and Millner, 2022; Nesje et al., 2022; Pindyck, 2019) to compute the SCC or optimal carbon prices under specific assumptions.

Finally, we discuss whether expert recommendations bring anything new to the table, or whether expert responses are just a (fuzzy) representation of numbers that the experts have seen in (or contributed to) other parts of the literature. We already noted above that our approach is complementary to existing literatures. As such, it is beyond doubt that experts’ recommendations contain a reflexive component. While we are unable to quantify the amount of additional information, there are clues in the data that speak against the majority of responses being merely a recollection of numbers from the literature.

First, if experts were mainly recollecting numbers from the literature, we would not expect their carbon price recommendations to differ according to their recommendations for policy instruments, in particular tax versus cap-and-trade, or their preference for the implementation of BCA. There is no obvious reason why such relations should exist if experts were simply reporting a fuzzy recollection of numbers from the literature. Our finding that experts who differ along those dimensions recommend substantially different carbon prices, may thus point at deeper underlying differences in their normative and positive considerations, or their “mental models of the climate-economy”. Relatedly, we find that country-level characteristics not only affect unilateral carbon price recommendations, but are also strongly linked to experts’ global carbon price recommendations. This also points at considerations shaping experts’ views on carbon pricing beyond a recollection of results from the literature.

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27 One respondent, e.g., stated: “The most difficult question concerns the path of the carbon price. My answer comes from my limited knowledge of IAMs and some of the survey work by Pindyck, as well as recent views about what are the target compatible prices for 1.5-2°C.”

28 For example, one expert reports that we do not have the “necessary reliable simulation models to forecast what the global socio economic situation will be if we fail to remain below the 2°C level.” According to another: “Current economic damage models do not properly account for possible positive feedback loops, such as arctic ice melting or other thresholds.”
Second, our observation that the price recommendations of experts who have published on IAMs or on the SCC do not differ systematically from those of other experts suggests that results from these literatures may not be an overly strong driver of responses to our survey. Under the (plausible) assumption that experts who publish on such issues have a better knowledge or more exposure to numbers from those strands of literature, one may otherwise expect to see systematic differences between these experts and those without such exposure.

Third, and relatedly, we explore how experts’ 2020 carbon price recommendations relate to potential recollections of SCCs in the literature. To begin with, we compare recommendations to official guidance. At the time of the survey, the Trump administration in the US had set the SCC at $1 to $7, substantially lower than experts’ recommendations (t-tests: p<0.000); experts’ recommendations align closely with the previous SCC estimate used under the Obama administration ($43 in 2007 USD, around $53 in 2019 USD; t-test: p=0.296). By contrast, carbon price recommendations are much lower as compared to the official SCC of around $200 in Germany, the country with the second largest number of respondents (t-test: p<0.000). Next, we compare recommendations with the central SCC estimate from the latest prior version of DICE by Nordhaus (2018) of $35 in 2010 US dollars, around $42 in 2019 US dollars, which is lower than the mean 2020 carbon price recommendation (t-test: p=0.002). Finally, we compare recommendations to the more than 5000 SCC estimates from the meta-analysis by Tol (2022), adjusting these SCC estimates to 2019 US dollars and per ton of CO₂ values. SCC estimates in the literature are more dispersed and skewed towards much higher values, such that both the means and distributions differ significantly (t-test: p<0.000; Kolmogorov-Smirnov test: p<0.000; see Figure C.1 and corresponding text in Appendix C.1 for details).

While experts’ recommendations likely heavily draw on the literature, these observations suggest that they contain additional (positive and normative) information beyond fuzzy recollections of the literature. Nevertheless, it is
important to stress that our flexible approach of eliciting carbon pricing recommendations from experts directly is highly complementary to the theoretical and empirical literature. Indeed, without these literatures, well-founded views on carbon pricing that can be evaluated using expert elicitation might not exist to begin with. Thus, while expert elicitation can complement other approaches to systematically determine (dis-)agreements, it is by no means meant to replace them.

5.2 Discussion of the “Glocal-wedge”
Next, we provide a more detailed discussion of a key (but unexpected) finding: That experts’ recommendations, on aggregate, do not exhibit a “free-riding” pattern of lower unilateral than global prices, but that many experts, instead, tend to recommend higher carbon prices in the unilateral scenario with BCA than globally (Result 3 in Section 3.2). We already indicated that the “Glocal-wedge” becomes negative and larger (in absolute terms) with increasing GDP per capita (linear regression, p=0.003), illustrated in Panel A of Figure 8. Our data can shed some light on potential explanations for these patterns.

Suppose that experts exhibit altruistic values, partially factoring in impacts of non-domestic citizens when recommending unilateral policies, or other global welfare considerations, and consider the following two hypotheses. First, assuming that climate damages are convex in aggregate emissions, and that experts have in mind a unilateral scenario with BCA where other countries do not step up their climate policies when their own country does, may explain why experts’ unilateral carbon price recommendations with BCA are relatively high. Namely, an expert may then recommend a high unilateral price to their domestic government to avert the worst climate damages (see Schmidt et al. (2022) for a formal analysis). Second, experts’ concerns regarding a higher vulnerability of poorer nations’ economies in relation to a uniform global carbon price may offer an explanation for why global carbon price
recommendations are relatively low.\footnote{One respondent, e.g., remarked: “The first question suggests a universal global tax. The tax that would be suitable in a fully developed country would seem inhumane in many countries with substantially lower per capita income. Hence, I do not agree to any such global tax without clearly specified compensating mechanisms.” This concern is mirrored by other experts, while some state that they abstract from “political considerations”.} In conjunction, these two hypotheses may offer explanations for the lack of the free-riding pattern of higher global than unilateral with BCA carbon prices in experts’ recommendations.\footnote{In Schmidt et al. (2022), we test the free-rider hypothesis in countries’ implemented carbon prices, based on a country-size effect predicted by theory, and find no indication for such a free-riding pattern in countries’ implemented carbon prices.}

While we cannot directly test these hypotheses, we can shed some light on their plausibility. First, we consider the BCA-wedge as a proxy of an expert’s expected international carbon price heterogeneity, with a higher BCA-wedge indicating the expectation that other countries may not (sufficiently) step up their policies when their own country implements a carbon price unilaterally. Panel B of Figure 8 shows that the 2030 Glocal-wedge becomes more negative with an increasing 2030 BCA-wedge (linear regression, $p<0.000$). This suggests that experts who are not expecting high efforts by other countries under unilateral action by their country, tend to recommend higher carbon prices to their country in the scenario with BCA (in line with our earlier hypotheses).

Second, we investigate how perceptions on damage convexity affect the Glocal-wedge. For this, we compare experts who put the highest probability on unabated climate change (beyond current policies) causing global damages of at least 20 percent of global GDP by 2070, with those who put the lowest probability on this (see Panel C of Figure 8). We find that those who expect the highest probability have a substantially—albeit insignificantly—more negative 2030 Glocal-wedge ($-$21) than those who expect a low probability ($-$6; t-test: $p=0.334$), again in line with our earlier hypothesis.

Additionally, we consider the recommendation to use carbon pricing revenue for international transfers as a proxy for global welfare considerations. Panel D of Figure 8 shows that the 2030 Glocal-wedge for experts recommending this option is more negative ($-$20 vs. -$9; t-test: $p=0.073$).
Figure 8: The “Glocal-wedge” along selected determinants

Notes: Panels (A) and (B) show linearly fitted Glocal-wedges for the year 2030, with spikes representing 95 percent confidence intervals, along GDP per capita (Panel A), and along the difference in the BCA-wedge (Panel B). Panels (C-E) depict relations of additional survey question and the 2030 Glocal-wedge, with means and standard errors. Panel C splits the Glocal-wedge by views on climate damage convexity, Panel D by whether experts recommend to use carbon pricing revenue for international transfers, and Panel E by views on utility discounting.

Relatedly, we consider utility discounting as a proxy for altruistic motifs more generally and investigate how the 2030 Glocal-wedge depends on discounting views. An ordered logistic regression shows that the 2030 Glocal-wedge becomes more negative with a higher utility discount factor ($p=0.020$). Panel E of Figure 8 shows that experts putting the highest weight on future generations, as compared to those with the lowest, exhibit a more negative 2030 Glocal-wedge ($-30$ vs. -$4$; $t$-test: $p=0.098$).

Further explanations that may help to rationalize why unilateral with BCA carbon price recommendations can be higher than global ones in higher income countries, and hence to produce a negative Glocal-wedge on aggregate,
may relate to differences in mitigation costs or unilateral policy potentially requiring more effort to achieve mitigation targets, to the role of co-benefits of emission reductions, such as improved health due to reduced air pollution, which is valued more highly in richer countries, or to mechanism design approaches to relocation risk (e.g., Ahlvik and Liski, 2022).

While these Glocal-wedge findings suggest that other drivers may more strongly shape experts’ carbon price recommendations than free-riding concerns, this does not imply that experts think that free-riding is not a major issue in practice. We leave delineating and substantiating the specific mechanisms giving rise to this pattern and its generalizability for future work.

6. Conclusion
Implementing effective climate policy remains a key challenge for policy makers around the globe. We focus on the most prominent solution derived from economics and investigate what price should be put on carbon emissions. Specifically, we study the variation of global and unilateral carbon price recommendations and selected determinants based on a global survey among experts. We quantify the extent of agreement on carbon prices and analyze how recommendations vary with additional survey data and with country- and expert characteristics. Our paper provides useful data for researchers and practitioners alike. For example, the distribution of carbon price recommendations may be used in scenario analyses of climate-economy models (Hänsel et al., 2022), and experts’ recommendations may also directly inform policy.

31 “I recommend slightly higher prices as the unilateral targets that they are bound to are more costly than those required by a global carbon reduction effort.”
32 Local co-pollutants, such as particulate matter, nitrogen and sulfur oxides or volatile organic compounds, are often discharged in combination with CO2. While co-benefits could be dealt with using a separate instrument, they tend to be considerably under-internalized (e.g., Shapiro and Walker, 2020), and may constitute an additional determinant of carbon pricing (e.g., Parry et al., 2021). Due to a positive income elasticity of health benefits (e.g. Viscusi and Masterman, 2017), co-benefit-related price recommendations are likely higher in richer countries.
Future research should investigate, why real-world carbon prices are generally much lower than what experts would recommend. This begs the question whether economists should keep focusing on pricing carbon when the approach is difficult to implement for political leaders (e.g., Martinez-Alvarez et al., 2022) and has so far only led to suboptimal prices. While some experts question the merits of carbon pricing for exactly these reasons in their qualitative comments, there are also strong reasons for continuing to focus on pricing, especially if the urgency and potential costs of implementation delays can be addressed (Goulder, 2020). The literature offers a wide range of possible explanations why policy-makers are reluctant to implement (adequate) carbon prices (e.g. Klenert et al., 2018). Explanations comprise free-riding, vested interests of existing industries (“carbon lock-in”), lobbyism, status quo bias, lack of public support for active climate policy, among others. Our data do not point at free-riding as the main issue, at least as far as expert recommendations are concerned. It is crucial to further investigate which barriers to pricing carbon are most relevant, and how to address them adequately.

Likewise it will be interesting to investigate to what extent views on carbon pricing of experts in a given country are representative of the general population. While our results suggest that a number of expert recommendations reflect some degree of intra- and intergenerational altruism or other global welfare considerations, we naturally cannot determine to what extent this is representative of other populations. Future studies should thus target a broader population of experts and non-experts, and seek to obtain more responses from countries under-represented in our study. This can also help to shed more light on issues such as non-representation bias, to further investigate drivers of the considerable heterogeneity in views on carbon pricing, and to devise strategies that may help to increase the uptake of carbon pricing in different countries.

According to one expert: “In fact, as recent geopolitical events have revealed, pure carbon pricing in a policy vacuum is politically untenable (see: the Yellow Vest Protests) and incapable of mobilizing massive public spending in areas like renewable energy, public transportation, sustainable agriculture, and adaptation.”
Appendix: The survey text

The survey asked publication-based experts about recommended carbon prices and a number of related policy design issues. We also asked for the names of participants and explained in the invitation e-mail that we would protect their anonymity by publishing results only in such a way that no individual participant could be identified. The survey began with the following contextual preamble, followed by eight quantitative and qualitative questions as well as an optional comments section for additional qualitative responses:

We seek your advice on hypothetical new carbon pricing policies for CO2 emissions covering all sectors of the economy. We first ask for your recommendations on global uniform carbon pricing. We then move to a national level and seek recommendations on unilateral carbon pricing. This includes questions regarding policy design issues. These include the use of revenues from carbon pricing as well as instrument choice, that is whether carbon pricing should be implemented in the form of a tax, a cap-and-trade scheme or some other instrument.

(Q1) Suppose that a “world government” exists, which seeks to maximize the well-being of all present and future people and plans to implement a uniform global carbon price (measured in real US dollars per ton of CO2). Which carbon price would you recommend to the “world government” for the years 2020 [X], 2030 [X], and 2050 [X]? Which range of carbon prices would you still be comfortable with recommending for the years 2020 [X] – [X], 2030 [X] – [X], and 2050 [X] – [X]?

(Q2) Please specify the country you are most familiar with or that you would feel most comfortable advising on carbon pricing (below, we will refer to this as “your country”): [__].
(Q3) Suppose that your country unilaterally introduces a carbon price. Suppose further that any competitive disadvantages are neutralized by border carbon adjustment, exempting exports from the carbon price and pricing the carbon content of imports at the domestic rate. In this case, which carbon price would you recommend to your government for 2020 \([X]\) and 2030 \([X]\), and which range of carbon prices would you still be comfortable with recommending for 2020 \([X] – [X]\) and 2030 \([X] – [X]\)?

(Q4) Suppose that your country unilaterally introduces a carbon price without border carbon adjustment. In this case, which carbon price would you recommend to your government for the years 2020 \([X]\) and 2030 \([X]\)? Which range of carbon prices would you still be comfortable with recommending for the years 2020 \([X] – [X]\) and 2030 \([X] – [X]\)?

(Q5) If your country implements a carbon pricing scheme unilaterally, would you strongly recommend introducing a border carbon adjustment scheme (if that is possible)? Yes \([x]\), No \([x]\).

(Q6) Assuming that no carbon pricing scheme has been implemented in your country yet, which instrument would you recommend using for it to be implemented? Carbon tax \([x]\), cap-and-trade with price collar (price floor and price cap) \([x]\), cap-and-trade without price collar \([x]\), other instrument (or mix of instruments), please specify \([__]\), no clear recommendation \([x]\).

(Q7) Considering the case of unilateral carbon pricing without border carbon adjustments, how should your government use the revenues raised by carbon pricing? (Multiple answers are possible.)
   a) General government spending \([x]\); b) Equal lump-sum transfers to households \([x]\); c) Transfers to particularly affected households \([x]\); d) Reduction of distortionary taxes \([x]\); e) Grandfathering or tax cuts for firms \([x]\); f) Transfers to particularly affected firms \([x]\); g) Spending on environmental public goods \([x]\); h) Green R&D \([x]\); i) Subsidies for renewable energy \([x]\);
j) International transfers to countries particularly affected by climate change [x]; k) International transfers to support climate policy in other countries [x]; l) Other, please specify [__].

If you suggest more than one use, please indicate your most recommended option by its letter [__]. Please also specify which percentage of total revenues should (roughly) be allocated to it [X].

(Q8) Please also provide your (very rough) views on the following issues:

(a) By what percentage should global CO2 emissions be reduced by 2050 as compared to today?
   <20% [x], 20% to <50% [x], 50% to <80% [x], 80% to <100%, [x] ≥100% [x];

(b) How costly would it be to reduce global CO2 emissions by 80% by 2050 (average abatement cost per year as percentage of global GDP until 2050)?
   <0.25% [x], 0.25% to <0.5% [x], 0.5% to <1% [x], 1% to <3%, [x] ≥3% [x];

(c) In the absence of effective climate policy (beyond current policies), what is the probability that in 2070, climate change will cause global damages, comprising both market and non-market impacts, of at least 20 percent of global GDP?
   <5% [x], 5% to <10% [x], 10% to <20% [x], 20% to <50% [x], ≥50% [x];

(d) How large are the expected annual global damages from climate change, measured as a percentage of future global GDP and comprising both market and non-market damages, for 3°C global warming (in the absence of effective climate policy beyond current policies we may reach 3°C by around 2070)?
   <2% [x], 2% to <5% [x], 5% to <8% [x], 8% to <12% [x], ≥12% [x];

(e) As compared to the utility of a person today, what is the weight (measured in percent) that should be put on the utility of a person in 2070 in global public decision-making?
   <40% [x], 40% to <60% [x], 60% to <80% [x], 80% to <100% [x], 100% [x].

Feel free to provide us with any additional comments or feedback: [___].
References


Nesje, F., Drupp, M.A., Freeman, M.C., & Groom, B. (2022). Philosophers reinforce economists' support for UN climate targets, but disagree on why. Available at Research Square.


Pindyck, R. S. (2013). Climate change policy: what do the models tell us? Journal of Economic Literature 51, 860-72.


