Pricing Carbon: Evidence from Expert Recommendations

Moritz A. Drupp
(University of Hamburg)

joint work with

Frikk Nesje (University of Copenhagen) and Robert Schmidt (University of Hagen)

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Introduction

- Pricing CO_2 emissions is widely appreciated as a corner stone of climate change policy, which has to become much more stringent to be aligned with the UN Paris Agreement in addressing *"the biggest market failure the world has seen"* (Stern 2008 *AER*)
  - see "Economists' Statement on Carbon Dividends" (WSJ 2019) and "Economists' Statement on Carbon Pricing" (EAERE 2019), signed by ≈5000 economists

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  - Trading-off well-being of current & future generations shapes carbon price paths
  - Instrument choice & architecture determine distribution of (net) policy costs

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- Suggestions for carbon prices or the social cost of carbon range from negative values to >1000 US$/t$CO_2$, often informed by integrated assessment models (IAM)
  (e.g. Dietz/Stern 2015 *EJ*; Hänsel et al. 2020 *NCC*; Nordhaus 2019 *AER*; Ricke et al. 2018 *NCC*; Tol 2022)

  ⇒ This seemingly enormous disagreement is regarded as an impediment to climate action

Introduction

- IAM results are criticized as very sensitive to or too strongly limited by parametric and structural modelling assumptions, which are often left to the modeler's judgement
  (e.g. Pindyck 2013 *JEL*, Stern & Stiglitz 2021 *NBER*, Weitzman 2010 *CCE*)
  - Numerous papers on individual structural changes (Moore et al. 2023)
  - Pindyck (2019 *JEEM*) uses expert elicitation to calibrate an analytic IAM
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⇒ We ask experts directly without imposing a tight IAM *'corset'* to facilitate a better understanding of the actual (dis-)agreement on carbon pricing among experts who may hold very diverse *mental models of the climate-economy* (cf. Andre et al. 2022 *REStud*)

"[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".

[Quote from an expert respondent]

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$\Rightarrow$ We present evidence on the variation of and agreement on global and unilateral carbon pricing recommendations based on a survey of >400 experts across almost 40 countries

The expert survey (June-Nov. 2019)

- Our definition of a potential expert:
  (Co-)Author of at least 2 pertinent & cited publications on the topic since the year 2000, indentified via a keyword-based search in SCOPUS on "carbon tax", "cap-and-trade", ...

  $\Rightarrow$ More than 2000 potential experts globally (excluding missings: N=2106)
  - More than 500 responded (445 with carbon price recommendations)
    - Response rate: 20-25%
    - Covering all major continents
    - Covering 39 countries with >80% of global CO_2-emissions

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- Questions: We elicited responses on
  - the recommended level and agreeable range of carbon prices across three scenarios,
  - potential determinants of carbon prices (discounting, damages & quantity targets, ...)
  - key policy design issues, including
    - support for border carbon adjustment (BCA/CBAM),
    - use of revenues from carbon pricing,
    - instrument choice.

Global carbon price

(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, 2030, and 2050? Which range of carbon prices would you still be comfortable with recommending for the years 2020, 2030, and 2050?

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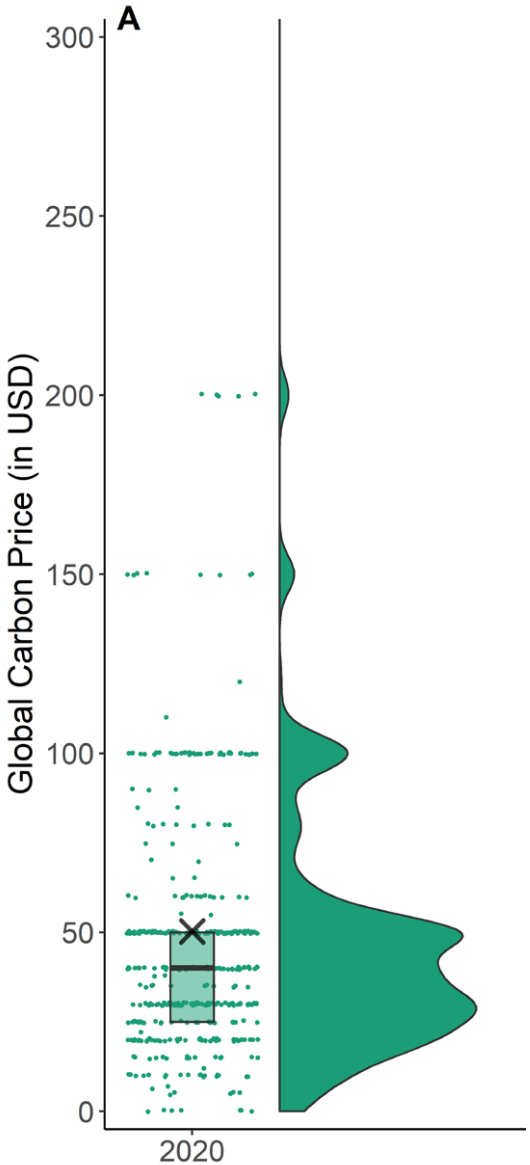
Which carbon price would you recommend to the "world government" for the following years?		Which range of carbon prices would you still be comfortable with recommending?	
2020		from	to
2030		from	to
2050		from	to

Global carbon price: 2020



	Mean
2020	$50

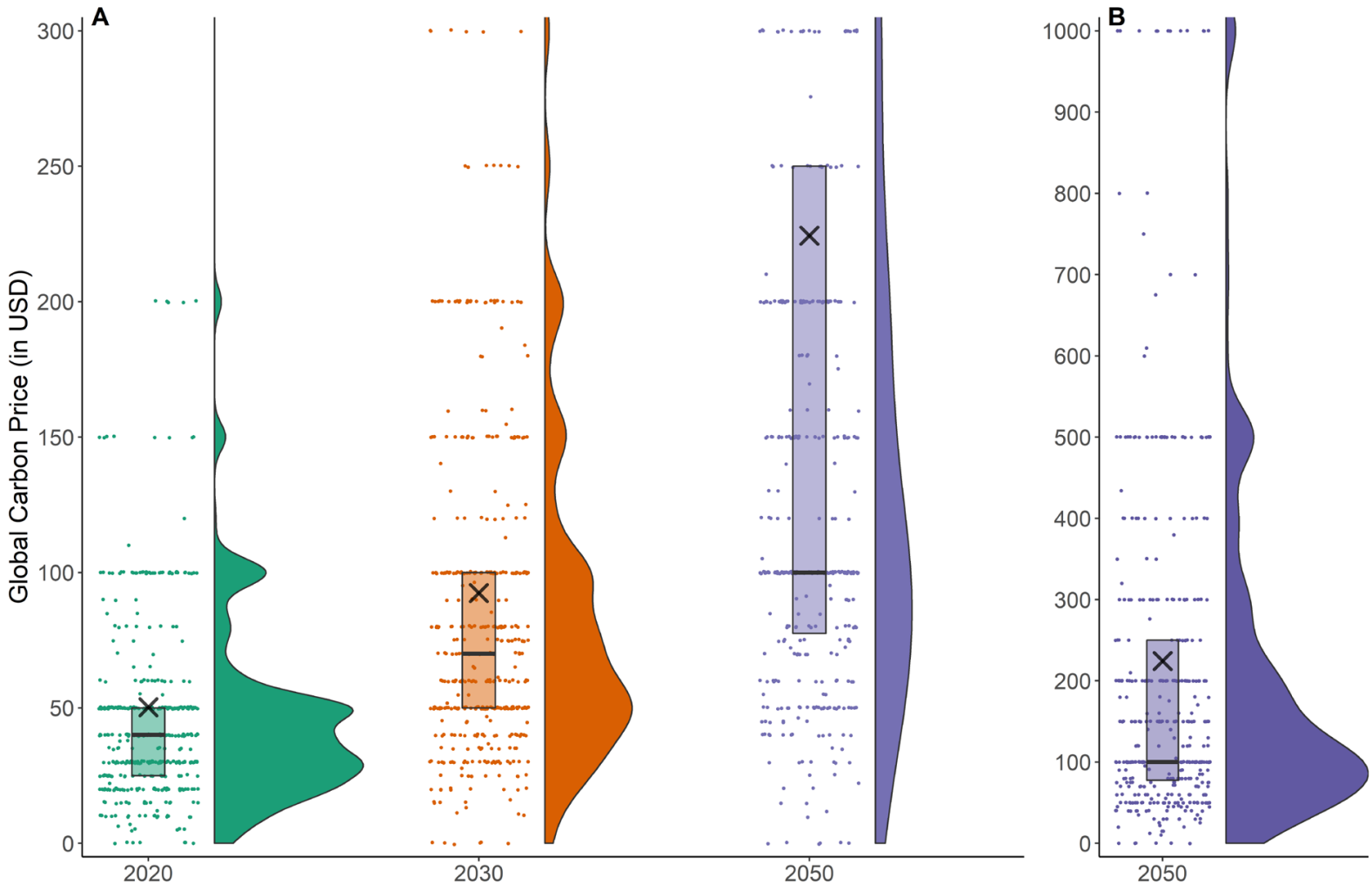
	Median
2020	$40

	IQR
2020	$25-$50

	5%-95%
2020	$10-$100

The emission-weighted global carbon price in 2020 was <$3 (Dolphin 2022)

Global carbon price: 2020 to 2050



	Mean
2020	\$50
2030	\$92
2050	\$224

	Median
2020	\$40
2030	\$70
2050	\$100

	5%-95%
2020	\$10-\$100
2030	\$20-\$250
2050	\$30-\$610

$\Rightarrow$ Median real carbon price growth rate is 4.1% p.a. (close to suggestion by Gollier 2021)

Global carbon price: Response bias and non-representation bias

- **Response bias:** Sample not representative of population across all observables
  - Some self-selection of experts into the sample (e.g. higher number of papers)
  - Re-balancing on observables leads to minor adjustments (global 2030: \$92.4→\$95.1)

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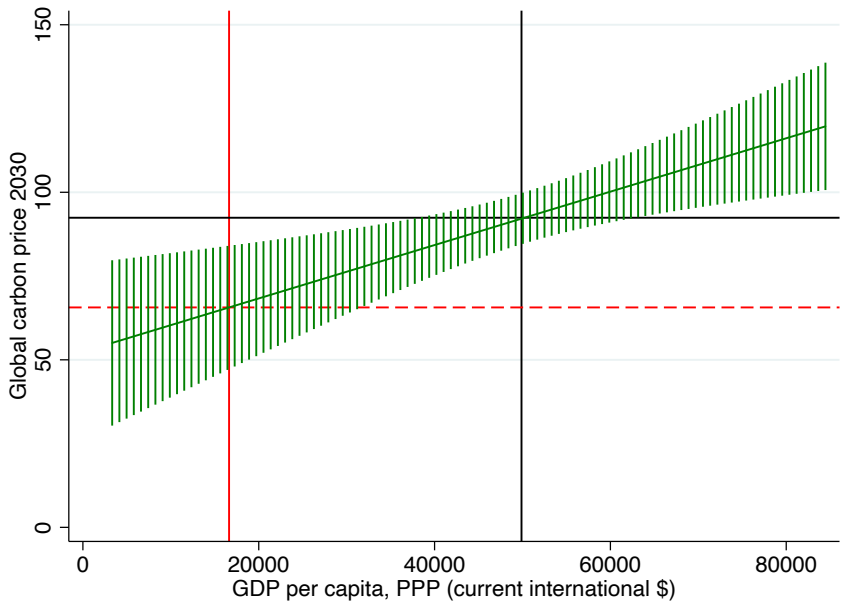
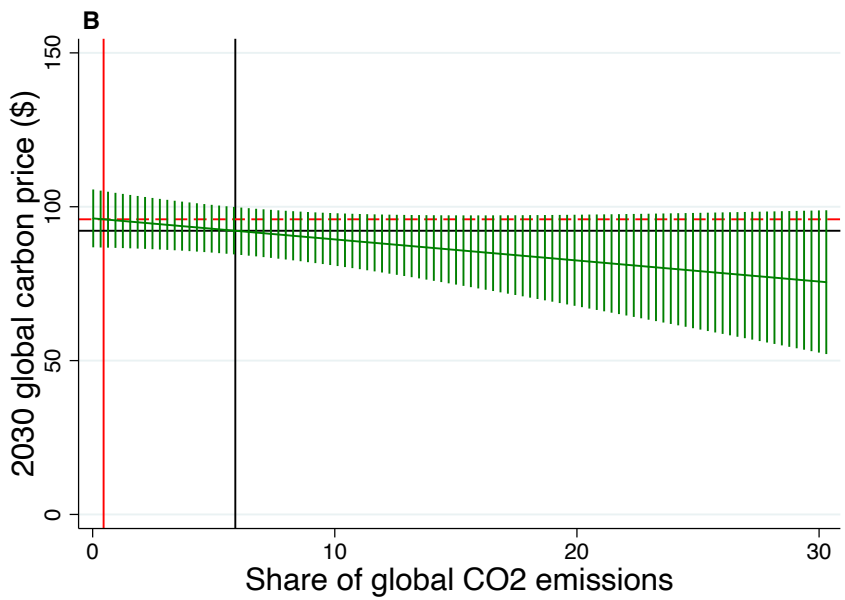
  - Re-balancing on observables leads to minor adjustments (global 2030: \$92.4→\$95.1)
- **Representation bias:** Sample and population are not globally representative
  - Global carbon price is subst. smaller at global mean GDP/capita (2030: \$66 vs. \$92), but no sign. adjustment for e.g. share of CO2-emissions/population/gender...



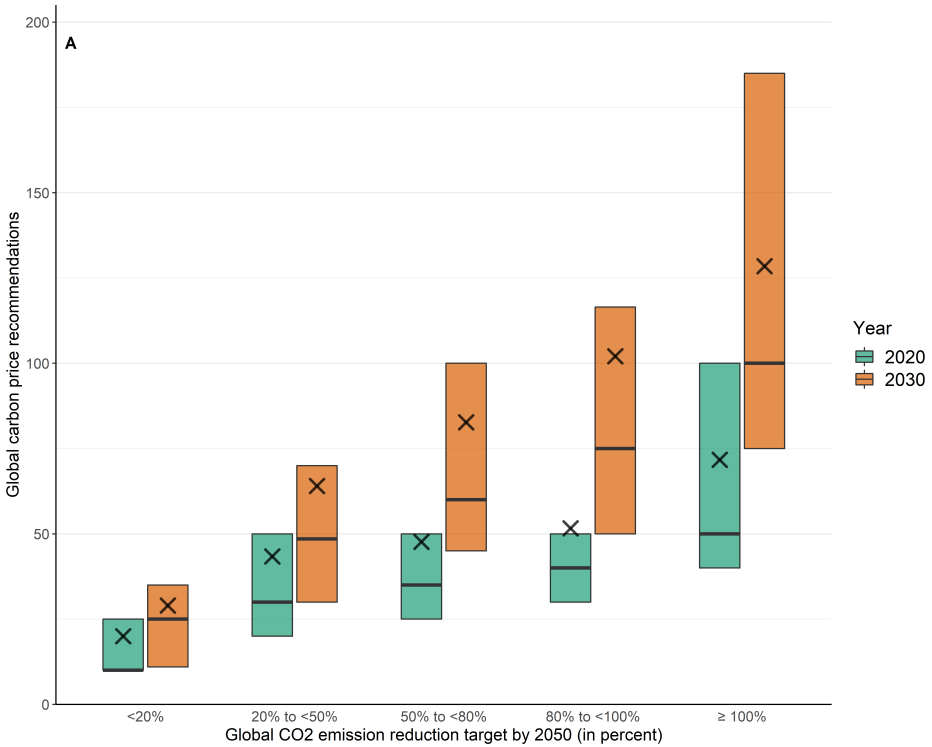


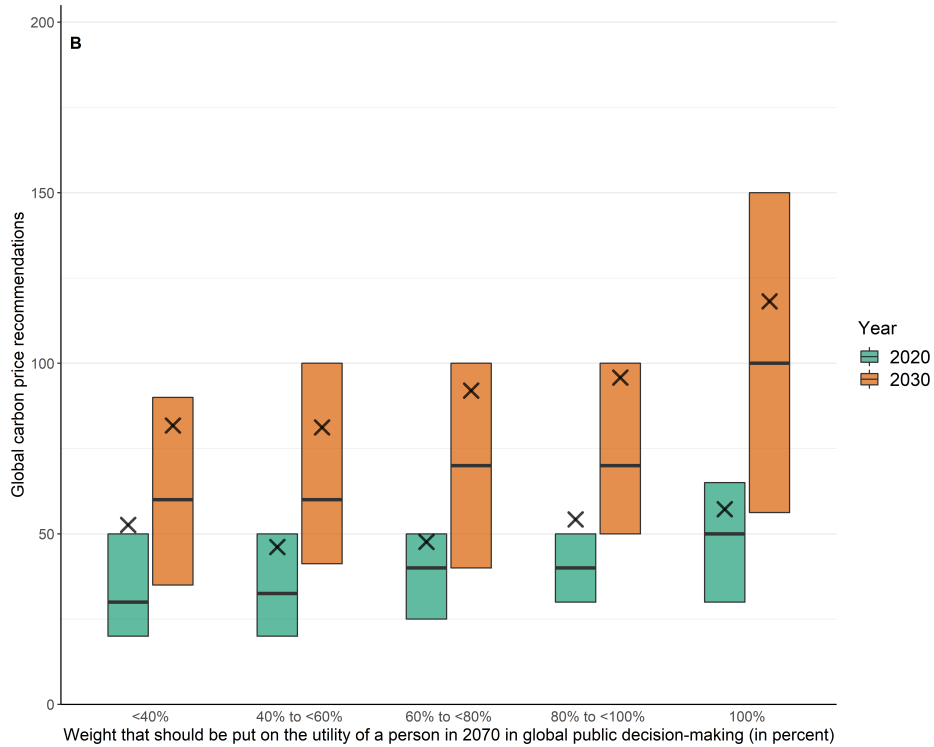
Strategic response bias

We winsorize the data for two extreme outliers, communicate median alongside mean estimates and compare early vs. late and the 57 anonymous vs. non-anonymous responses along carbon price recommendations and find no sign. differences.

- For example, two-sided t-test on 2030 global prices across non/anonymous: $p>0.35$

Global carbon price recommendations, targets and discounting





- Carbon price recommendations increase with the stringency of the quantity target, but are less sensitive to utility discounting (esp. if compared to IAMs like DICE)
  - Carbon price recommendations are a function of normative views

  $\Rightarrow$ Policy-makers can choose subset that aligns with their normative guidance

Global carbon price: Is there some “space for agreement”?

Proportion of experts whose range of carbon prices for 2020 that they would still be comfortable with recommending includes a given price:

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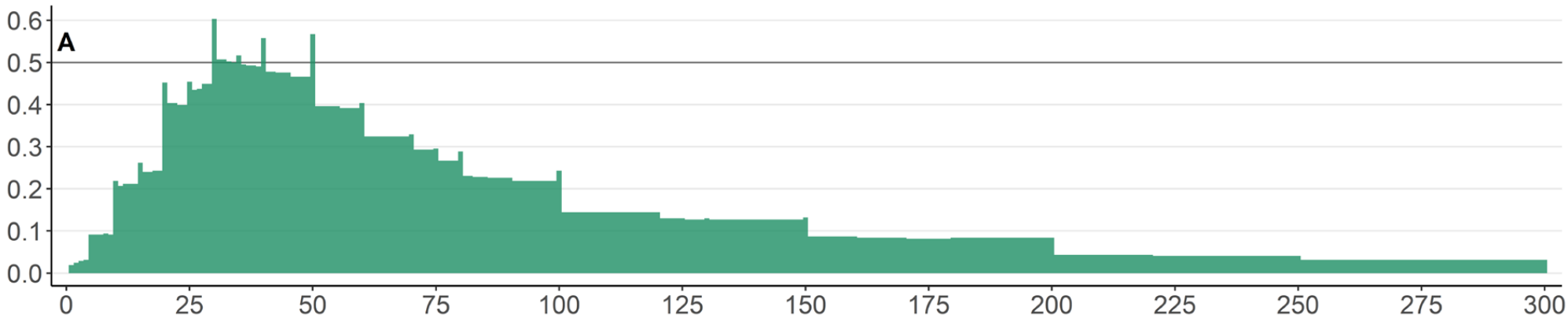
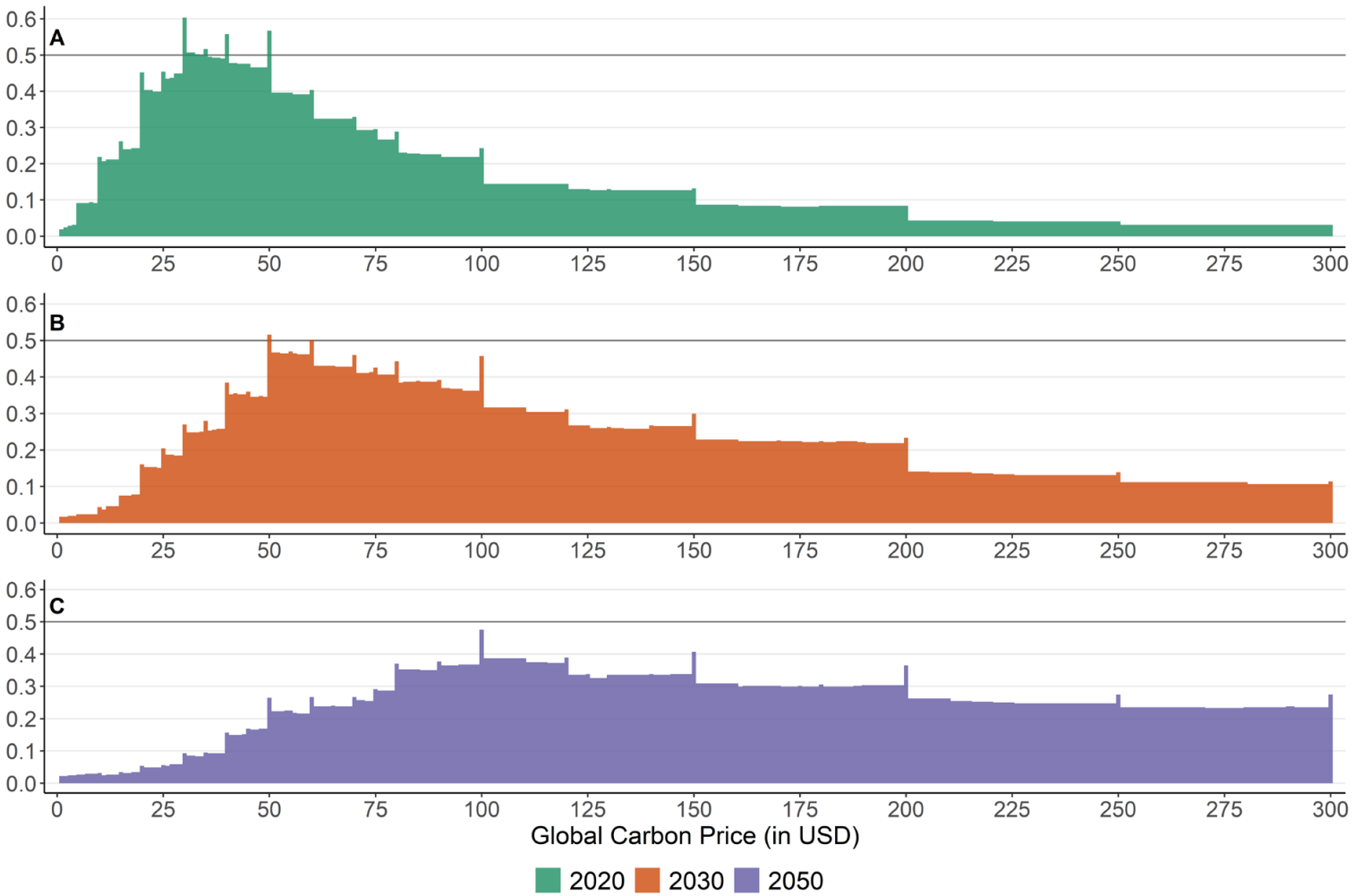


⇒ Majority considers global carbon prices of \$30-35, \$40 or \$50/tCO$_2$ in 2020 acceptable

⇒ 96% recommend lower bounds for the 2020 global carbon price strictly above the existing emissions-weighted global carbon price of ≈\$3

Global carbon price: Is there some "space for agreement"?



⇒ >50% consider carbon prices of \$50 and \$60 acceptable for 2030

⇒ No single carbon price is supported by a majority in 2050 (48% find \$100 acceptable)

Results on global carbon prices

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.*

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

$\Rightarrow$ Global carbon price of \$50 is supported by a majority in both 2020 and 2030

Carbon prices across the 3 scenarios

(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]?

$\Rightarrow$ *Global vs. unilateral with BCA: "Glocal-wedge" is indicative of free-riding*

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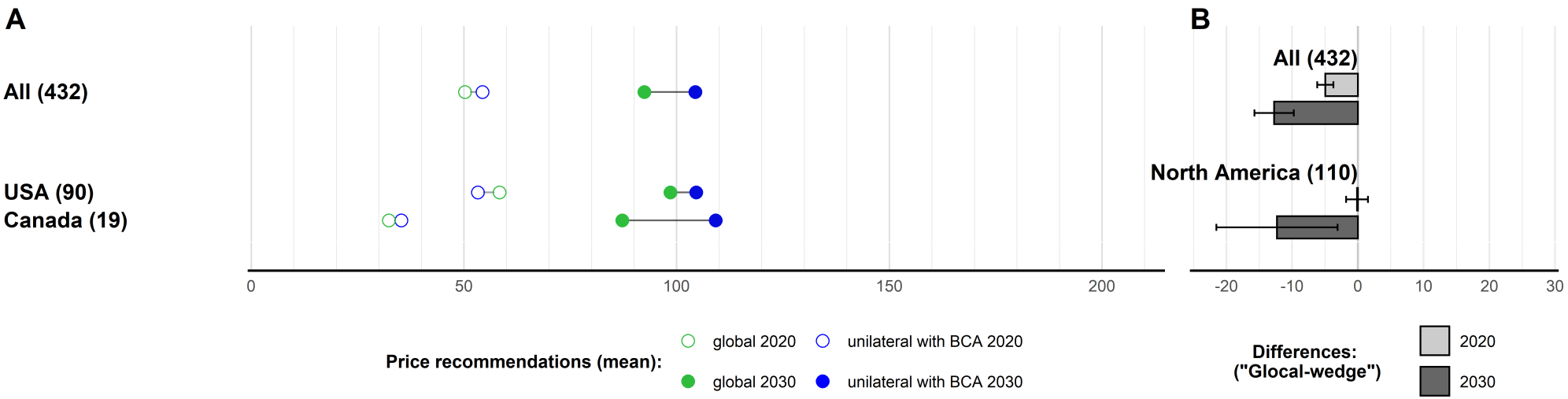
$\Rightarrow$ *Global vs. unilateral with BCA: "Glocal-wedge" is indicative of free-riding*

(Q4) As in Q3 but without border carbon adjustment, i.e. "unilateral without BCA"

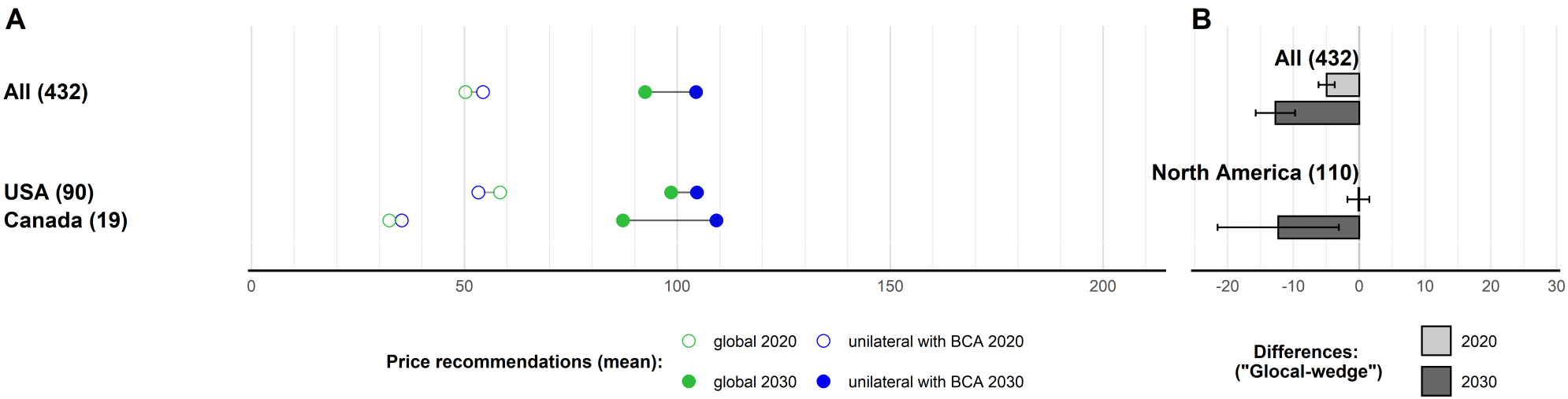
$\Rightarrow$ *Unilateral with vs. without BCA: "BCA-wedge" indicative of competitiveness concerns*

Glocal-wedge: Difference of unilateral with BCA & global prices



- Left panel: Green (blue) dot is the average global (unilateral with BCA) carbon price recommendation in 2030, and in 2020 [shallow dots].
- Right panel: Global minus unilateral with BCA carbon price recommendations (*"Glocal-wedge"*).

Glocal-wedge: Difference of unilateral with BCA & global prices



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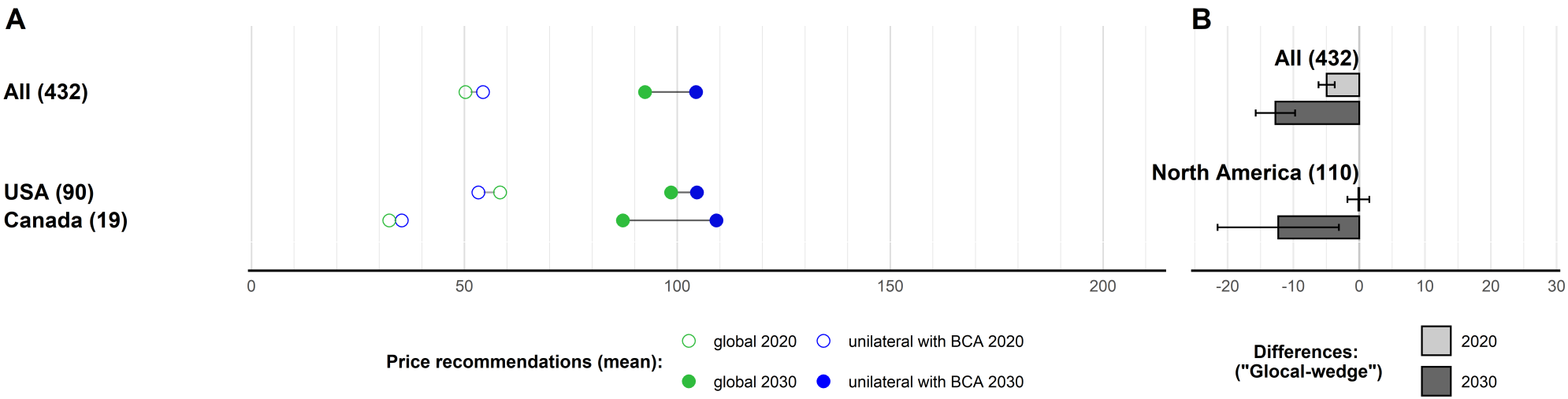
- Right panel: Global minus unilateral with BCA carbon price recommendations (*"Glocal-wedge"*).

$\Rightarrow$ "Glocal-wedge" is negative on average (two-sided t-tests for 2020 & 2030: $p<0.000$).

$\Rightarrow$ In contrast to the ubiquitous notion of free-riding in climate policy (e.g., Barrett, 1994), we detect a signature of free-riding in only 16 percent of expert responses.

Glocal-wedge: Difference of unilateral with BCA & global prices



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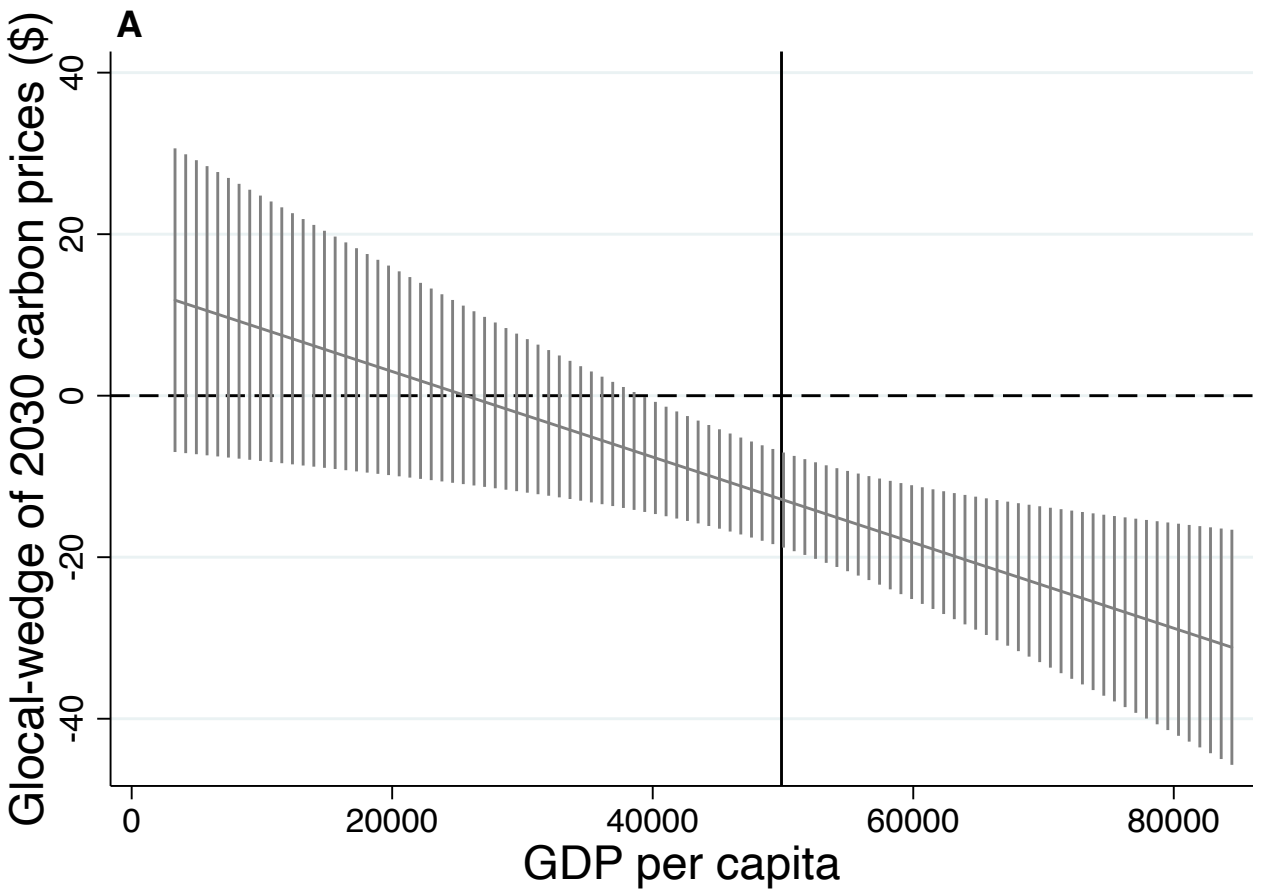
- Right panel: Global minus unilateral with BCA carbon price recommendations (*"Glocal-wedge"*).

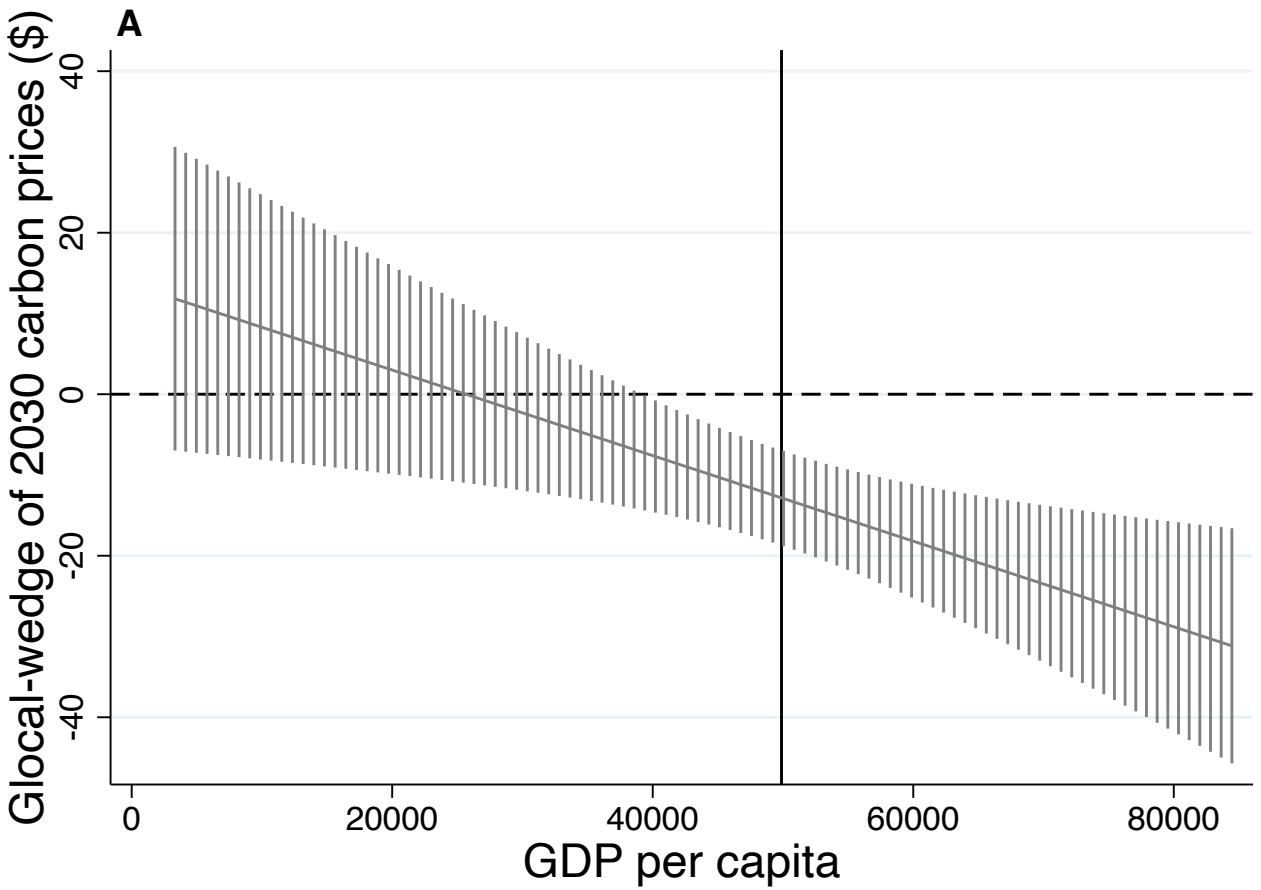
Result 3: *The majority of experts' carbon price recommendations do not exhibit a pattern of free-riding. Instead, unilateral price recommendations with BCA are, on average, higher than global price recommendations.*

Glocal-wedge as a function of GDP/capita



Higher unilateral carbon prices with BCA than global prices in richer countries

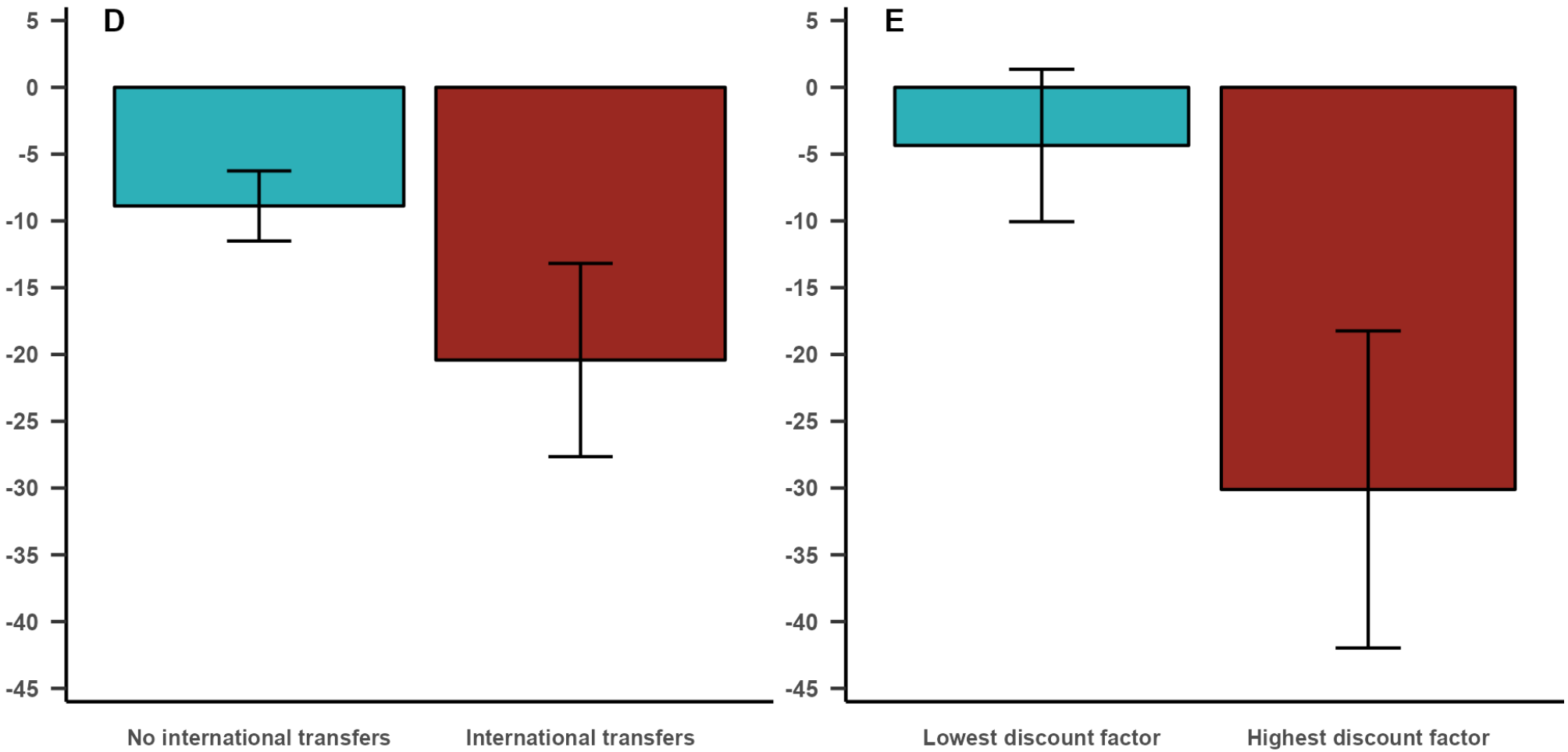
Glocal-wedge as a function of GDP/capita



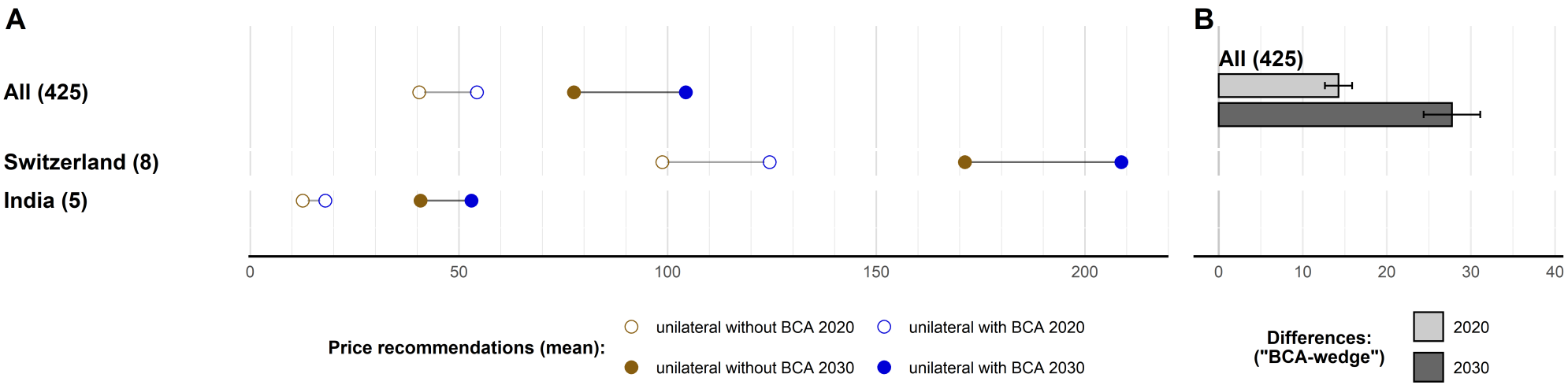
Higher unilateral carbon prices with BCA than global prices in richer countries may be due to

- **Altruism:**
  Richer countries shoulder higher mitigation burden
- **Co-pollution:**
  Local health co-benefits are valued higher in richer countries, due to a positive income elasticity of value of statistical life
- ... (e.g., abatement costs, convexity of damages, strategic firm selection)

2030 Glocal-wedge and altruism / global welfare concerns



BCA-wedge: Difference between unilateral carbon prices

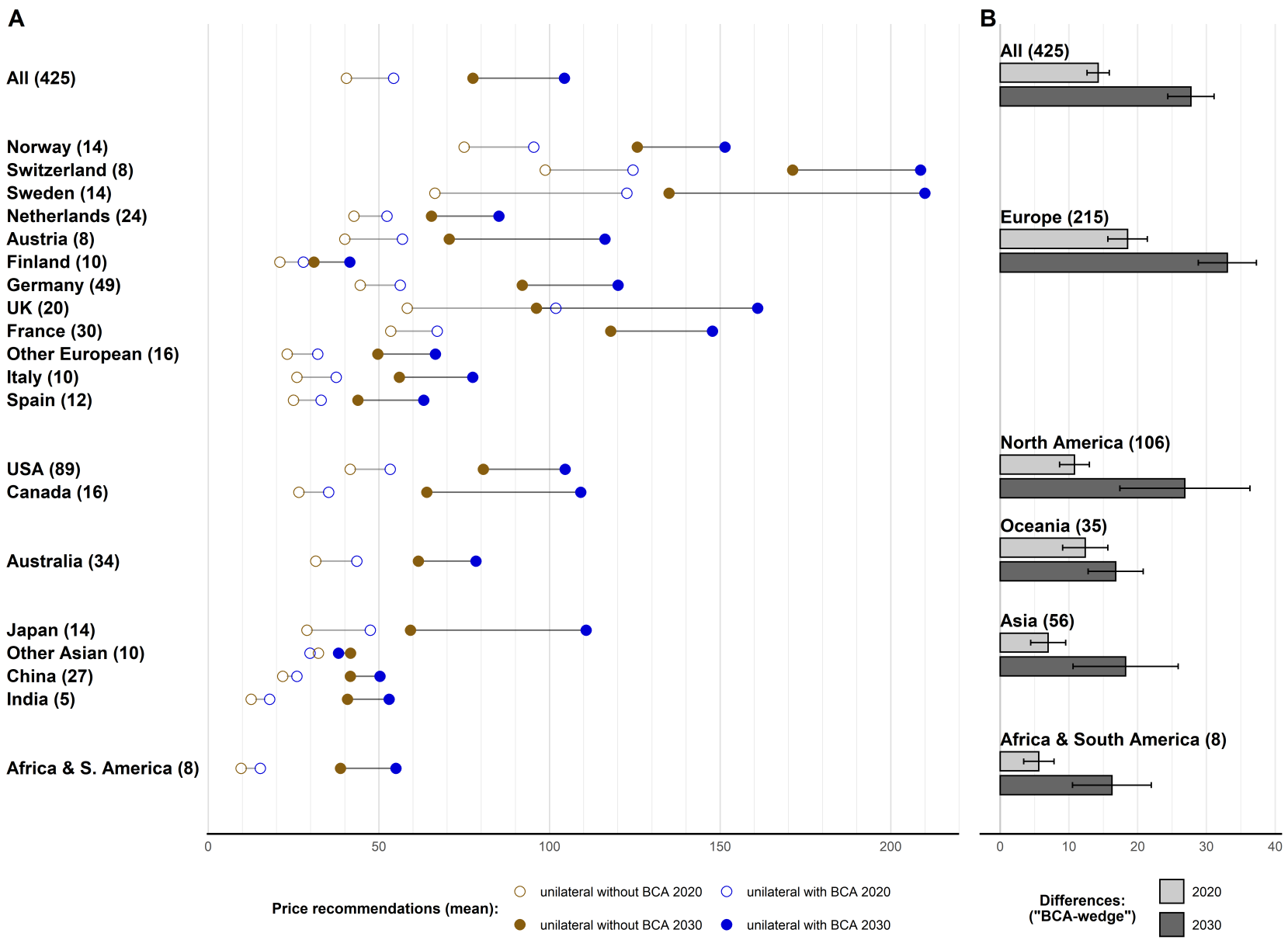


- Left panel: Blue (red) dot is the average unilateral with (without) BCA price in 2030 and 2020 [shallow]
- Right panel: Difference between unilateral prices with / without BCA (*"BCA-wedge"*)

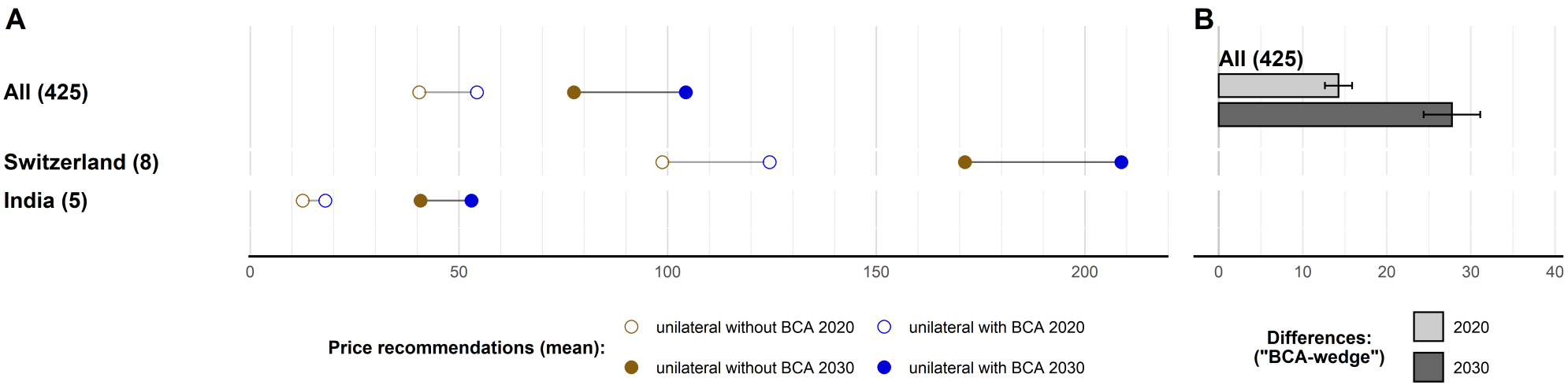
$\Rightarrow$ Unilateral carbon price recommendations are very heterogeneous across countries: From \$13 (\$41) in India to \$99 (\$171) in Switzerland in 2020 (2030) without BCA

$\Rightarrow$ Substantial BCA-wedge on average (two-sided t-tests for 2020 & 2030: $p<0.000$).

Heterogeneous unilateral carbon prices, consistent BCA-wedge



Difference between unilateral carbon prices ("BCA wedge")

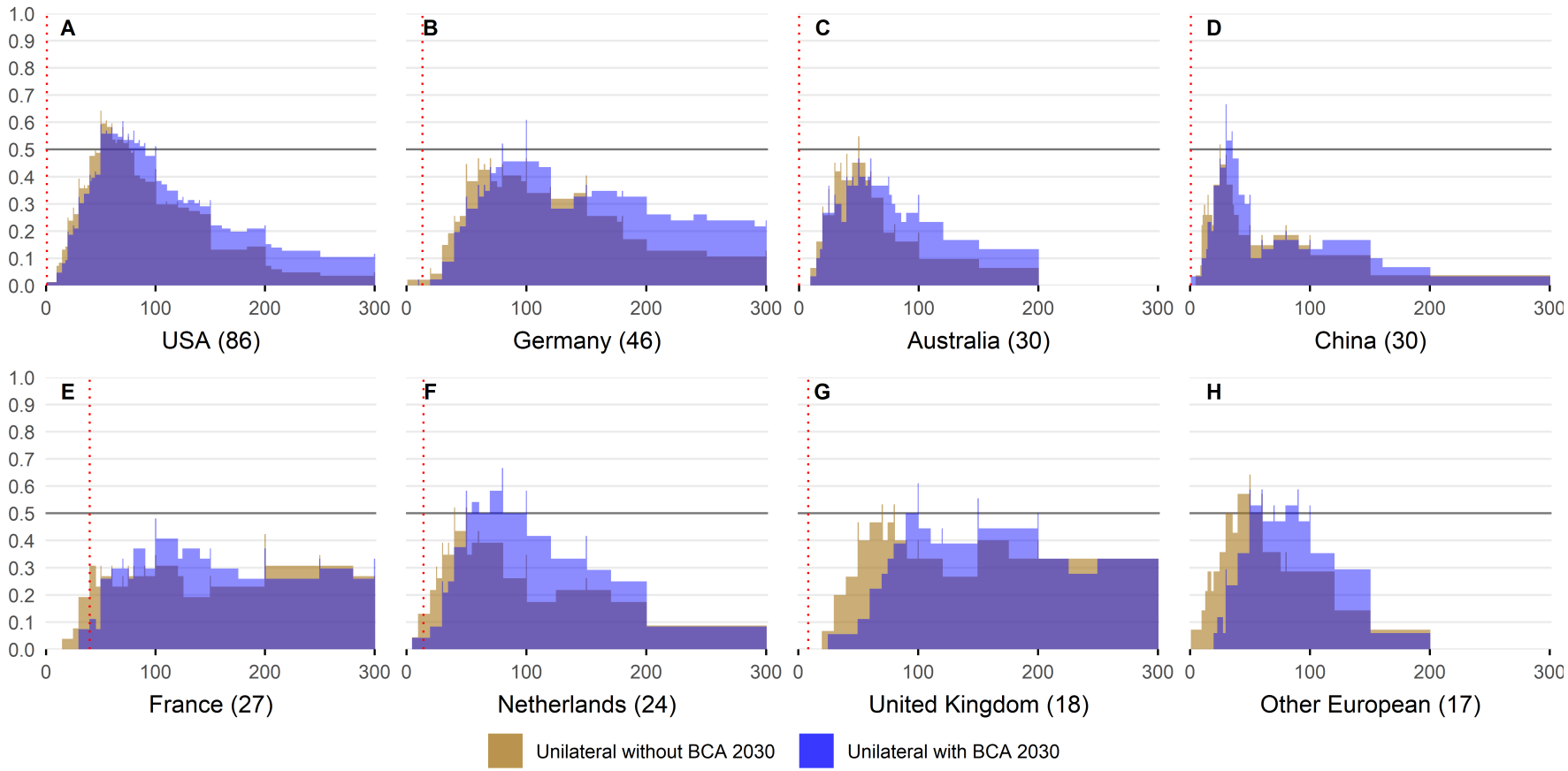


- Sizable competitiveness concerns across all continents
  - Introduction of BCA facilitates higher carbon price recommendations ($+ \approx 30\%$)

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

BCA facilitates agreement on unilateral carbon prices

- In ≈75 percent of countries, majority agreement on 2030 unilateral carbon prices is possible with BCA as compared to only in ≈55 percent without BCA
- Integral of agreement ($p<0.000$) and majority agreement ($p=0.056$) is larger with BCA

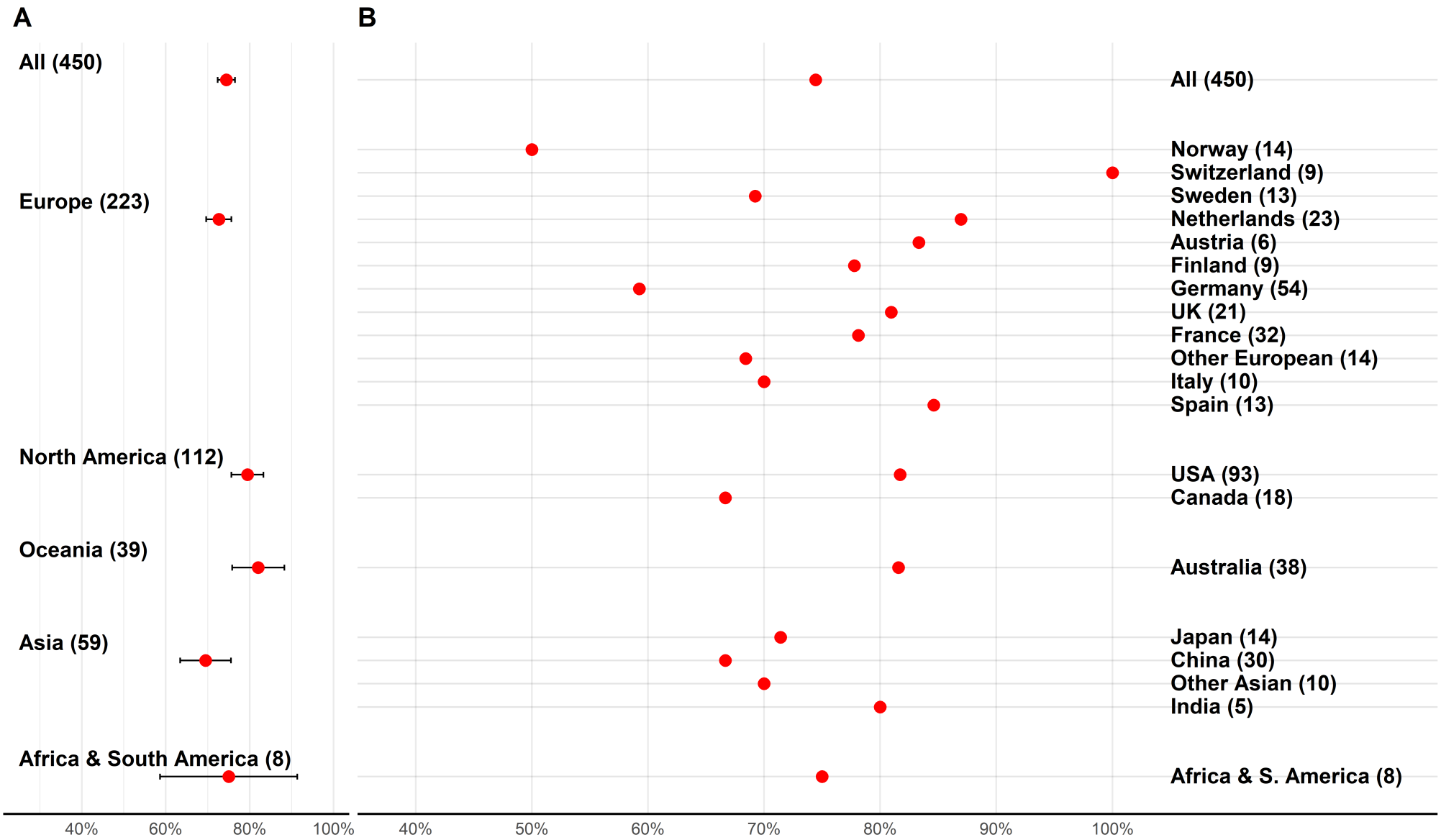


Analysis of carbon price recommendations

We shed light on potential drivers of the heterogeneity of carbon price recommendations and (implicit) *mental models of the climate-economy* by drawing on four pillars of data

1. Survey questions on policy design issues (BCA, instruments, revenue use)
   $\Rightarrow$ Seperate paper "Designing carbon pricing policies" (Nesje et al. 2022)
2. Survey questions on determinants from IAM studies (e.g. discounting, damages, ...)
3. Country characteristics (e.g. GDP/capita, existing carbon prices, ...)
4. Expert characteristics (e.g., publications, citations, research foci, gender, ...)

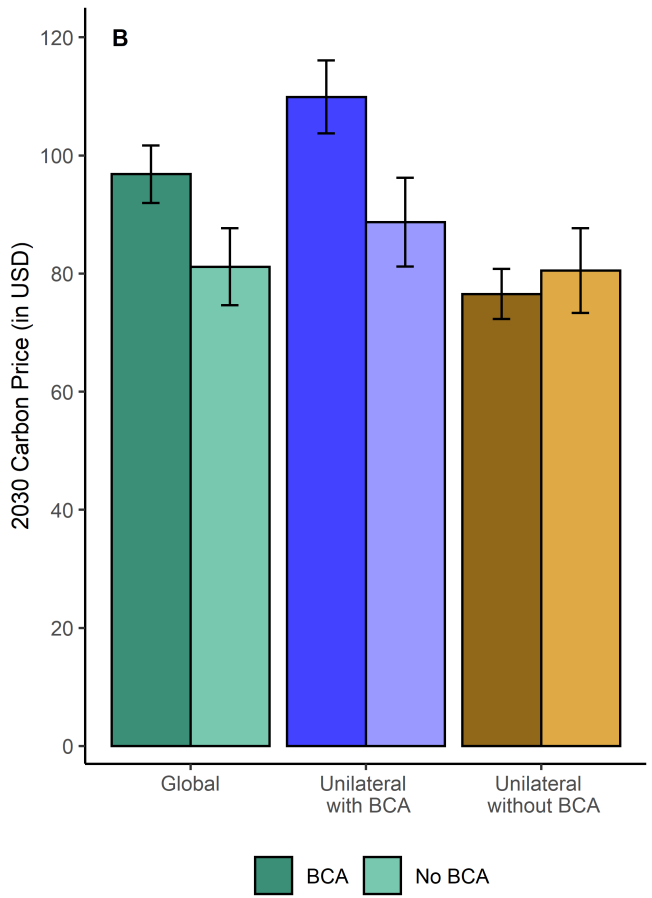
Very strong support for introduction of BCA, almost everywhere



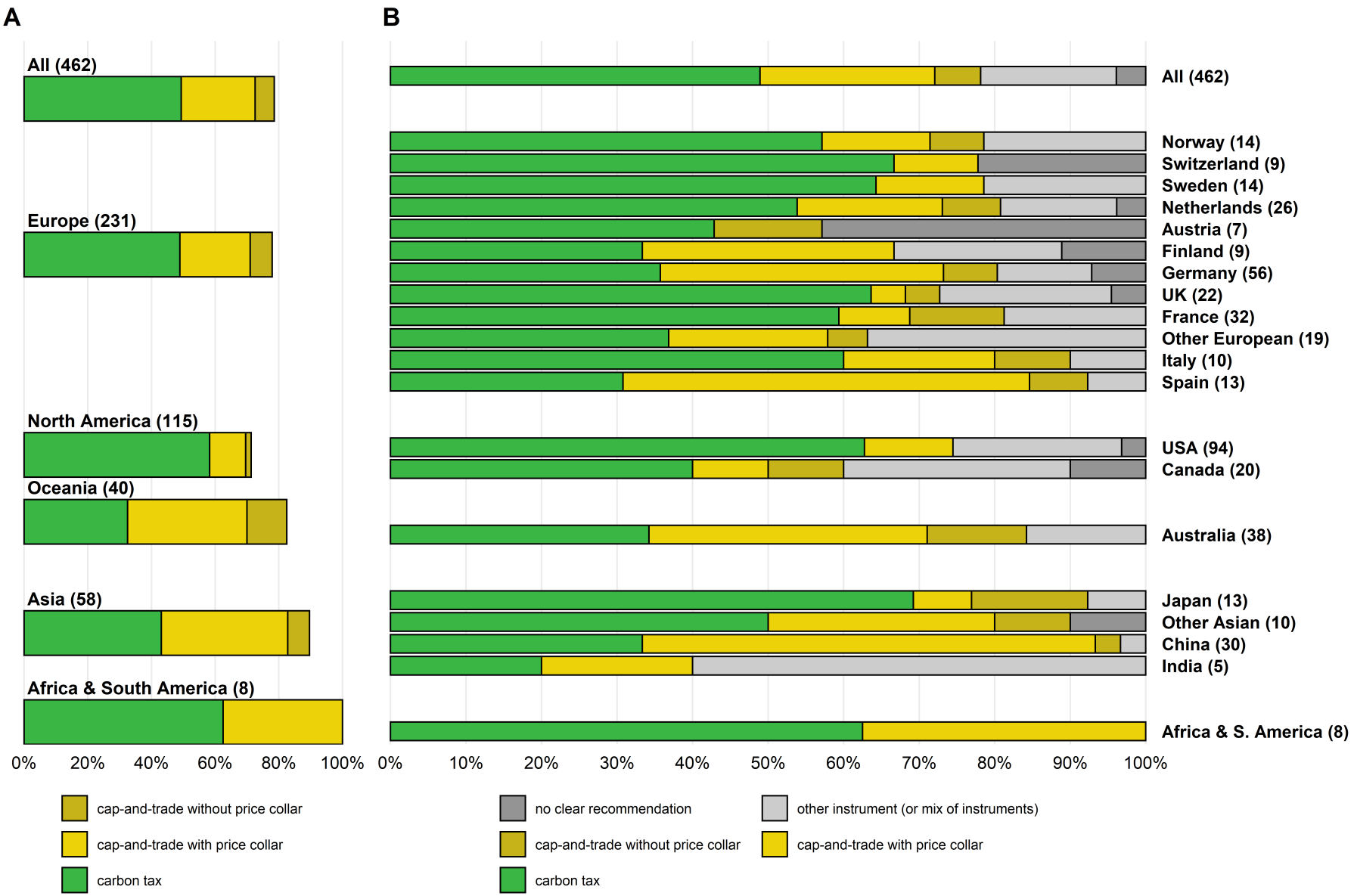
Carbon price recommendations and BCA support

⇒ Experts who strongly support the introduction of BCA ($\approx$ 75%)

- recommend significantly higher global and unilateral with BCA carbon prices
- recommend unilateral carbon prices without BCA that do not differ



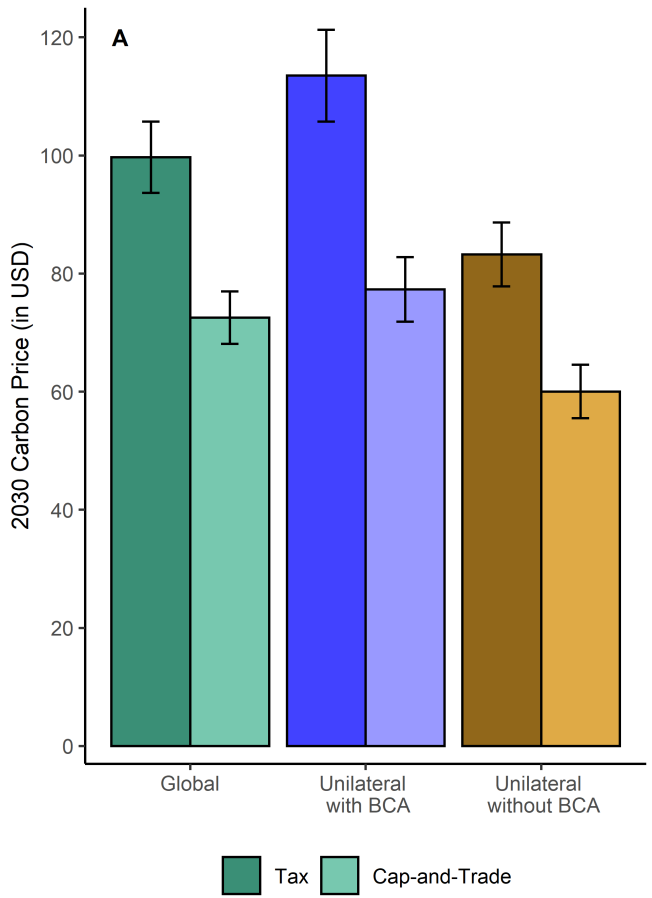
Carbon tax recommended twice as often as cap-and-trade



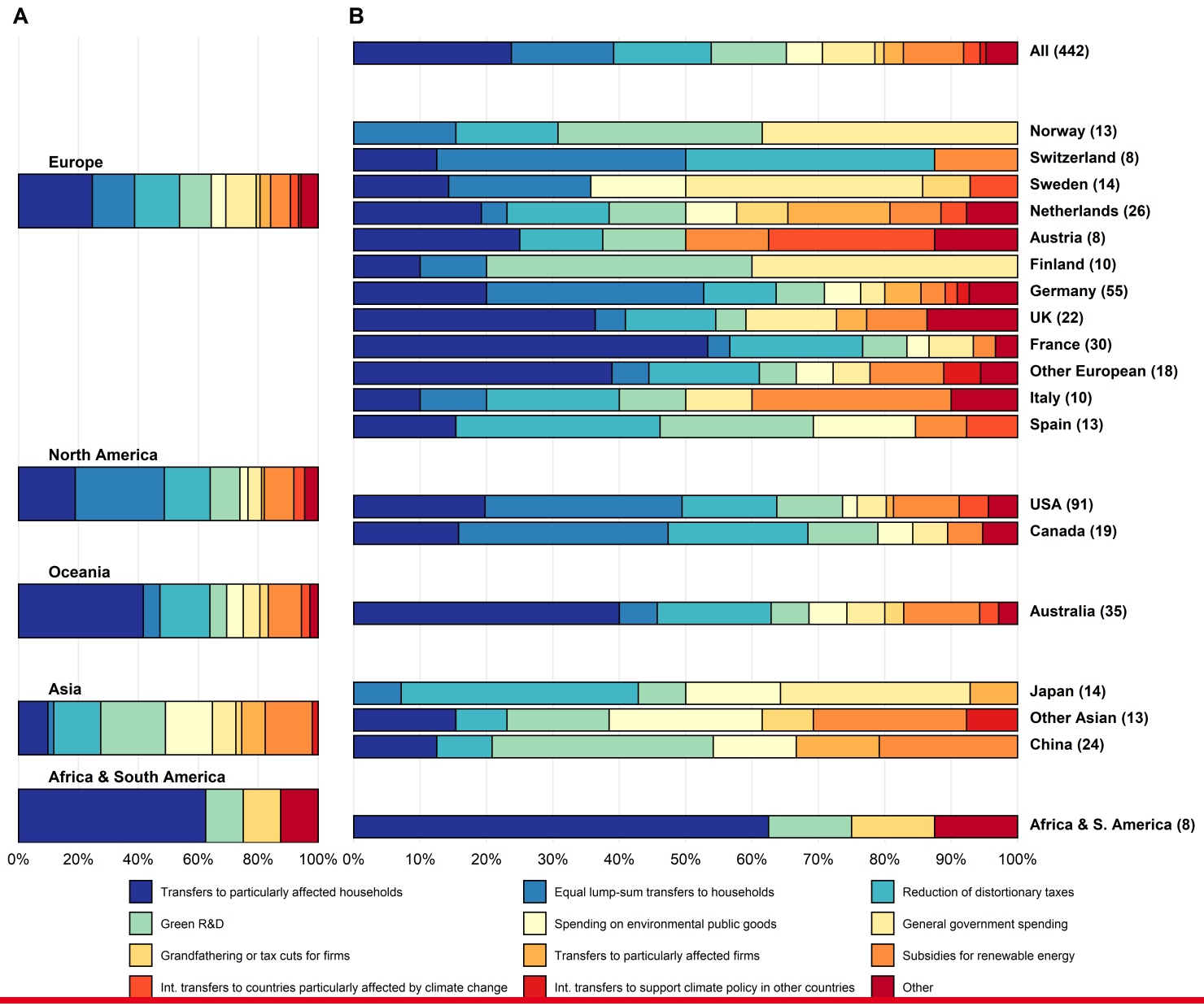
Carbon price recommendations and instrument choice

⇒ Experts who recommend carbon taxes (≈50%) as opposed to cap-&-trade (≈30%)

- recommend significantly higher unilateral and global carbon prices in 2030 ($p<0.01$)
- effect persists in multi-variate analyses with sign. determinants of tax vs. cap-&-trade



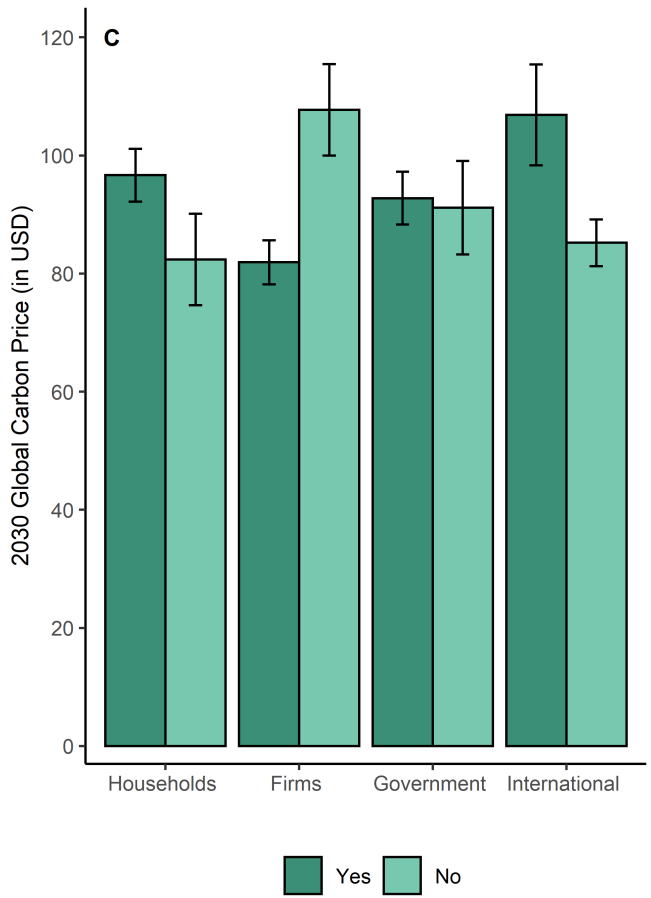
Heterogeneous views on revenue use (household transfers $<$ 50%)



Carbon price recommendations and revenue usage

⇒ Experts who recommend using parts of the pricing revenues for transfers to

- households & internationally ⇒ Higher carbon price recommendations
- firms and tax reductions ⇒ Lower carbon price recommendations



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1. Survey questions on policy design issues (BCA, instruments, revenue use)
2. Survey questions on determinants from IAM studies (e.g. discounting, ...)
3. Country characteristics (e.g. GDP/capita, existing carbon prices, ...)
   - **(+)** GDP/capita **(+)** existing carbon prices in 2020 **(+)** Europe **(+)** mean world governance rank **(+)** knowledge about climate change
   - **(-)** CO2 emissions/capita **(-)** fossil fuel consumption **(-)** Asia
4. Expert characteristics (e.g., publications, citations, research foci, gender, ...)

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3. Country characteristics (e.g. GDP/capita, existing carbon prices, ...)
4. Expert characteristics (e.g., publications, citations, research foci, gender, ...)
   - Recommendations do not differ by having published on the SCC/IAMs, in economics journals, or by number of publications/citations

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3. Country characteristics (e.g. GDP/capita, existing carbon prices, ...)
4. Expert characteristics (e.g., publications, citations, research foci, gender, ...)

$\Rightarrow$ All four pillars of (additional) data in combination can explain only up to $\approx$25 percent of the variation in expert's carbon price recommendations
   - Large & largely unexplained heterogeneity in *mental models of the climate-economy*

Conclusions

We present evidence on the variation of and agreement on global and unilateral carbon pricing recommendations based on responses of >400 experts across almost 40 countries

1. Almost all experts agree on considerably higher-than-existing carbon prices
   ⇒ Consensus on more ambitious carbon pricing policies

2. Majority agreement on specific short- and medium-term carbon prices is possible
   ⇒ Provides anchor points for public and political discourse

3. No aggregate evidence of "free-riding" in carbon price recommendations
   ⇒ Other rationales more important (i.a. distribution, competitiveness, ...)

4. BCA facilitates higher levels of and also more agreement on unilateral carbon prices
   ⇒ Lends support to recent efforts e.g. by the EU on CBAM

Back-up slides

Survey text

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.

(1) 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]?

Survey text

(2) 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"): [___].

(3) 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]?

(4) 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]?

(5) 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].

Survey text

(6) 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].

(7) 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]
...
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].

Survey text

(8) 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];

Survey text

(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: [___].

Potential drivers of global carbon prices (Ordered logit)

	(1) ERT	(2) global 2020	(3) global 2030	(4) global 2050
Emission red. target (ERT)		0.538***	0.750***	0.854***
		(4.70)	(6.57)	(7.44)
Abatement cost	−0.656***	−0.0199	−0.0575	−0.132
	(−6.26)	(−0.20)	(−0.59)	(−1.39)
Catastrophic damages	0.175*	0.0692	0.0897	0.0727
	(1.76)	(0.75)	(0.98)	(0.80)
Mean damages	0.418***	−0.208**	−0.199*	−0.127
	(3.68)	(−1.97)	(−1.89)	(−1.25)
Utility discount factor	0.184**	0.242***	0.254***	0.252***
	(2.42)	(3.40)	(3.62)	(3.62)

z statistics in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Carbon prices "in the wild"

- Implemented carbon prices, covering ≈20% of global GHGs, range from a few cents to >100 US$ per ton of CO_2 equivalents (cf. World Bank 2020); Global average ≈$3.
  - Klenert et al. (2018 *NCC*) emphasize the role of (dis-)trust, corruption control and ear-marked revenue-recycling

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  - Klenert et al. (2018 *NCC*) emphasize the role of (dis-)trust, corruption control and ear-marked revenue-recycling
  - Levi et al. (2020 *Global Environmental Politics*):

(+)	(-)
regulatory control,	GDP
public belief in climate change,	share of oil in electricity production.
government effectiveness,	share of coal in electricity production.
corruption control.	per-capita CO_2-emissions.

  - Best and Zhang (2020 *Energy Policy*):

(+)	(-)
climate change awareness,	GDP,
corruption control,	coal reserves,
EUETS.	gas reserves.

Determining carbon prices

- Suggestions for carbon prices or the social cost of CO2 equivalents (SCC) range from a few US$ to >1000 US$ (e.g. Dietz/Stern 2015 *EJ*; Hänsel et al. 2020 *NCC*; Nordhaus 2019 *AER*; Pindyck 2019 *JEEM*; Ricke et al. 2018 *NCC*; ...)

- Different approaches to determining appropriate carbon prices:
  Cost-Benefit Analysis, Cost-Effectiveness Analysis, Cost-Risk Analysis, ...

  – The social cost of carbon (SCC) has been traditionally informed by large-scale integrated assessment models (IAM) such as DICE, FUND, PAGE, MIND, WITCH, ...

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    - Major drivers of the SCC/optimal carbon prices:

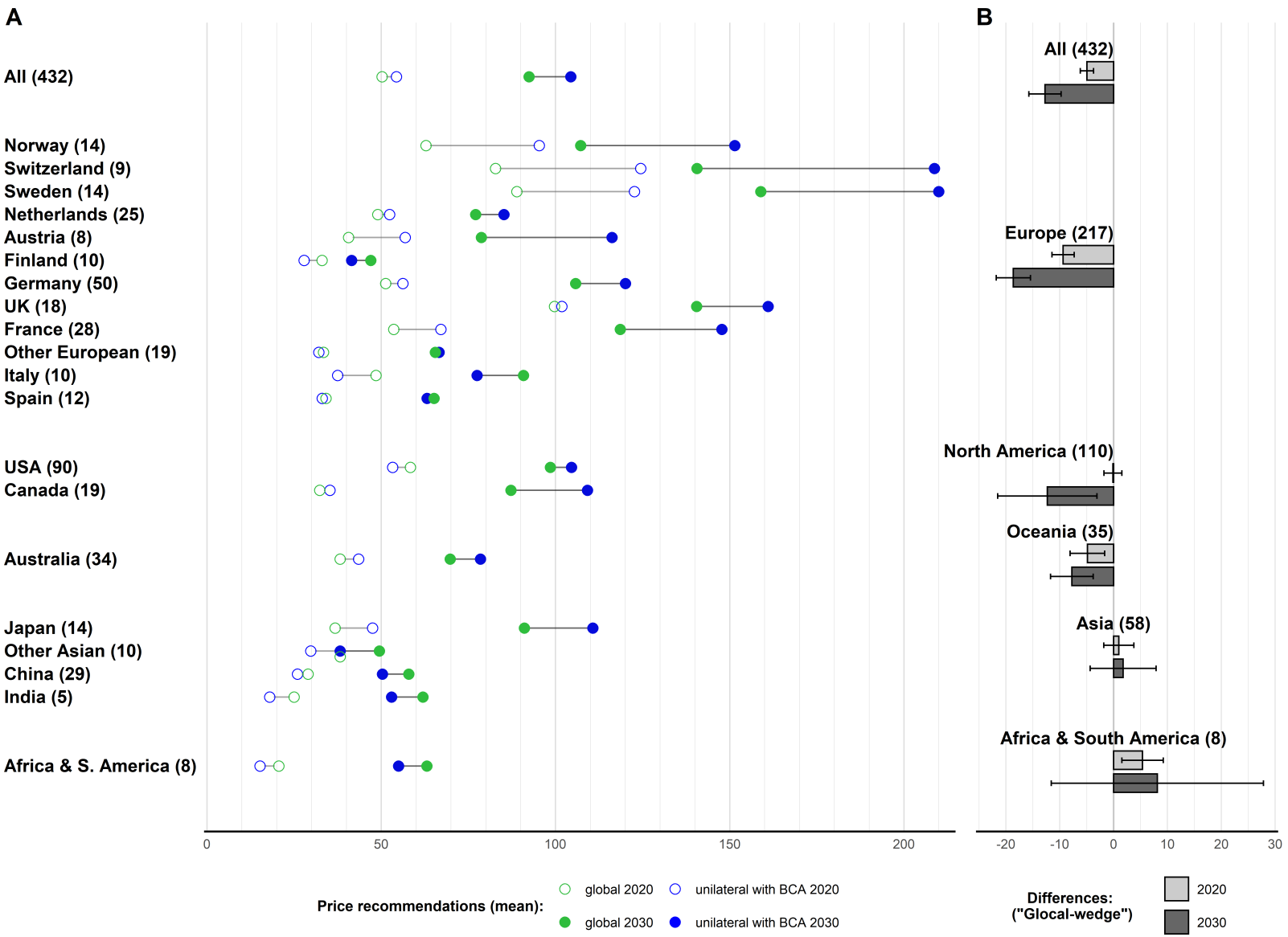
(+)	(-)
Expected climate damages	Discounting
Climate sensitivity (uncertainty),	Mitigation costs
...	...

Determining carbon prices

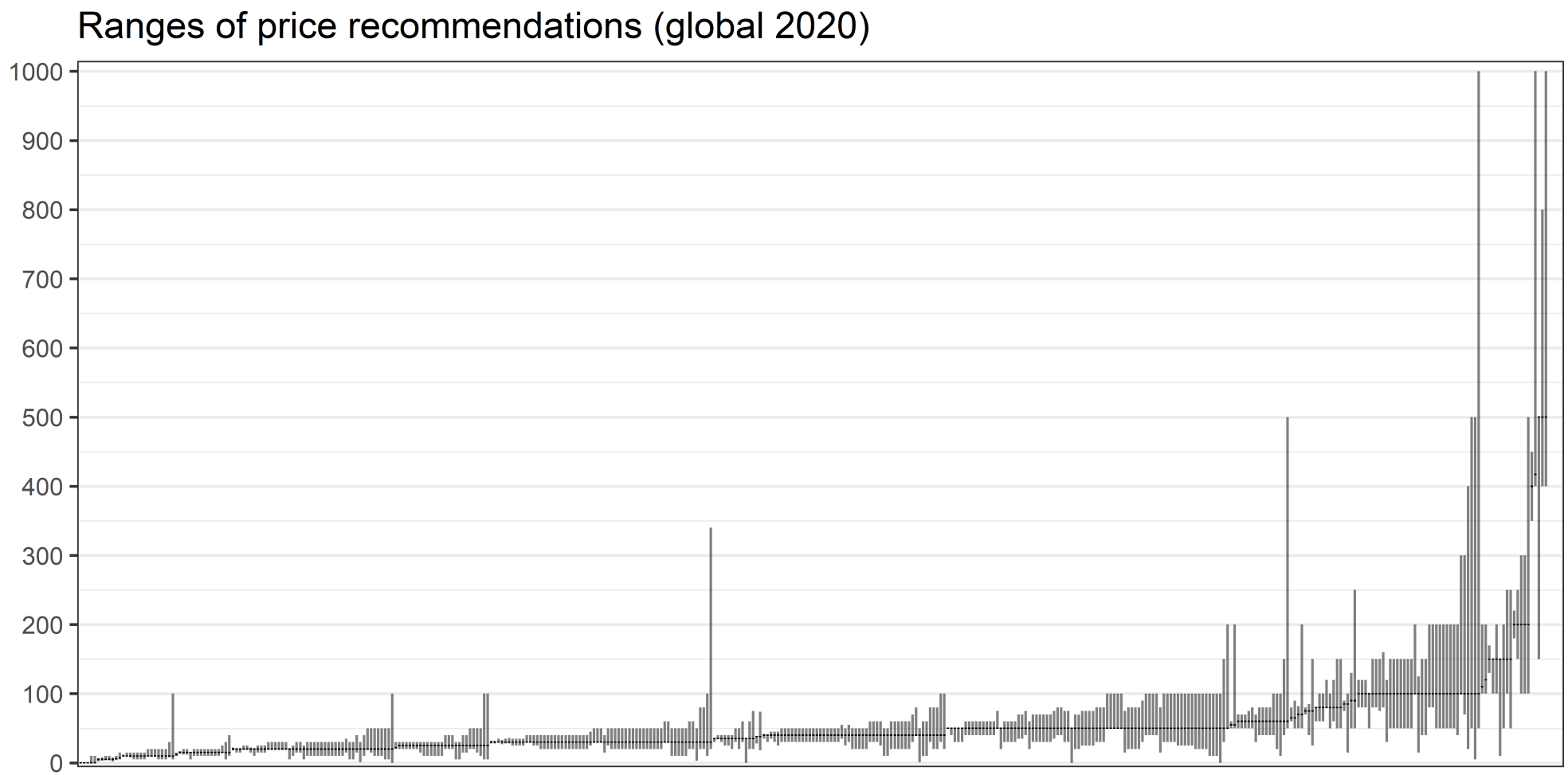
- IAM results are still very sensitive to or are too strongly limited by crucial structural modelling assumptions, which are typically based on the modeler's judgement (e.g. Pindyck 2013 *JEL*, Stern & Stiglitz 2021 *NBER*).
- Alternative: Ask experts directly without imposing such a tight structure
  - Schauer (1995 *ERE*) interviewed 16 hand-selected experts on determinants of carbon prices to calibrate a pre-curser to the recent set of analytic climate models, he received only 9 direct carbon price recommendations
  - Howard & Sylvain (2015 WP) surveyed >200 economists (anonymously) who have published on climate change. They elicit likert-scale views on a 2015-SCC of \$37 $\Rightarrow$ 51% thought that a SCC of \$37 in 2015 is too low

$\Rightarrow$ What is needed is a more precise/comprehensive/representative understanding of the extent of (dis-)agreement on carbon prices that experts feel comfortable with recommending and what may drive these recommendations

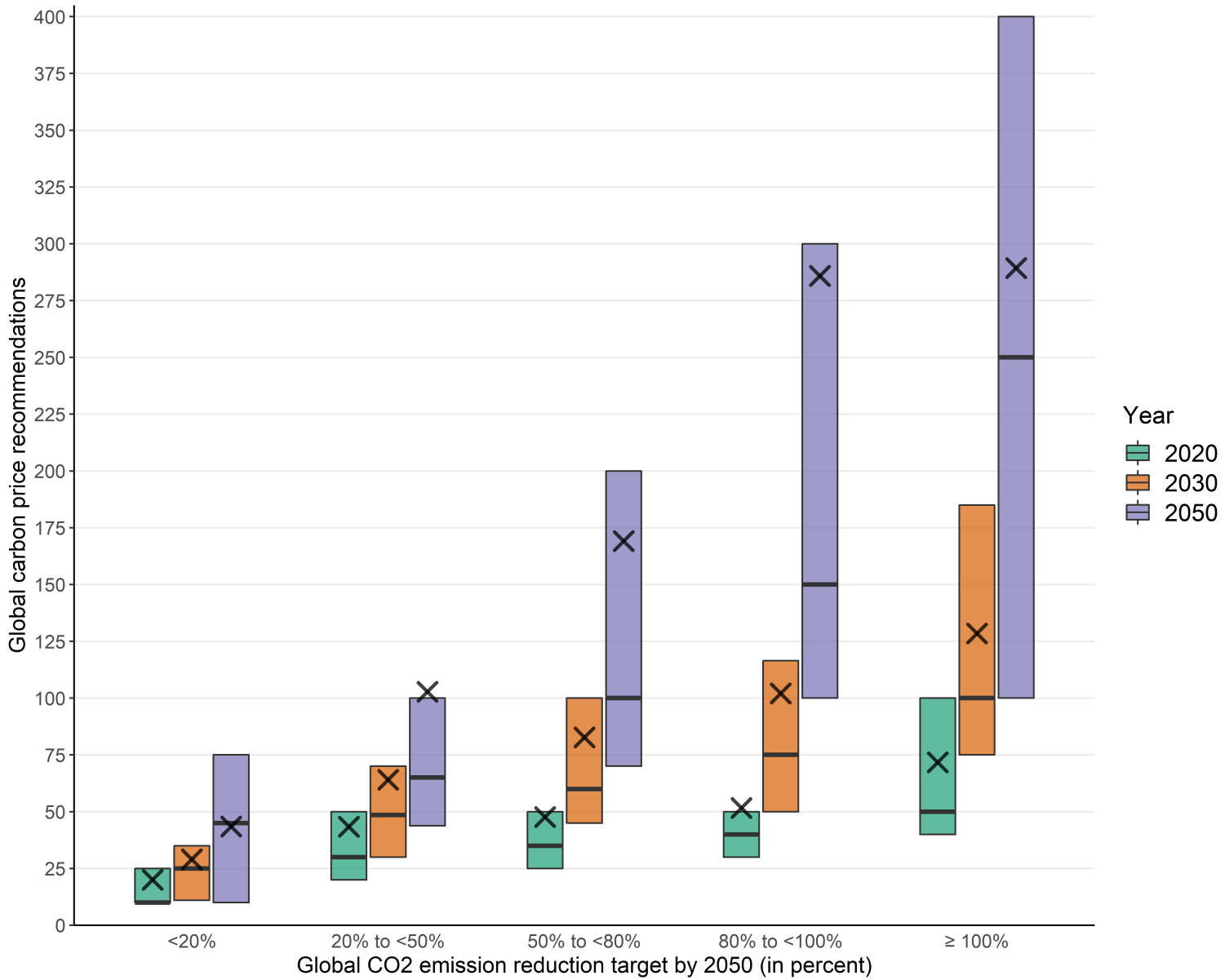
Difference unilateral wBCA & global



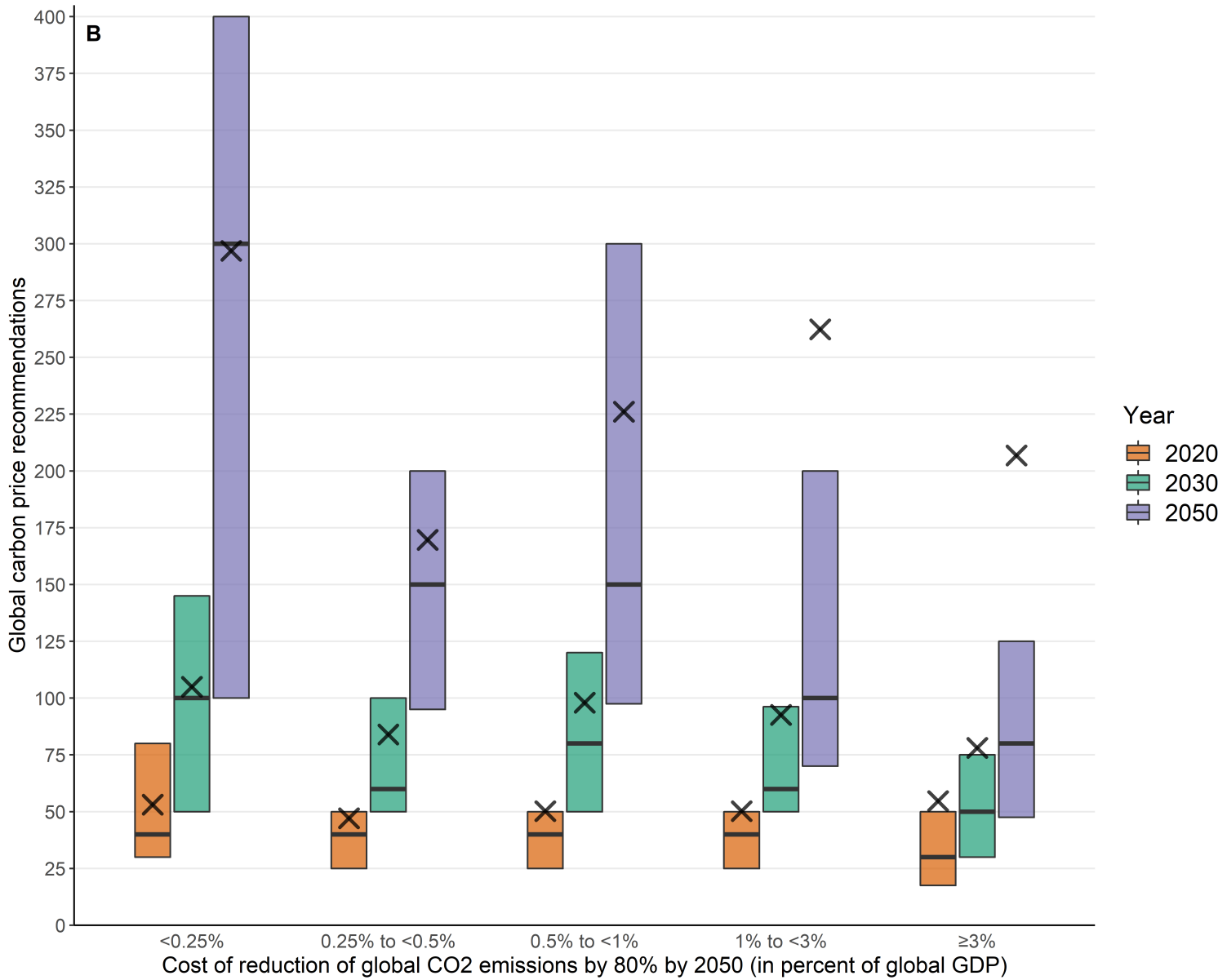
Ranges of carbon prices



Carbon prices and IAM determinants



Carbon prices and IAM determinants



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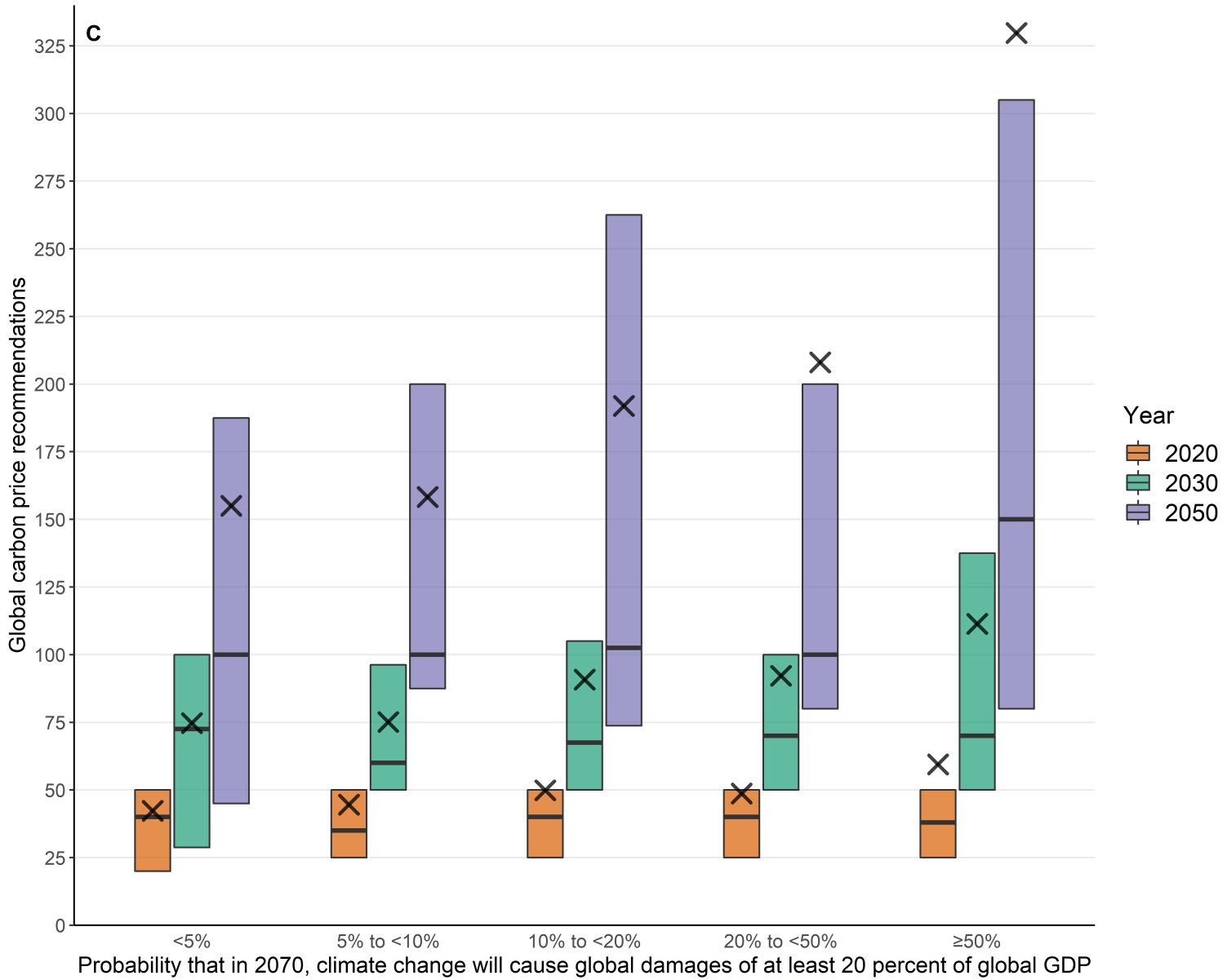

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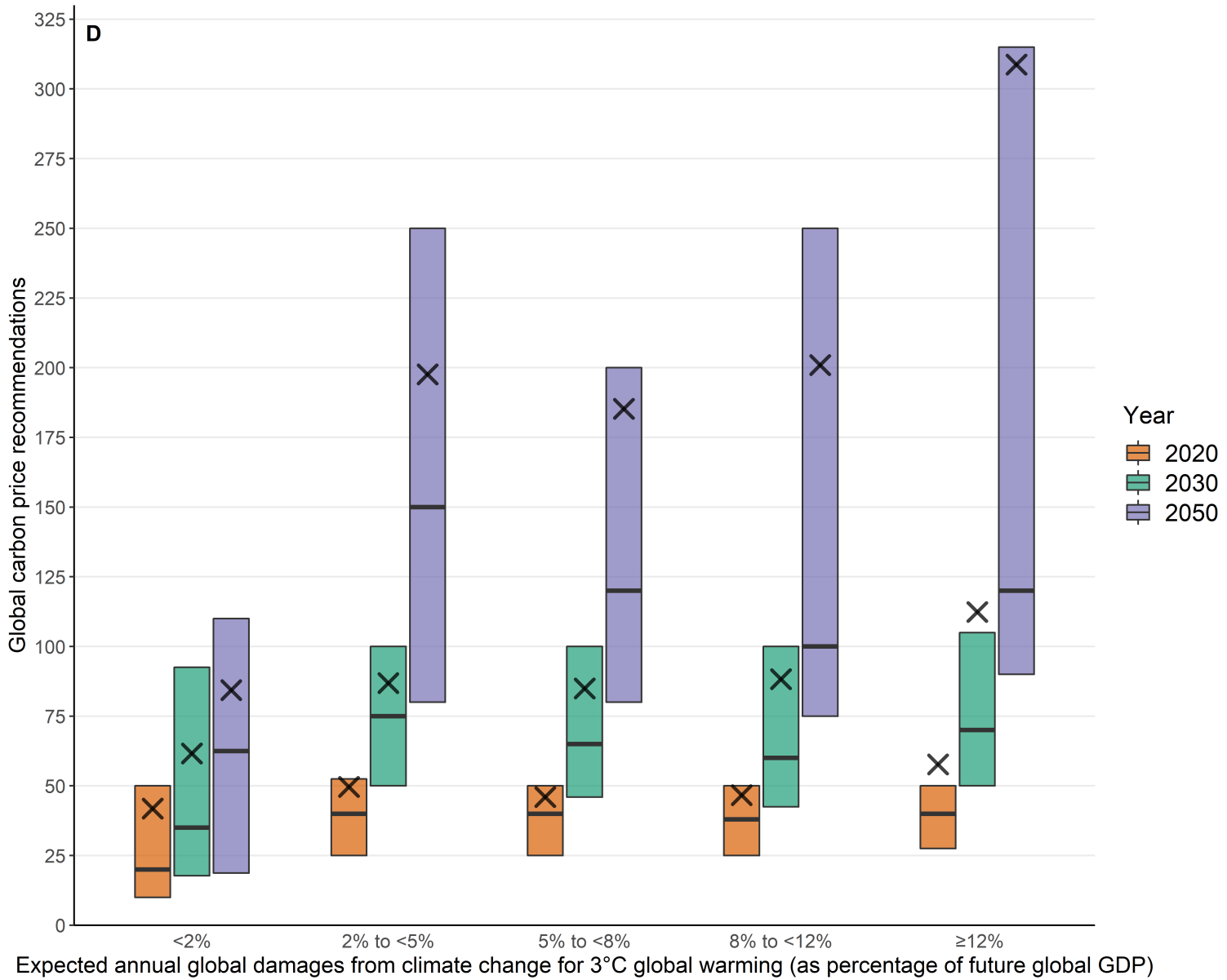

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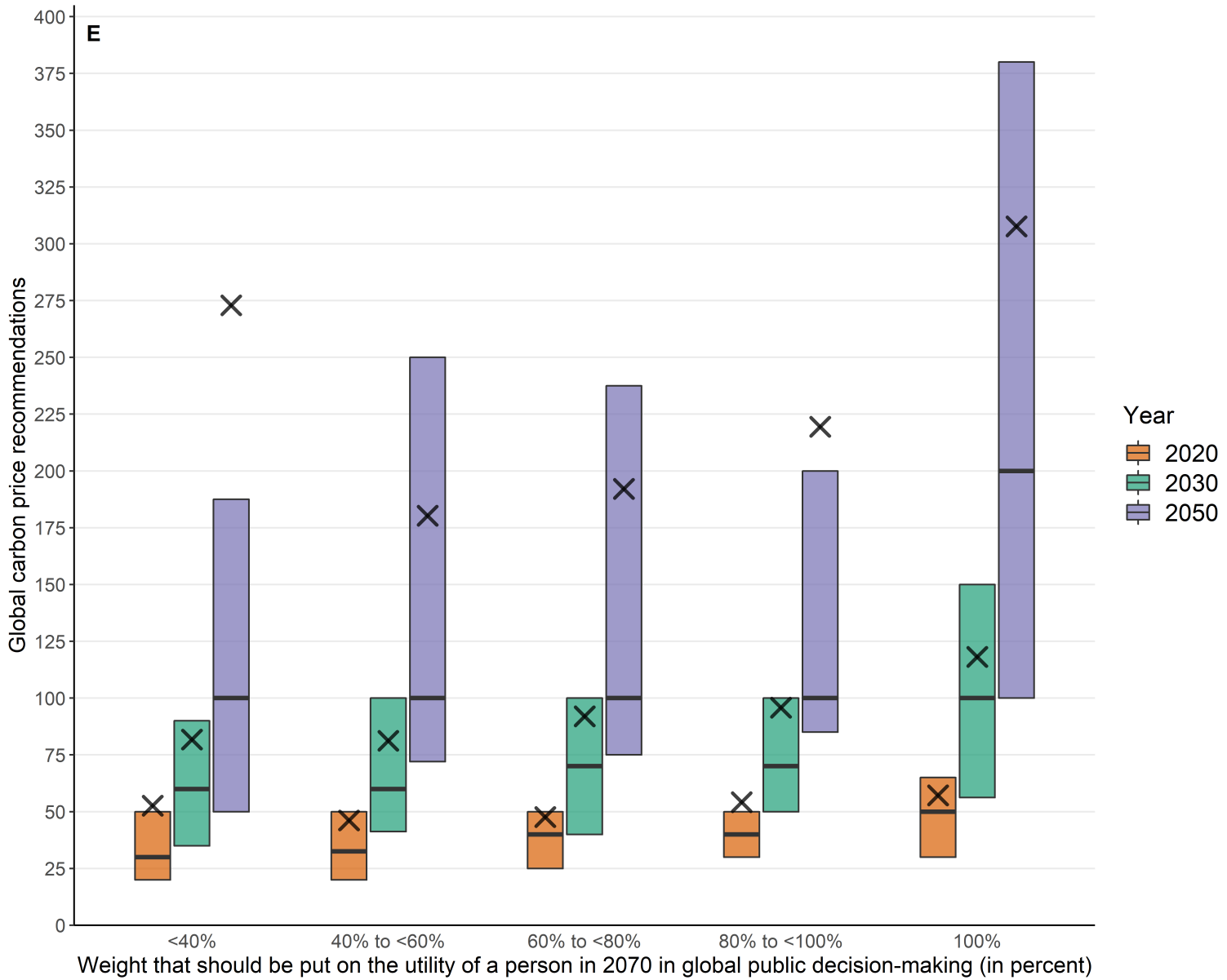
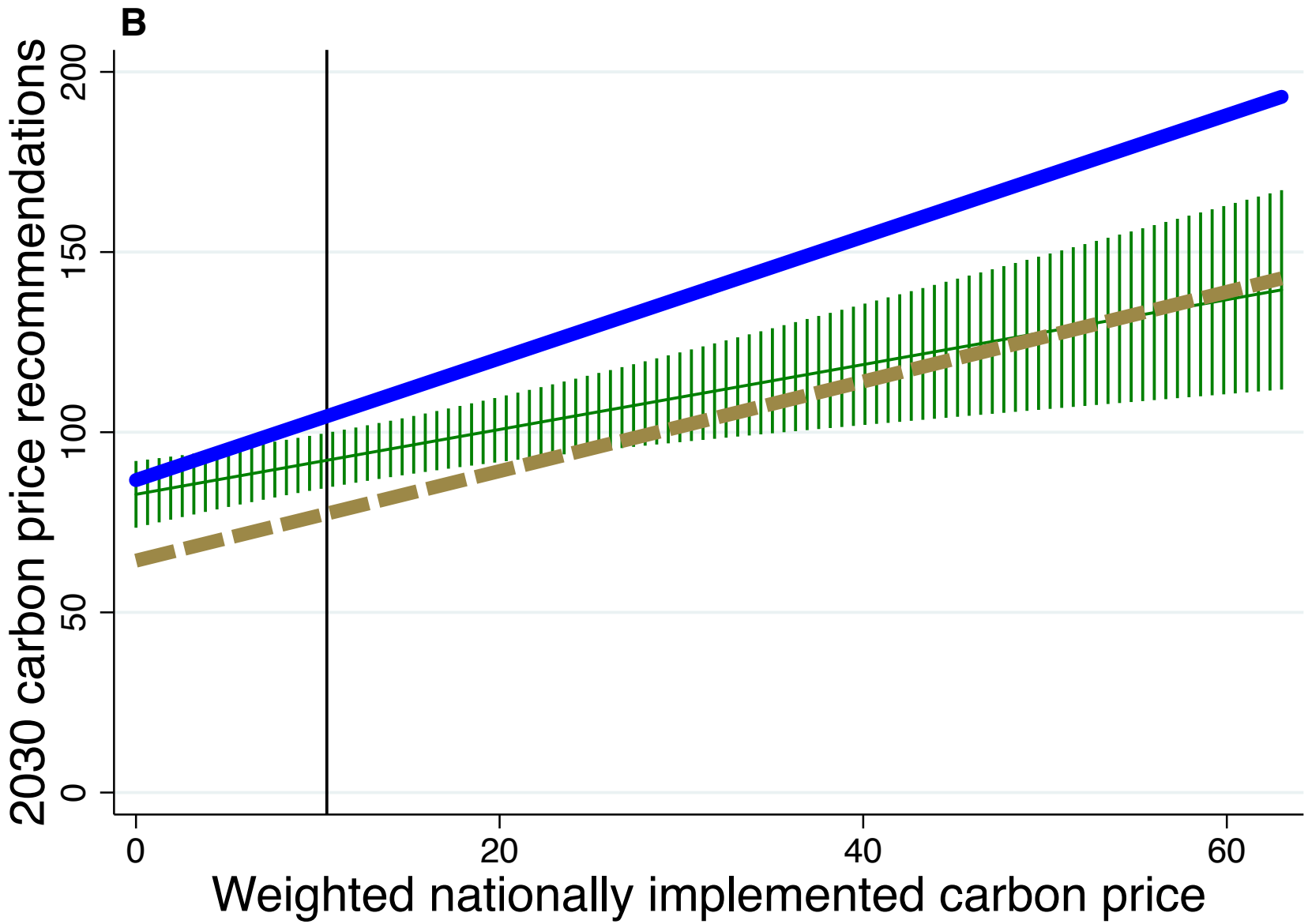


Carbon prices and country characteristics



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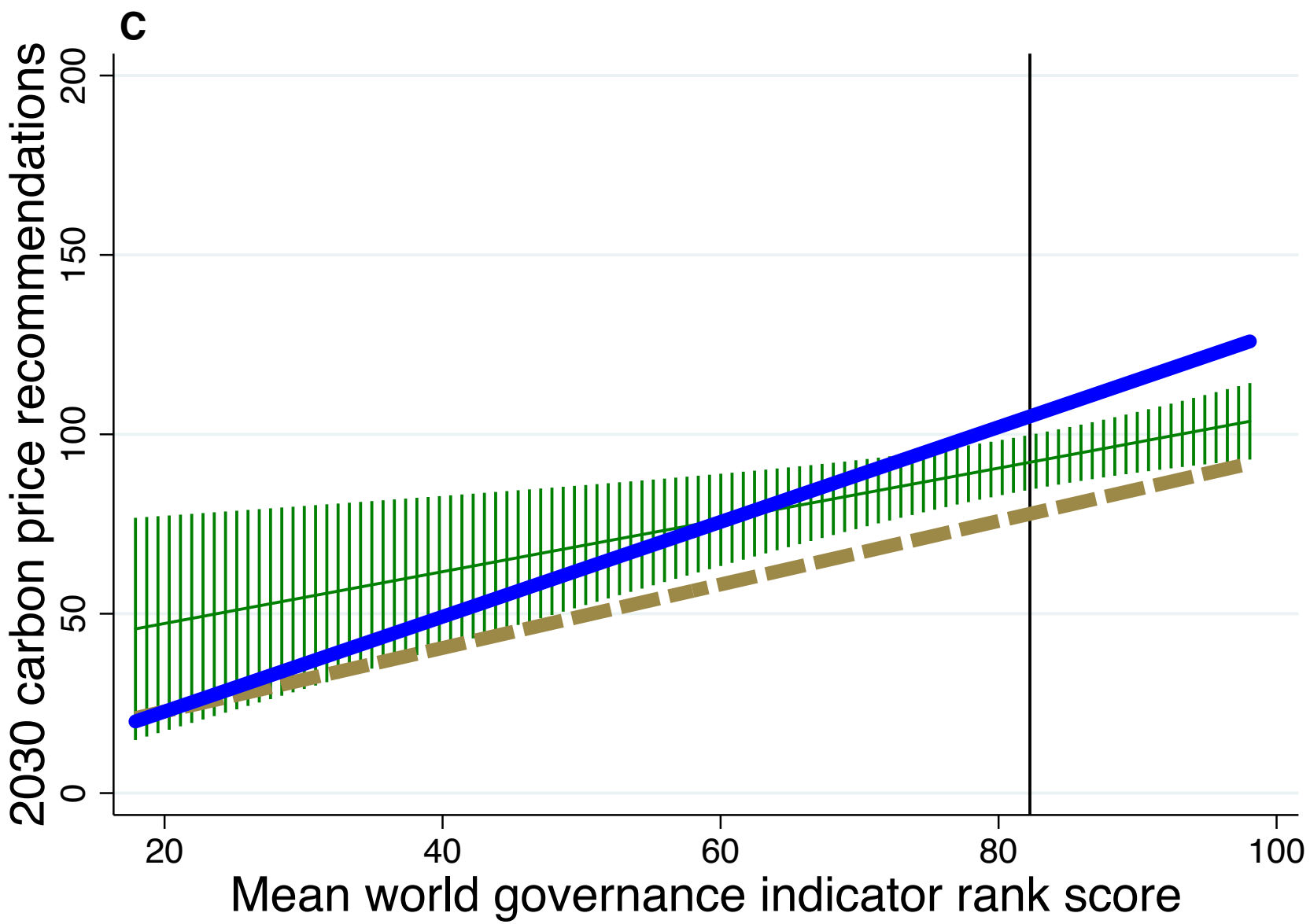

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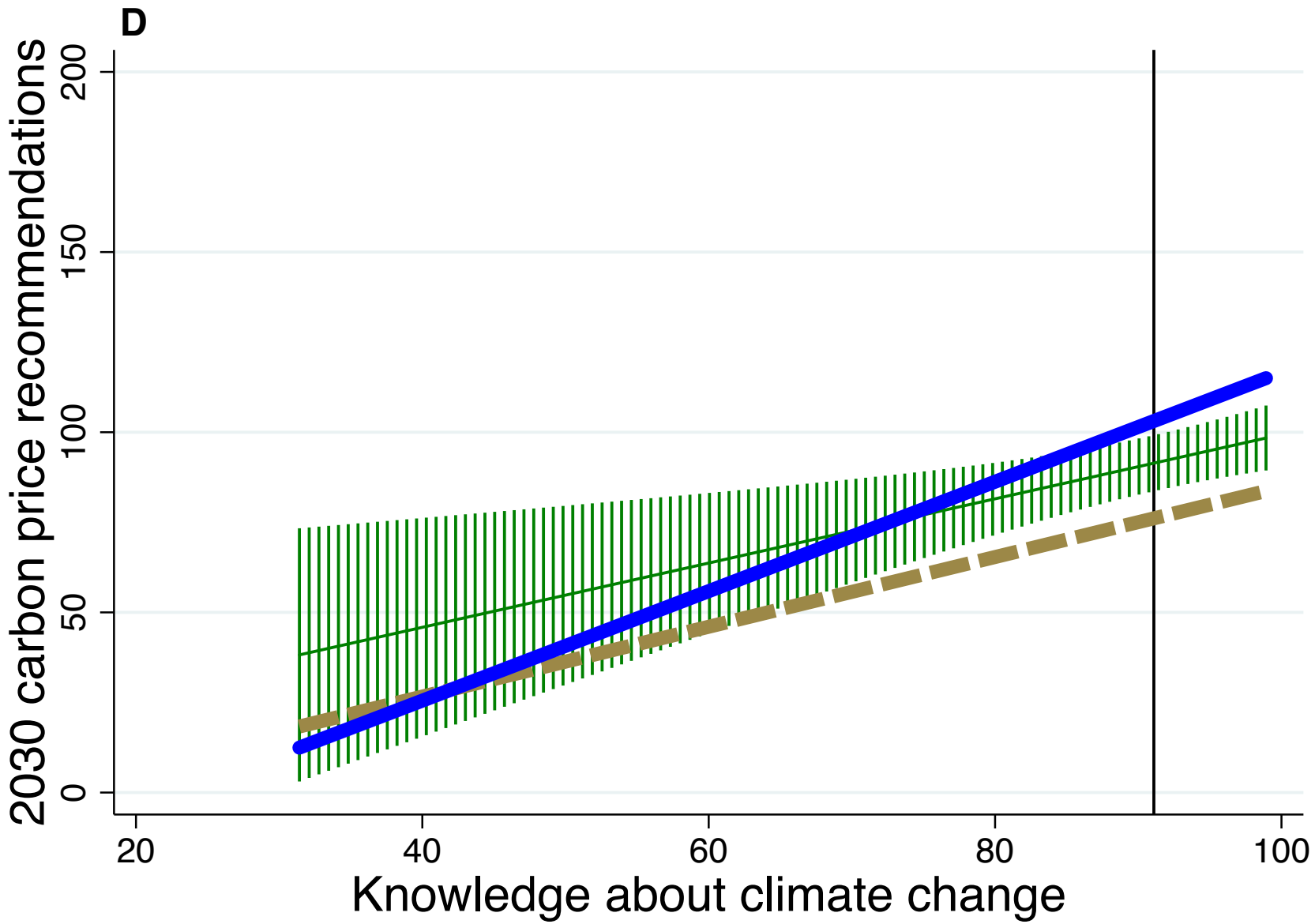

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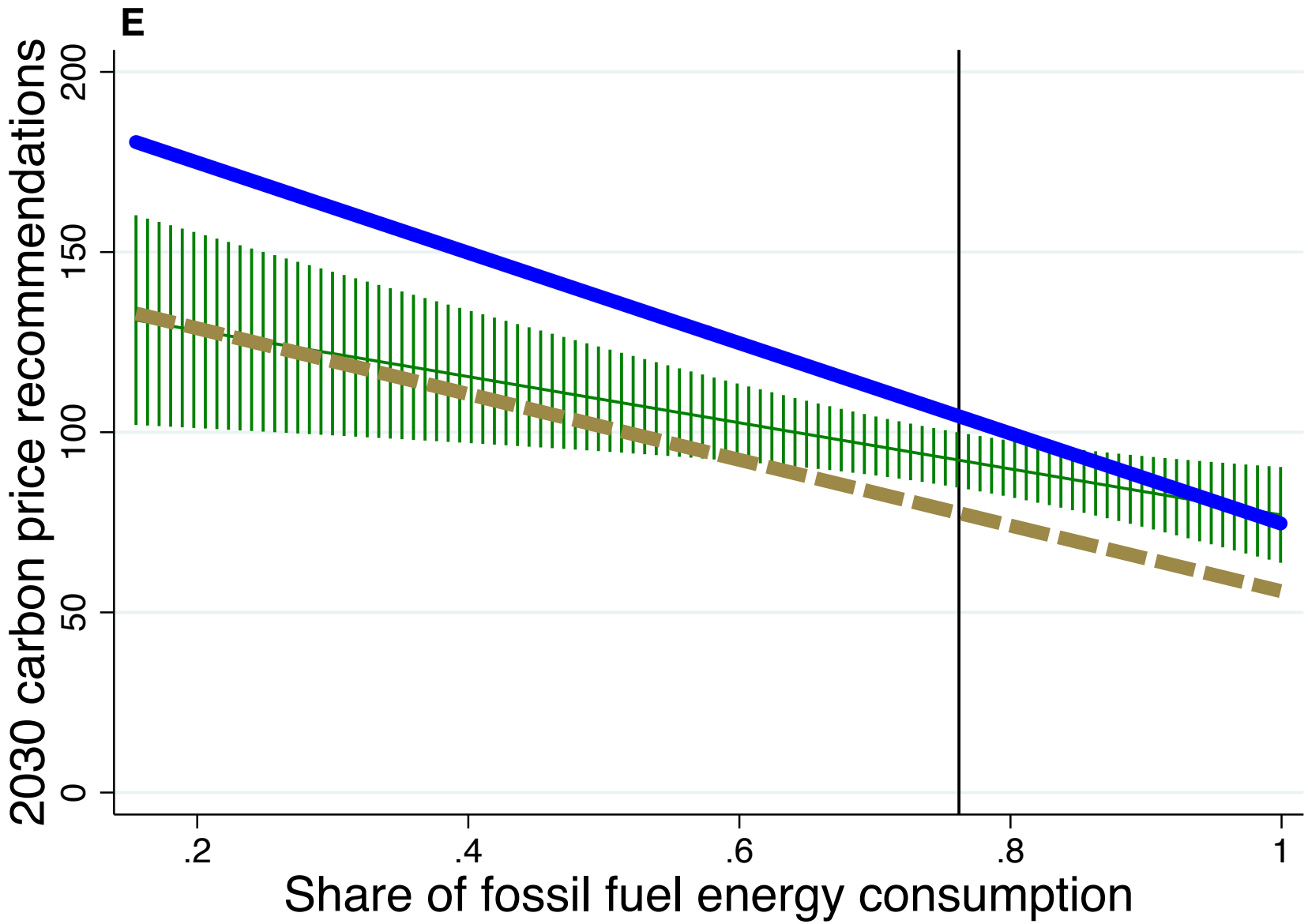

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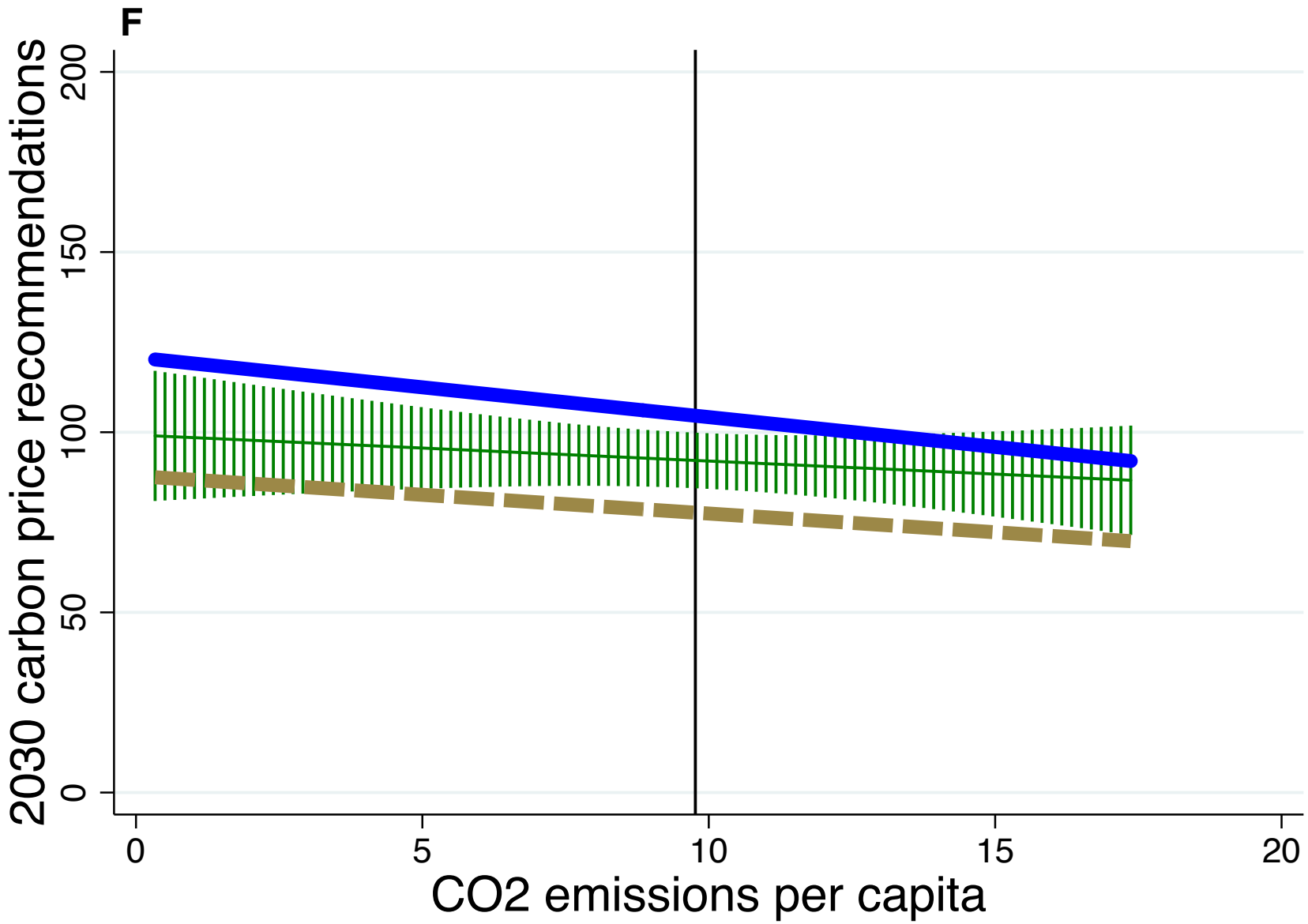
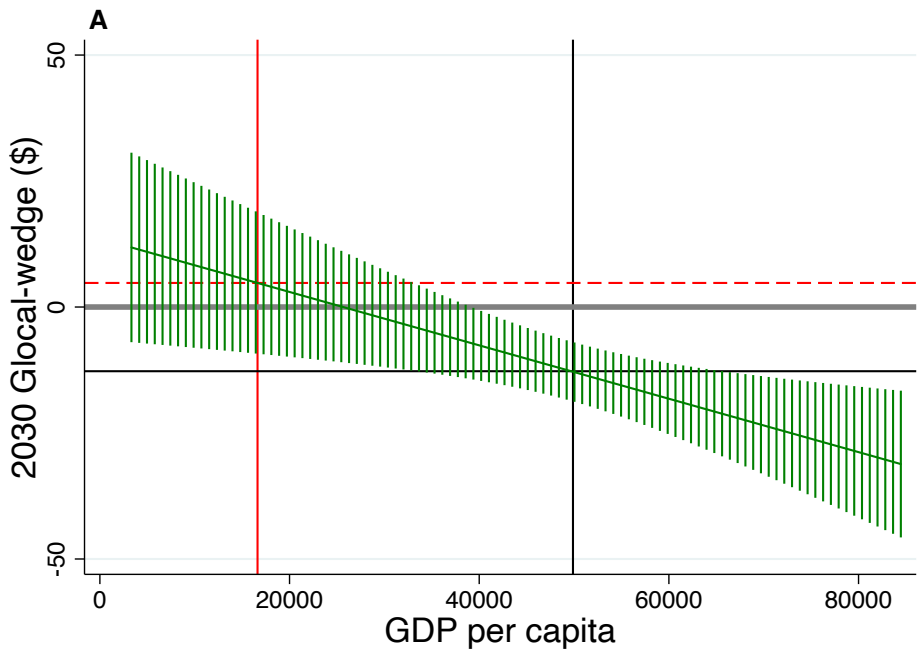
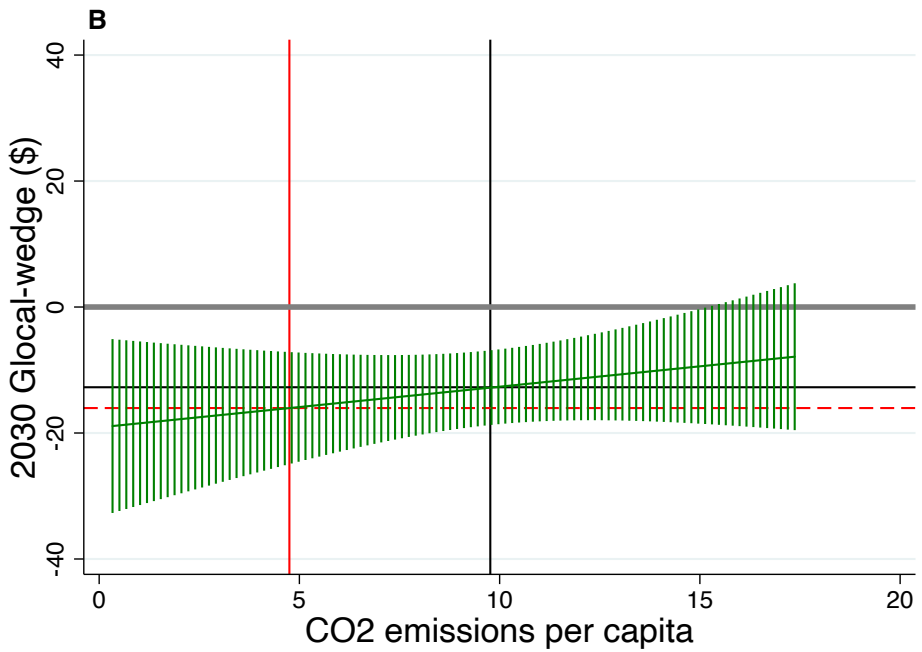


2030 Glocal-wedge: Non-representation bias

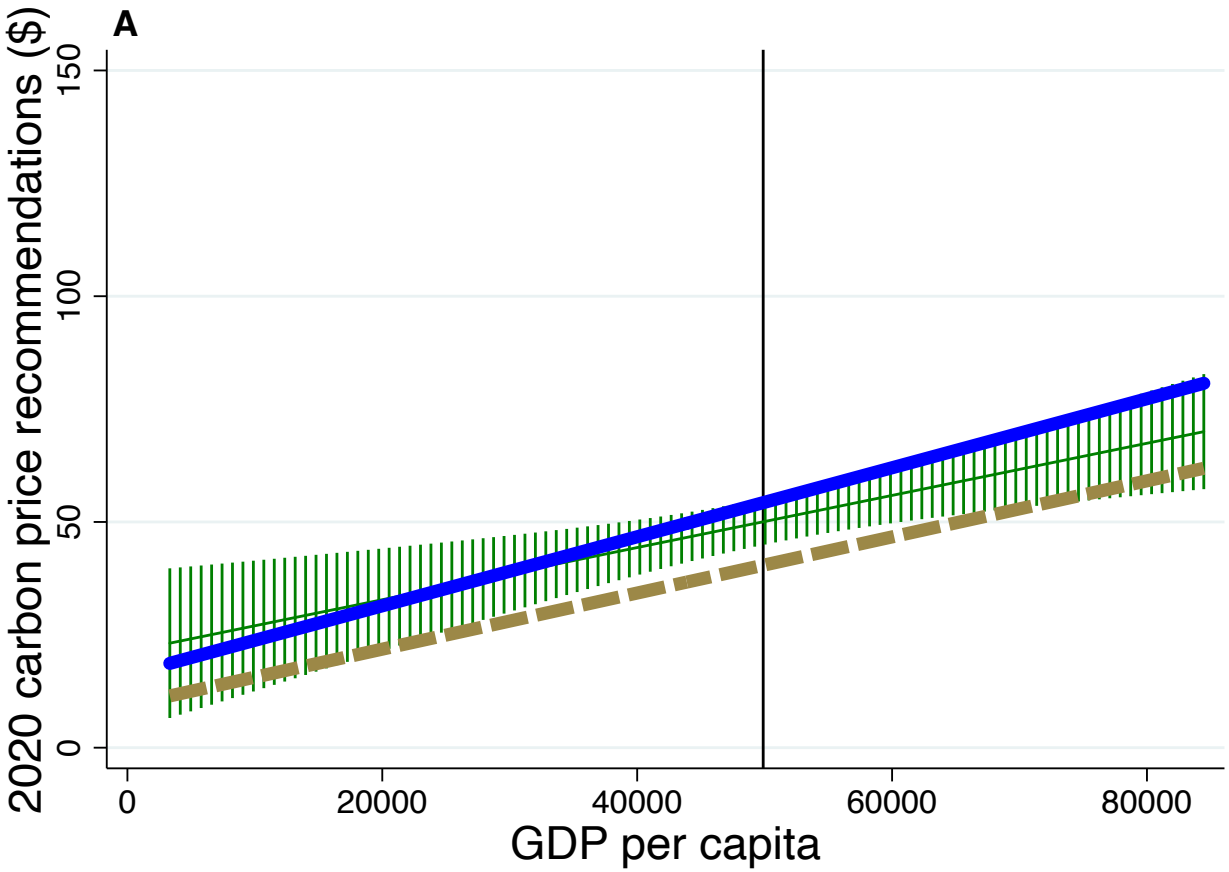




Carbon prices and country characteristics

Carbon price recommendations:

(+) GDP/capita (+) existing carbon prices in 2020 (+) mean world governance rank
(+) knowledge about climate change (-) CO2 emissions/capita (-) fossil fuel consumption

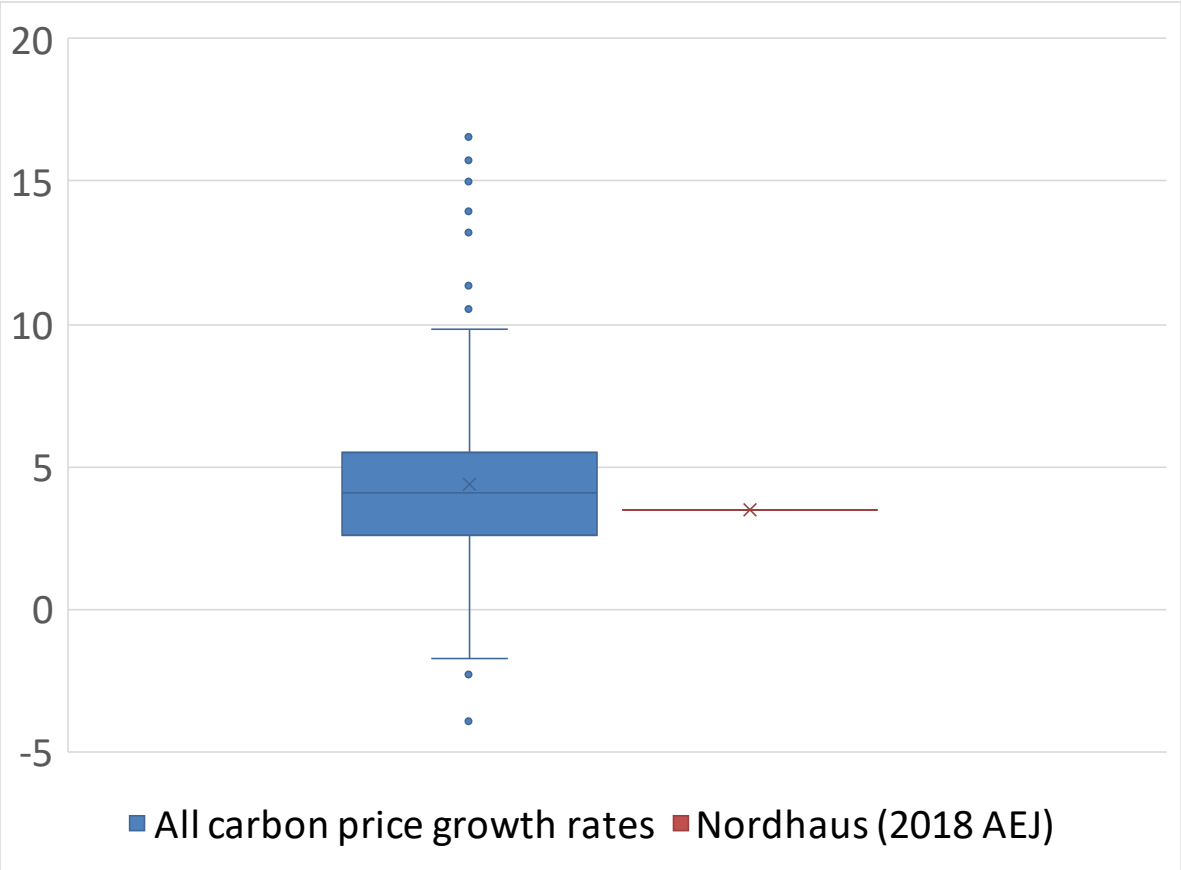


Carbon prices and expert characteristics

Carbon price recommendations do not differ sign. along observable expert characteristics:

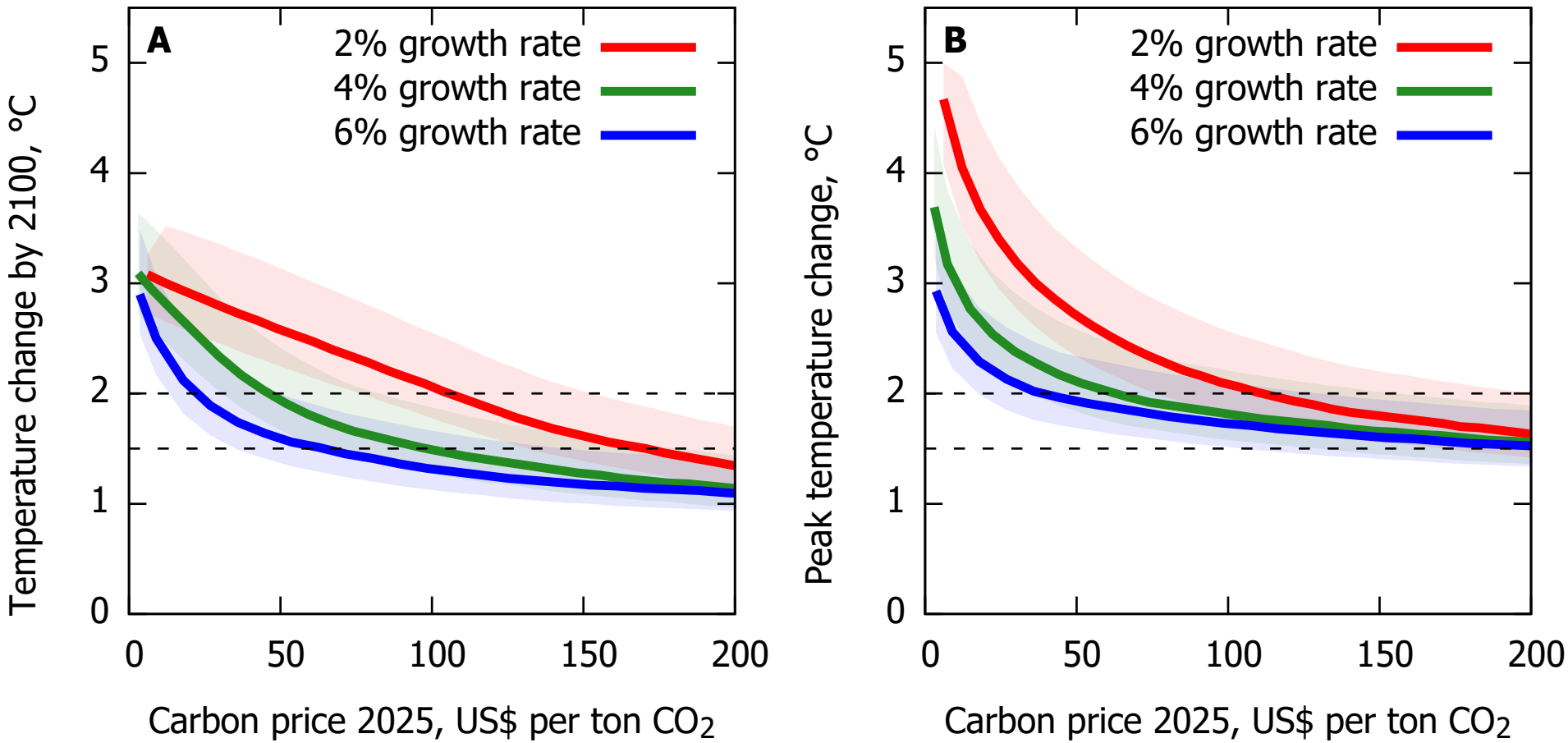
- Number of pertinent publications
- Number of citations
- Gender
- Having published in economics journals ($\neq$ Pindyck 2019 *JEEM*)
- Having published on IAMs or the SCC
  - The 67 experts who have published on IAMs recommend, on average, a 2030 global carbon price of \$98 (versus \$93 by all others; two-sided t-test: p=0.676)

Growth rates of global carbon prices (2020-2050)



- Wide dispersion of global carbon price growth rates:
  Median (mean) growth rate of carbon prices is 4.1% (4.4%);
  $\Rightarrow$ Slightly higher compared to 3.5% (Nordhaus 2018 *AEJ*) or 3.75% (Gollier 2020 *WP*)
  $\Rightarrow$ Much lower than as suggested in policy circles (cf. PIK/MCC: $\geq$10% in Germany)

Climate Policy Curves (Hänsel et al. 2022)



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