The impact of time discounting in deep mitigation pathways[a]

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Motivation

Discounting in cost-benefit analysis of climate change has been widely acknowledged (Stern, 2006; Nordhaus, 2007; Weitzman, 2007; Dasgupta, 2008).

How to compare future climate change impacts against today's mitigation costs?

A low discount rate has been proposed in the Stern Review (2006) and used in the IWG on Social Cost of Carbon (2013).

Low discount rate in CBA

- More short term abatement
- Lower temperature increase (2°C is attainable only for very low discount rate in DICE)

DP-IAMs

DP-IAMs have studied the sensitivity of low carbon emission pathways to a series of factors:

- Economic and population (Riahi et al., 2017)
- National versus international climate policies (Vrontosi et al., 2018)
- Fossil fuel availability (Kriegler et al., 2016)
- Low carbon technologies availability (Luderer et al., 2018)

Very few exercises have looked at the choice of the discount rate (Ermoliev et al., 2008; Chen and Tavoni, 2013).

Time discounting in CEA?

In these exercises, DP-IAMs evaluate Cost-Efficient emission reduction strategies and do not embed CC impact costs.

The case of negative emissions

Stringent policy targets will require negative emissions (Rogelj et al., 2018).

What is the role of discount rate with negative emissions?

These emission pathways are shaped by

- very large investments in Negative Emissions Technologies (NETs)
- a fast pace of installation
- a strict timing over the century

Ethical considerations

“Don’t deploy negative emissions technologies without ethical analysis” (Lenzi, 2018,)

Table 1: Time Discounting in DP-IAMs — WIP

DP-IAM	Discount rate	Components
WITCH	$\approx 3.5\%$	$(\rho = 1\%, \eta = 1.5)$
REMIND	$\approx 4.5\%$	$(\rho = 3\%, \eta = 1)$
GCAM	5%	
MESSAGE	5%	
TIAM	5%	
IMAGE/FAIR		
POLES		

Source: (IAMC documentation wiki + online documentation)

A lower discount rate

In this context, lower discount rate should be considered:

- Economists suggest to use risk-free, public, long-term interest rates. 2–3% (Drupp et al., 2018)
- Cost-effective and cost-benefit analysis should be consistent.
- Inter-generational equity.

This study

This study

How does the discount rate influence the emission pathways for climate policies compatible with 1.5–2°C?

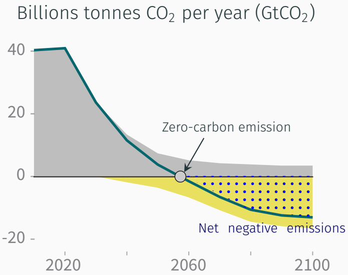
We use both

1. an analytical model — Hotelling's problem
2. a numerical DP-IAM with CDR options — WITCH

Key mitigation indicators

We study 3 key indicators:

1. The carbon price [$/t$CO_2$]
2. Zero-carbon emission year
3. Carbon budget overshoot [%]



Adapted from IPCC SR1.5C SPM

Carbon budget overshoot

Total net negative emissions relative to the carbon budget

100% means net negative emission = total carbon budget

Models

Optimal control problem

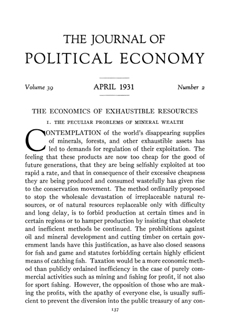
Minimization of the discounted abatement costs to implement a carbon budget

$$\min_{p(t)} \int_0^T e^{-rt} BAU(t) \underbrace{\left(\int_0^{MAC^{-1}(p(t))} MAC(a)da \right)}_{\text{abatement costs at } t} dt,$$

$$\text{s.t. } CE'(t) = E(t),$$

$$CE(T) \leq \alpha \int_0^T BAU(t)dt$$

$\Rightarrow$ Closed-form expressions of the 3 key indicators.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THE ECONOMICS OF EXHAUSTIBLE RESOURCES

I. THE PECULIAR PROBLEMS OF MINERAL WEALTH

CONTEMPLATION of the world's disappearing supplies of minerals, forests, and other exhaustible assets has led to demands for regulation of their exploitation. The feeling that these products are now too cheap for the good of future generations, that they are being selfishly exploited at too rapid a rate, and that in consequence of their excessive cheapness they are being produced and consumed wastefully has given rise to the conservation movement. The method ordinarily proposed to stop the wholesale devastation of irreplaceable natural resources, or of natural resources replaceable only with difficulty and long delay, is to forbid production at certain times and in certain regions or to hamper production by insisting that obsolete and inefficient methods be continued. The prohibitions against oil and mineral development and cutting timber on certain government lands have this justification, as have also closed seasons for fish and game and statutes forbidding certain highly efficient means of catching fish. Taxation would be a more economic method than publicly ordained inefficiency in the case of purely commercial activities such as mining and fishing for profit, if not also for sport fishing. However, the opposition of those who are making the profits, with the apathy of everyone else, is usually sufficient to prevent the diversion into the public treasury of any con-

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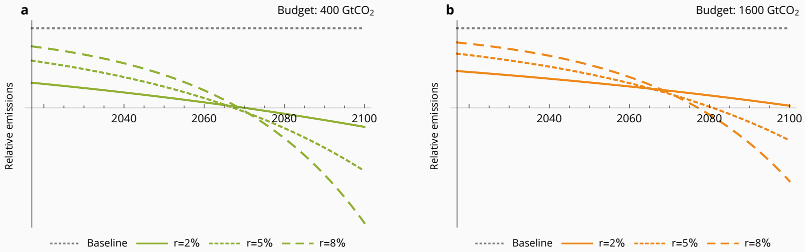
Hotelling's problem (1931)

E: emissions, BAU: baseline emissions, MAC: abatment curve, p: carbon price, r: discount rate, CE: cumulative emissions, α: CB factor

Analytical model

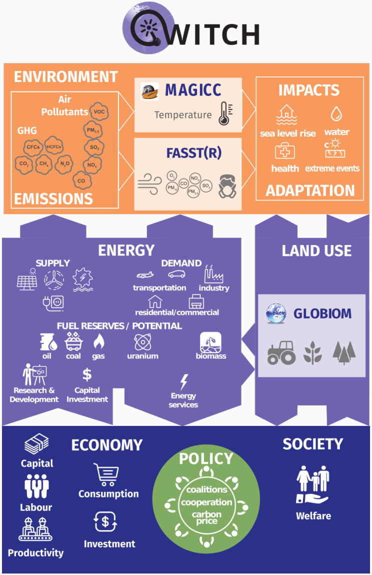


- Constant level of baseline emissions
- MAC has a power-law functional form (calibrated on SSP database)

Carbon price profile

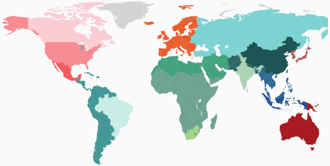
Under these conditions, the carbon price follows the Hotelling's rule, where the initial carbon price is increasing at the discount rate

Numerical DP-IAM WITCH



Intertemporal growth model

max regional discounted welfare

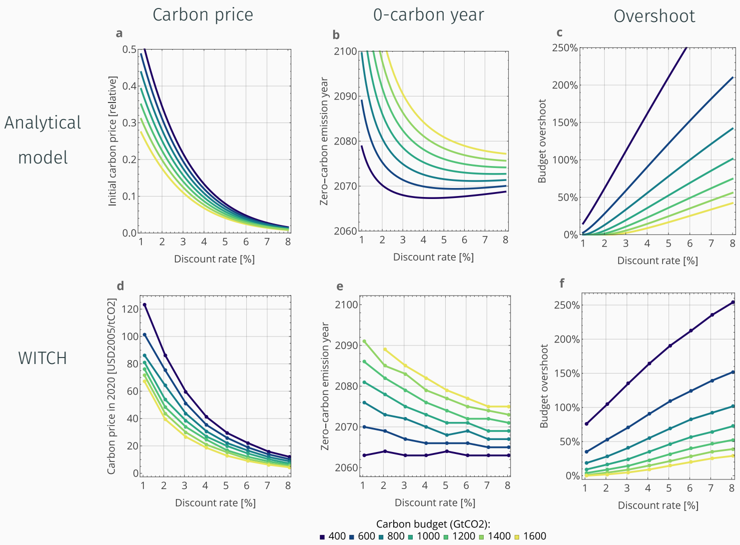


Runs for optimal carbon tax

- Discount rate 1–8% (var ρ, fix η)
- Carbon budgets: 400–1600 $GtCO_2$
- NETs options: (no, only BECCS, BECCS+DACS)

Results

Results — All NETs available



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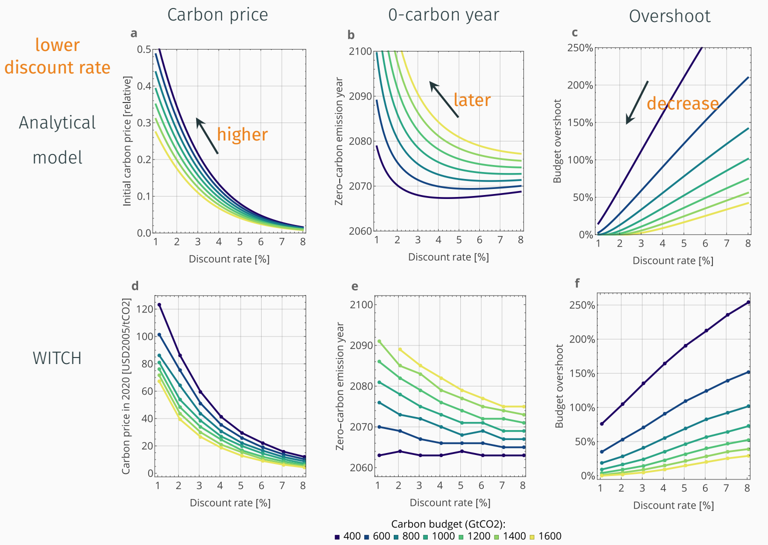


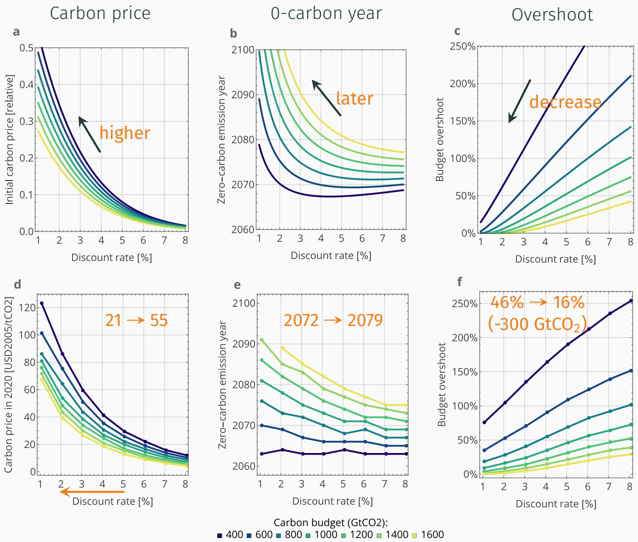
Results — All NETs available

lower discount rate

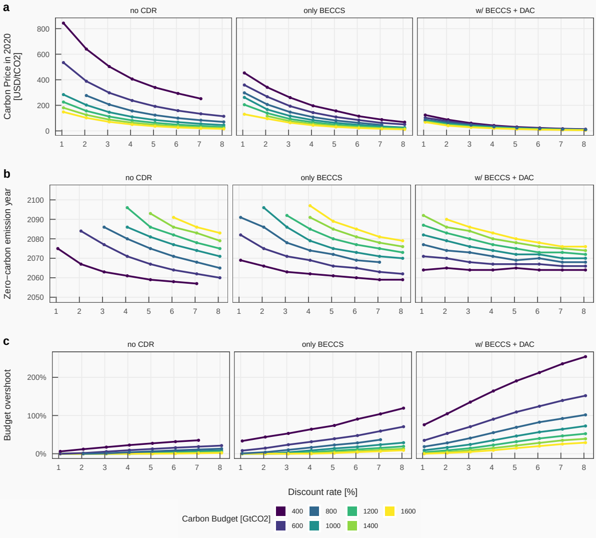
Analytical model

WITCH

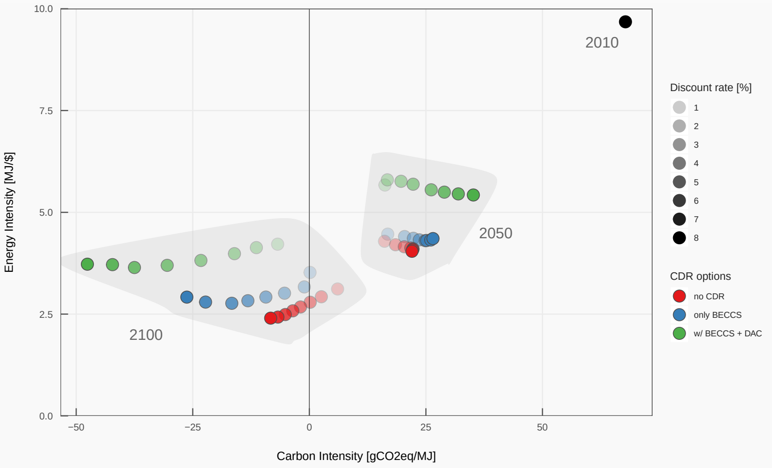
1000 $GtCO_2$ from 5% to 2%



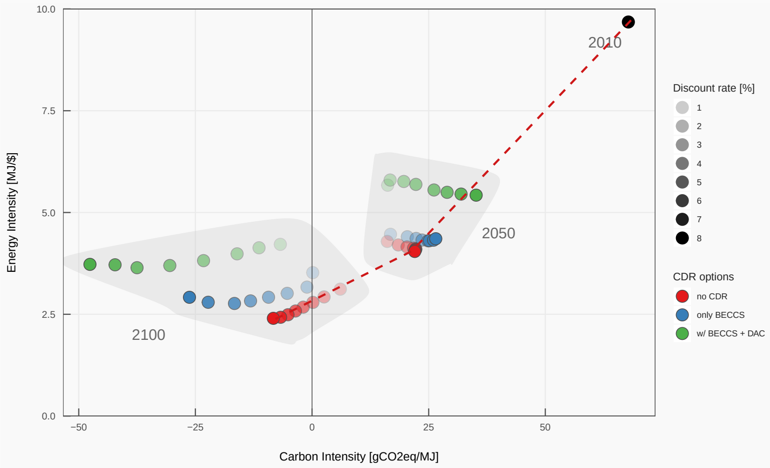
Results — NETs' availability



Energy and carbon intensity

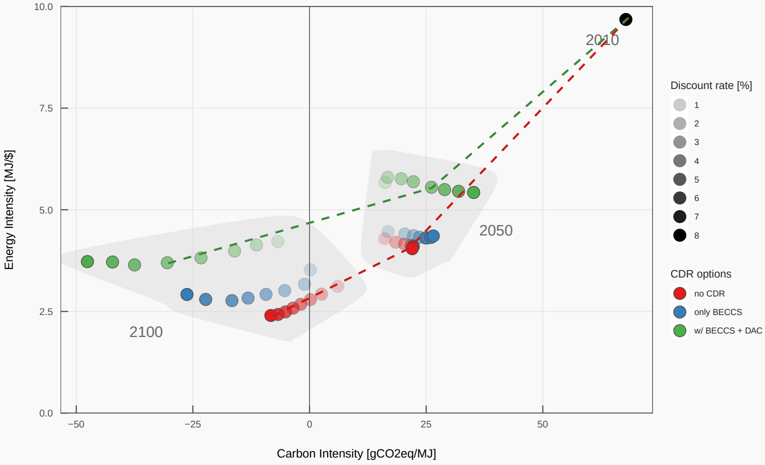


Energy and carbon intensity



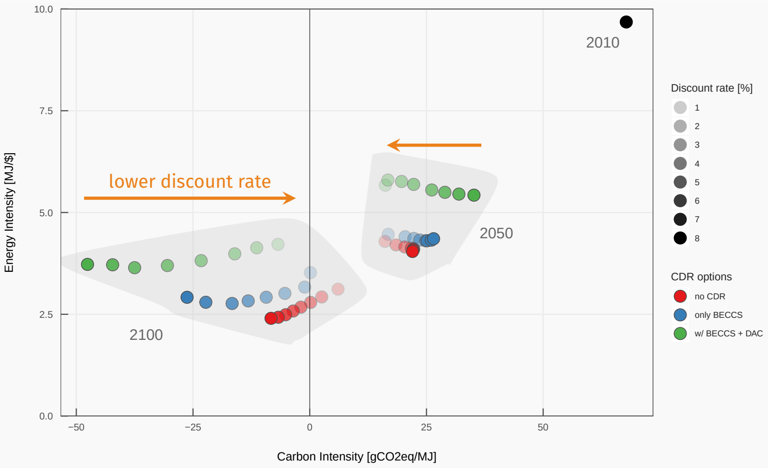
Without CDR, higher EE improvements are required.

Energy and carbon intensity



Without CDR, higher EE improvements are required. Lower with CDR options.

Energy and carbon intensity

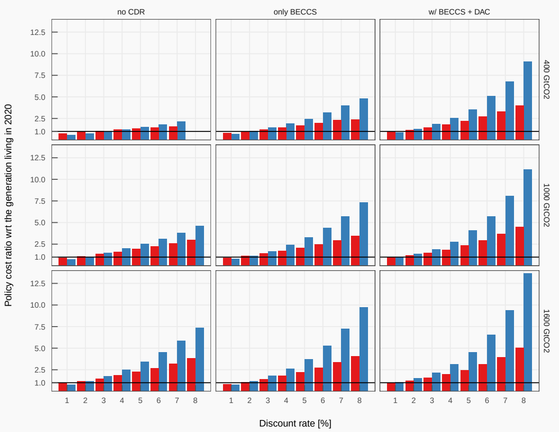


Low discount rate implies lower CI in 2050, but less decarbonisation in 2100.

Policy costs and Intergenerational equity

Comparison of climate policy costs (as % of GDP) over 3 generations:

2020–2050 (=1) 2050–2080 ■ 2080–2110 ■



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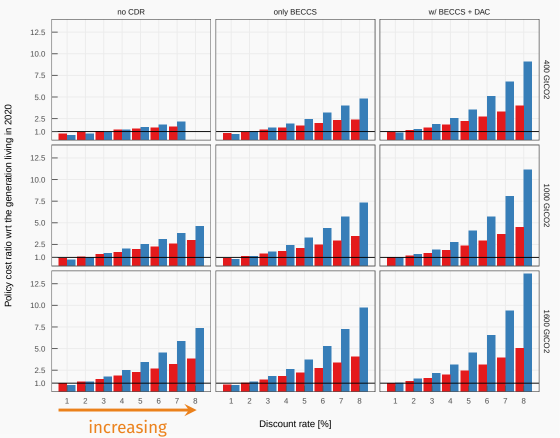

Intergenerational inequality increases with discount rate.

Policy costs and Intergenerational equity

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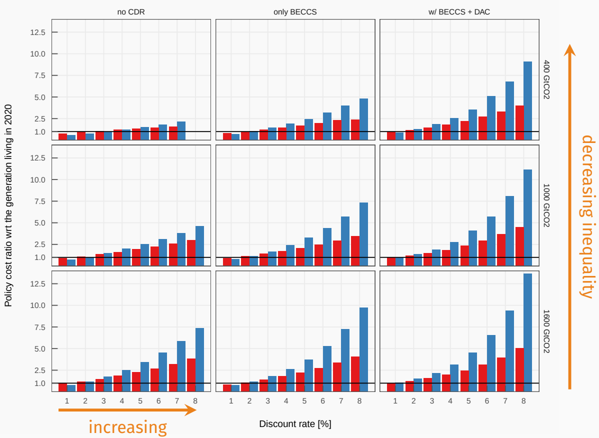

Lower carbon budget: less inequality but higher absolute costs

Policy costs and Intergenerational equity

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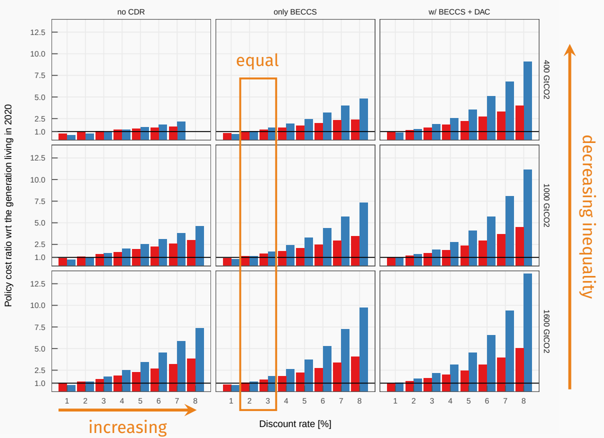


For 2–3%, efforts is equally distributed across generations

Conclusion

Conclusion

DP-IAMs should use lower discount rates

- to ensure inter-generation equity;
- to be consistent with cost-benefit analysis normative choice.

Using a normative time discounting would limit the role of NETs:

- being more ambitious in its early stage
- avoiding deeply negative carbon intensities

5% $\Rightarrow$ 2% dr (1000 $GtCO_2$)

- $\times 2$ today carbon price (from 21 to 55$/$tCO_2$);
- $\div 2$ carbon budget overshoot (-300 $GtCO_2$ NETs).

Questions?

Analytical model

Emissions definition:

$$E(t) = BAU(t)[1 - \mathrm{MAC}^{-1}(p(t))],$$

Optimal control problem:

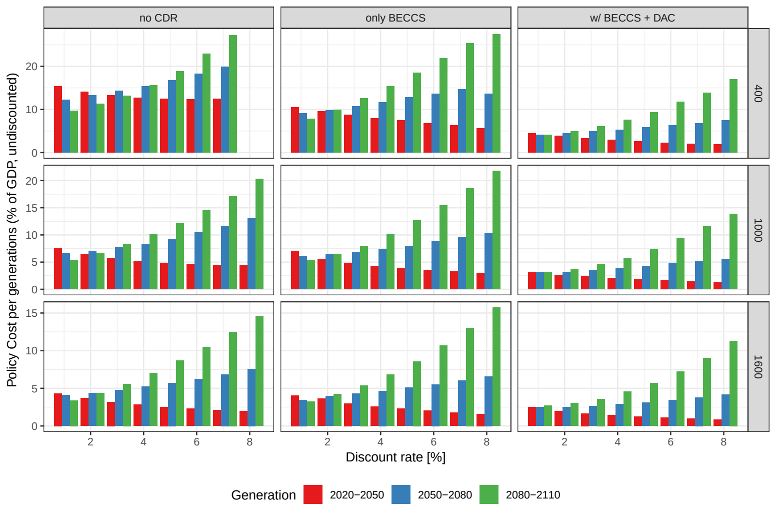
$$\min_{p(t)} \int_0^T e^{-rt} BAU(t) \underbrace{\left(\int_0^{MAC^{-1}(p(t))} MAC(a)da \right)}_{\text{abatement costs at } t} dt,$$

$$\text{s.t. } CE'(t) = E(t),$$

$$CE(T) \leq \alpha \cdot \int_0^T BAU(t)dt$$

E emissions, BAU baseline emissions, MAC abatment curve, p carbon price, r discount rate, CE cumulative emissions, α CB scaling factor

Policy costs



Econometric model

	Dependent variable:		
	Net-zero year	Budget overshoot	log(Carbon price (2020))
	(1)	(2)	(3)
dr	−2.256***	0.066***	−0.063*
	(0.159)	(0.009)	(0.033)
cb	0.021***	−0.001***	0.001***
	(0.001)	(0.0001)	(0.0002)
cdronly BECCS	−1.625*	0.151***	−0.023
	(0.850)	(0.052)	(0.183)
cdrw/ BECCS + DAC	−5.291***	0.544***	−1.014***
	(0.833)	(0.051)	(0.181)
Constant	2,069.181***	0.402***	4.136***
	(1.207)	(0.077)	(0.271)
Observations	138	164	164
R^2	0.833	0.665	0.258
Adjusted R^2	0.828	0.657	0.239
Residual Std. Error	3.824 (df = 133)	0.269 (df = 159)	0.949 (df = 159)
F Statistic	165.798*** (df = 4; 133)	79.070*** (df = 4; 159)	13.807*** (df = 4; 159)
Note:			*p<0.1; **p<0.05; ***p<0.01