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# **Policy lessons from integrating behavioural economics in climate- economy models**

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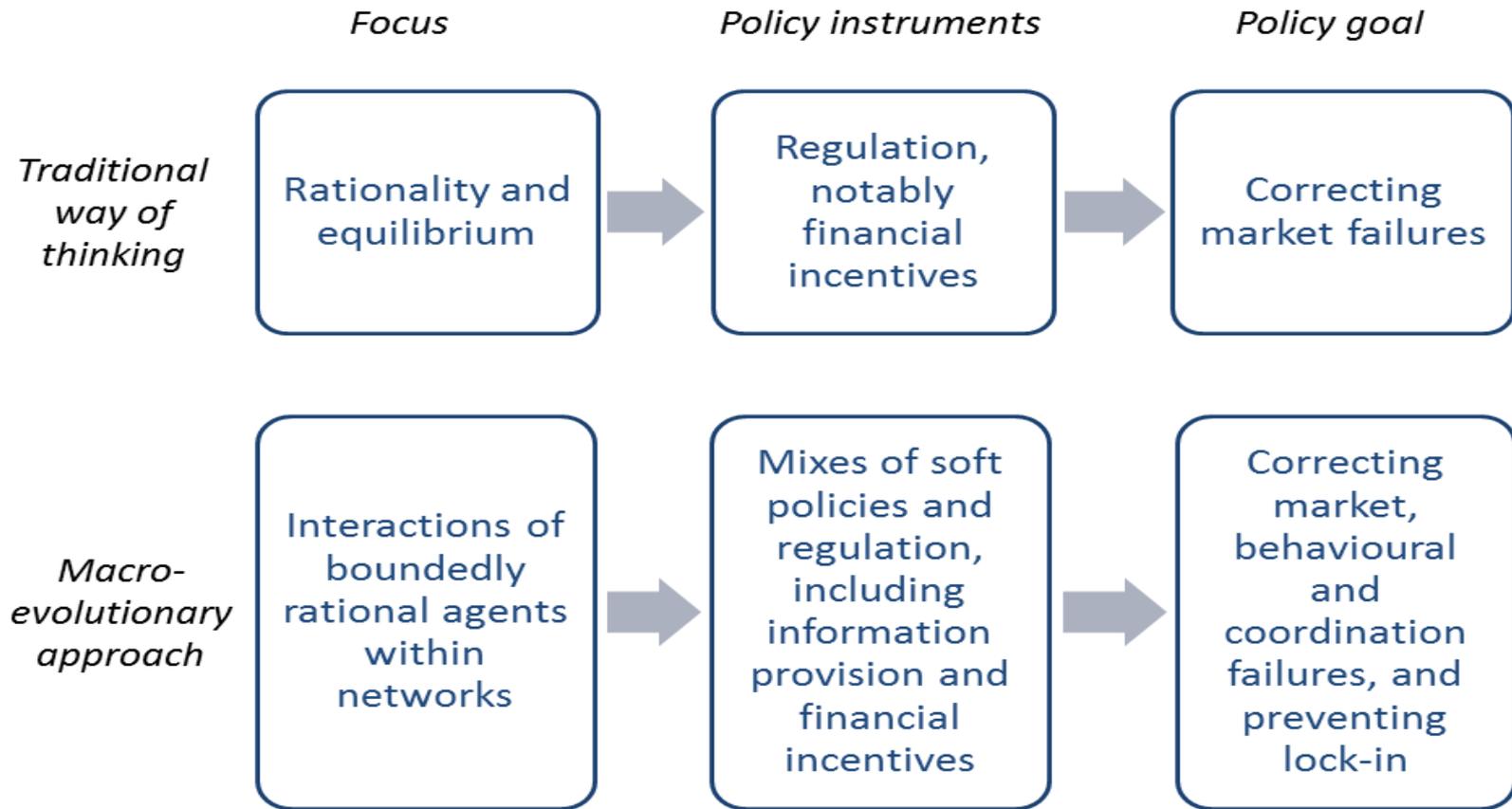
# Motivation

- There is a growing dissatisfaction with existing macroeconomic models used to assess climate policy (Pindyck, 2013; Dell et al. 2014; Farmer et al., 2015; Stern, 2016).
- The unrealistic and incomplete modelling of the physical impacts of climate change, the inherent uncertainty and the sensitivity of model outcomes to the discount rate have been widely discussed in the literature.

# Motivation

- Climate change economists have largely ignored alternative behavioural models, especially shying away from utility functions which are non-standard (an exception is Karp, 2005; Howarth, 2006).
- To date, policy discussions have only focused on how to address behavioural failures related to environmental choices in a descriptive manner (e.g. Brekke and Johanson-Stenmar, 2008; Shogren and Taylor, 2008; Gsottbauer and van den Bergh, 2010), but not in the macroeconomic assessment of climate policies.

# Traditional vs. evolutionary approaches



# Questions remain:

- How different types of bounded rationality affect equilibrium outcomes (consumption – saving choices) in the Ramsey model and IAMs?
- I will focus on
  - Optimal pollution tax
  - Rebound effect
  - Social carbon cost (SCC)

# A classic Ramsey model

- The literature on the economic impacts of climate change has been dominated by two approaches: the Ramsey model with pollution externality, and integrated assessment models (IAM) with a climate module.
- Is described by three equations: the Euler equation, capital accumulation and one describing accumulation of pollution

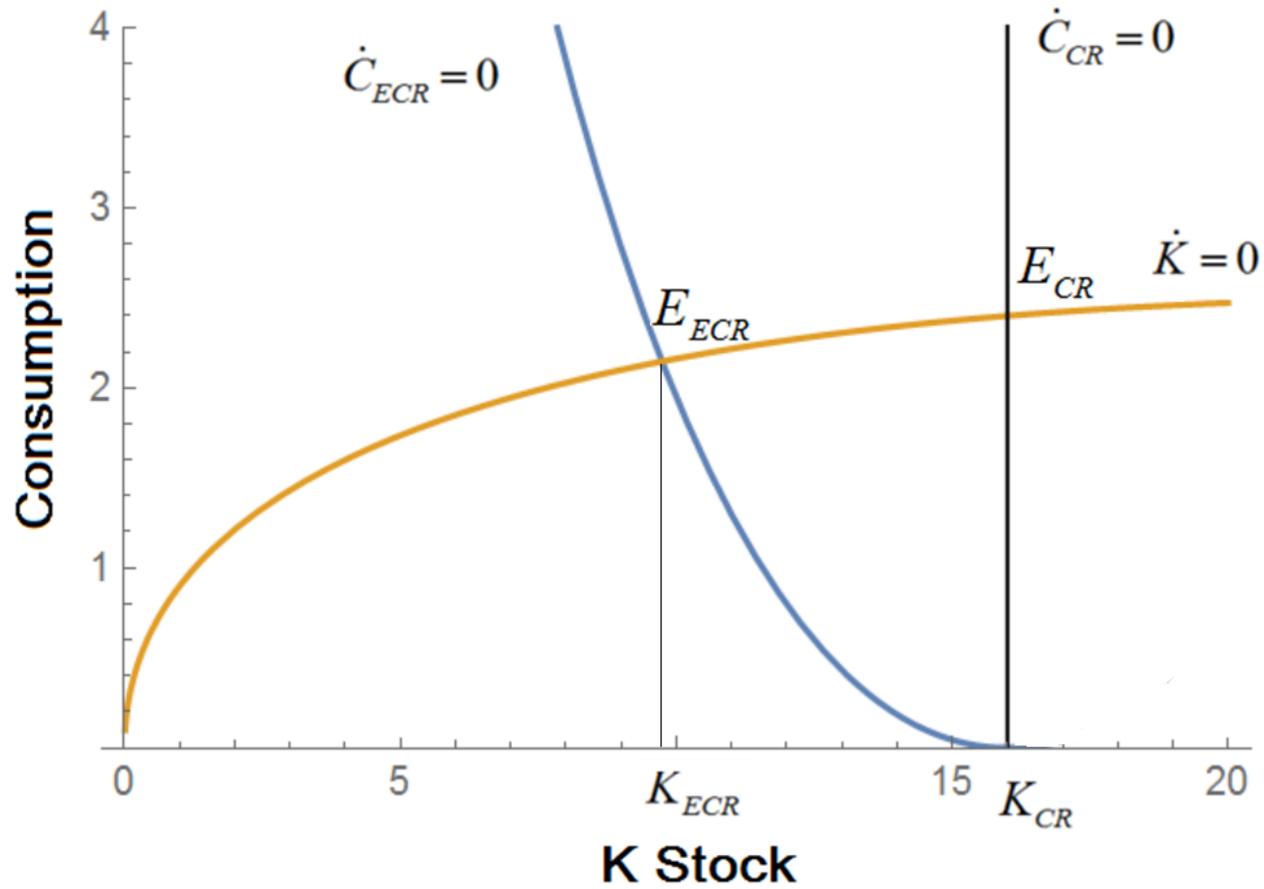
$$\dot{C}_{CR} = \dot{c}_t = \eta(c_t)c_t(f'(k_t) - \theta - \delta) \quad (1)$$

$$\dot{k}_t = f(k_t) - c_t - \delta k_t - A. \quad (2)$$

$$\dot{S}_t = g(Y_t) - \sigma(A)S_t \quad (3)$$

where  $\eta(c_t) = -\frac{U_c}{c_t U_{cc}}$  is the instantaneous elasticity of intertemporal substitution

# A classic Ramsey model



# Behavioral models

- Social status

$$u(c_t) = \frac{(c_t - xC_t)^{1-\sigma}}{1-\sigma} \quad \text{Ljungqvist and Uhlig (2000)}$$

- Agents fail to take into the effect of their spending on the consumption of others
- Overconsumption can be corrected with the optimal policy, which affects the economy countercyclically via procyclical taxes.

# Behavioral models

- Habit-following

$$u(c_t) = \frac{\left(\frac{c_t}{z_t^\gamma}\right)^{1-\sigma}}{1-\sigma}$$

Carroll et al., 2000

where habits change according to  $\dot{z}_t = \rho(c_t - z_t)$ :

- Habit formation makes agents more risk averse.
- They do not adjust consumption as much if productivity shock occurs.

# Behavioral models

- Loss-aversion

$$U(c_t, c_{t-1}) = (1 - \beta)u(c_t) + \beta v(c_t - c_{t-1}),$$

$$v(c_t - c_{t-1}) = c_t - c_{t-1} \quad \text{for } c_t - c_{t-1} \geq 0,$$

$$v(c_t - c_{t-1}) = \phi(c_t - c_{t-1}) \quad \text{for } c_t - c_{t-1} < 0,$$

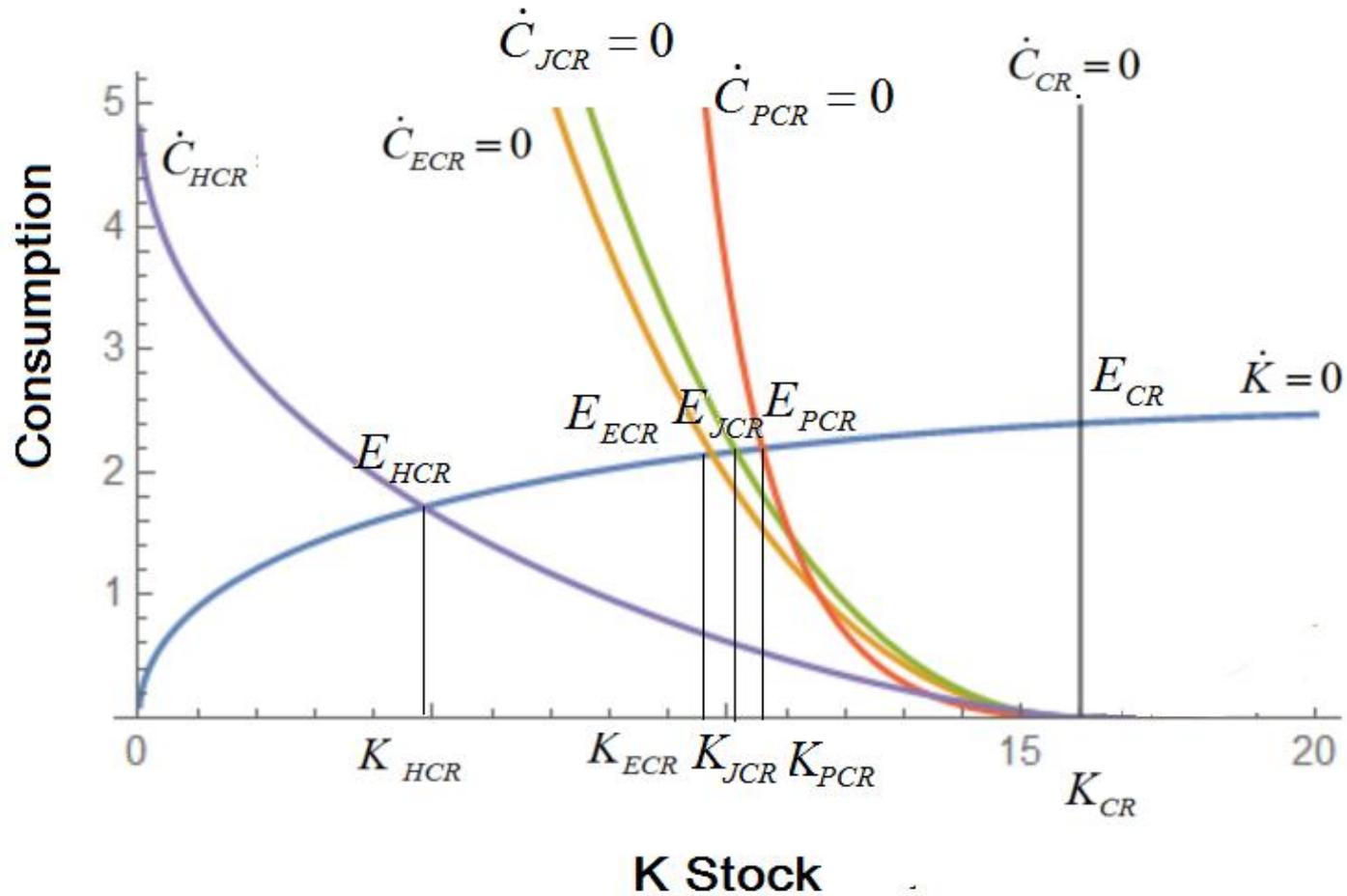
- High loss aversion makes individuals more concerned about current consumption than potential gains in future consumption.
- This leads to more extreme reductions in consumption during economic downturns.

*The flow externality under different behavioural models*

Model	Utility functions	$\eta(c_t)$	$U'(c_t)$	The size of externality flow compared to a rational-agent model
A model with rational agents	$u(c_t) = \frac{c_t^{1-\rho}}{1-\rho}$	$\frac{1}{\rho}$	$c_t^{-\rho}$	
Keeping up with Joneses	$u(c_t) = \frac{(c_t - xC_t)^{1-\sigma}}{1-\sigma}$	$\frac{1-x}{\rho}$	$((1-x)c_t)^{-\rho}$	<b>+</b>
Habit formation model	$u(c_t) = \frac{(\frac{c_t}{z_t})^{1-\sigma}}{1-\sigma}$	$\frac{1}{\rho + \gamma(1-\rho)}$	$\frac{(1-\gamma)(c_t^{1-\rho})^{1-\gamma}}{c_t}$	<b>-</b>
Prospect Theory	$u(c_t) = (1-\beta) \frac{c_t^{1-\rho}}{1-\rho} + \beta v(c_t - c_{t-1})$	$\frac{1-\beta + \beta c_t^\rho}{\rho(1-\beta)}$	$\beta + (1-\beta)c_t^{-\rho}$	<b>+</b>

Note: (+) larger than under the rational-agent model; (-) smaller than under the rational-agent model

# Behavioral models



# The rebound effect

- improvements in energy efficiency do not bring a proportional reduction in energy use (Jevon's paradox)
- direct rebound effect
- indirect rebound effects (Sorell, 2009):
  - embodied energy effects
  - re-spending effects
  - output effects
  - energy markets
  - composition effects

# A modified Ramsey model

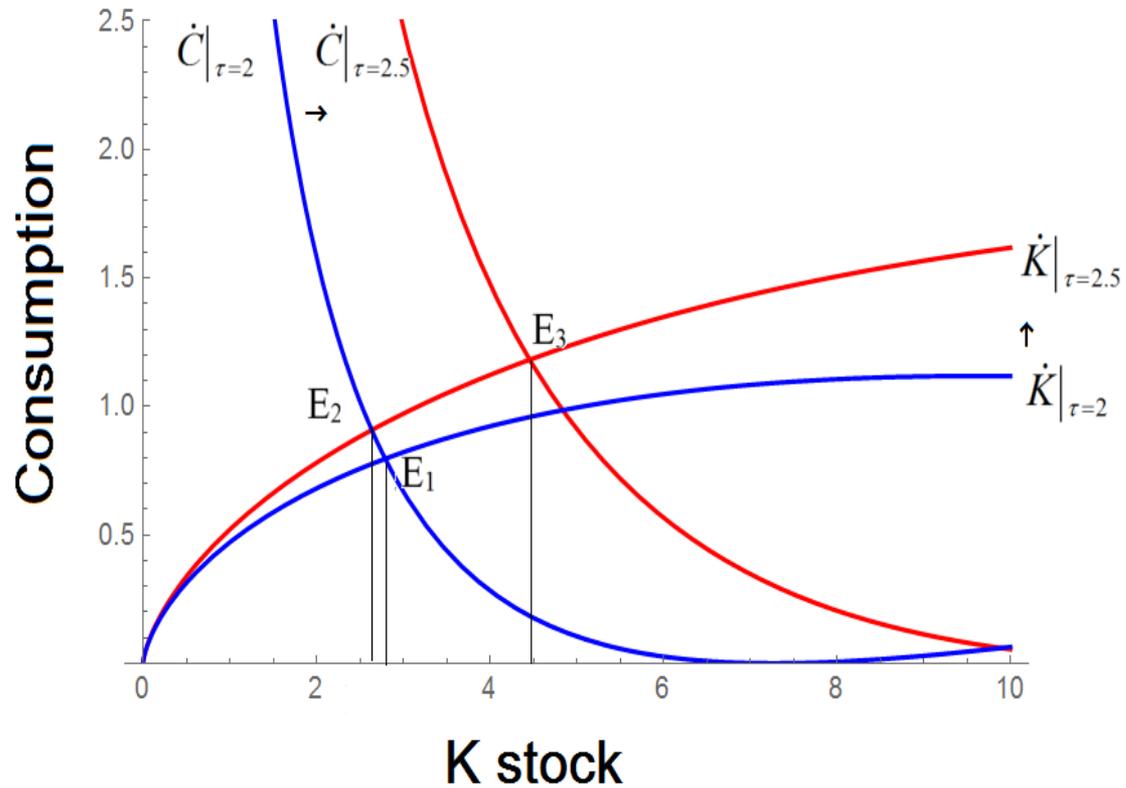
- Energy added as an input of production; damage is a function of the energy use

$$\dot{k}_t = f(k_t, e_t) - c_t - \delta k_t - p_e e_t \text{ with } f(k_t, e_t) = k_t^{\alpha_1} (\tau e_t)^{\beta_1}$$

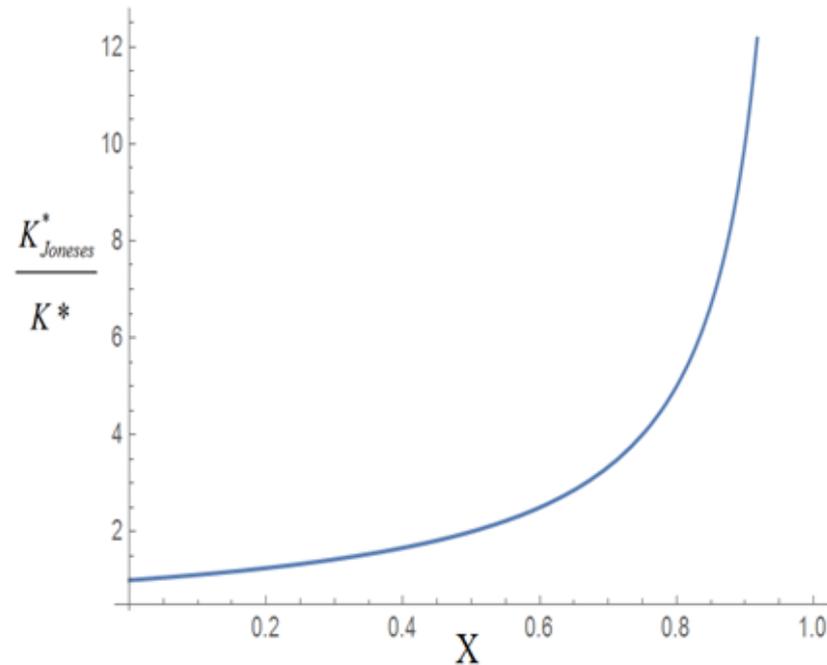
$$\dot{c}_t = \eta(c_t) c_t (f'(k_t) - \theta - \delta - \frac{\beta_1}{\alpha_1 \tau} \frac{a \frac{\beta_1}{\alpha_1 \tau} D'(a e_t)}{U'(c_t)})$$

$$U = \int_{t=0}^{\infty} e^{-\theta t} [u(c_t) - D_F(a e_t)]$$

# The rebound effect

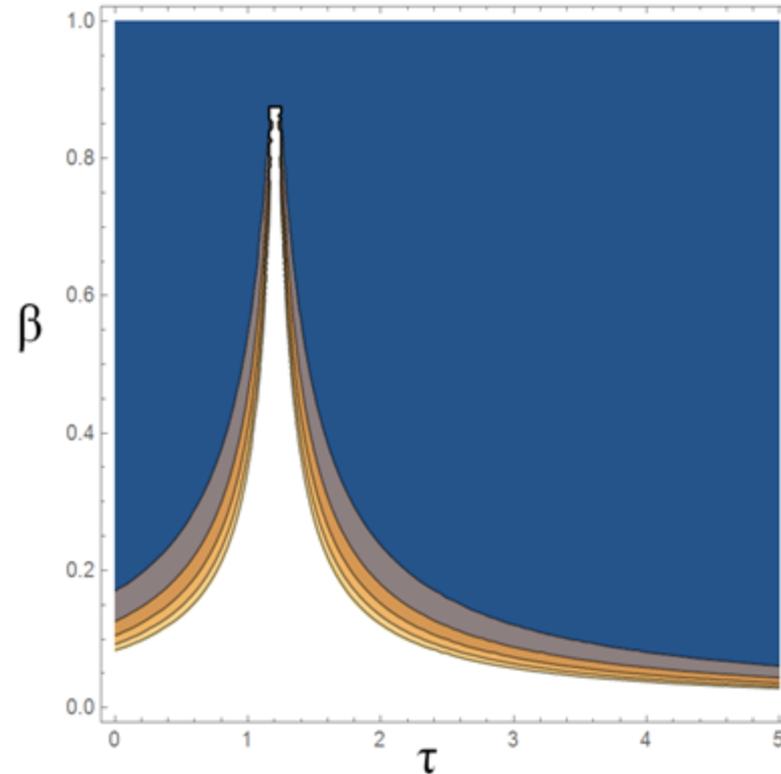


# The rebound effect



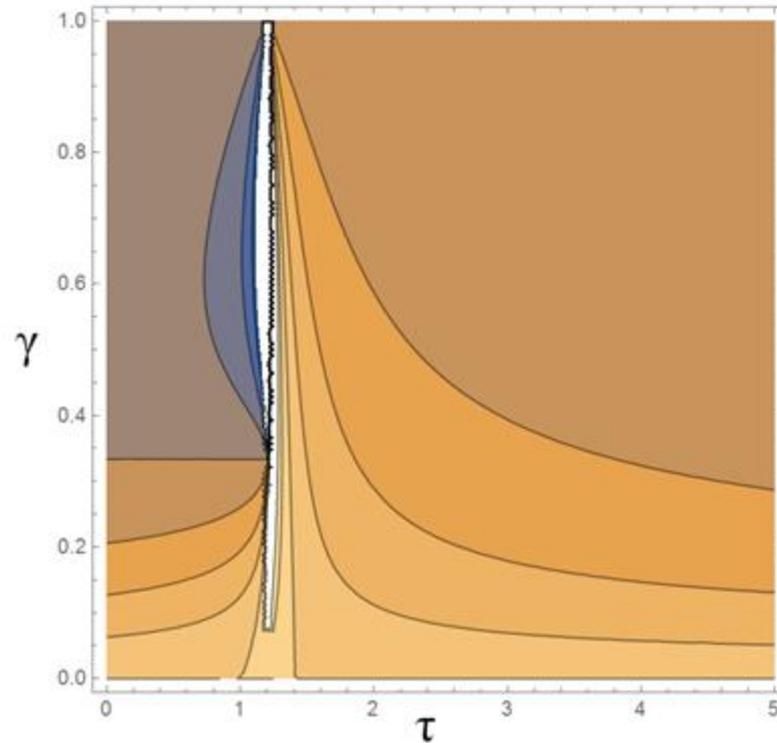
the impact of changes in  $x$  on  $\frac{K_{Joneses}^*}{K^*}$

# The rebound effect



the impact of changes in  $\beta$  on  $\frac{K_{Loss-aversion}^*}{K^*}$

# The rebound effect



the impact of changes in  $\gamma$  on  $\frac{K_{Habits}^*}{K^*}$

# Next steps

- Deriving the optimal path of consumption for each behavioral models, which is essential for assessing the SCC corresponding to each behavior anomaly
- The SCC is an estimate of the economic damages associated with a small increase in carbon dioxide (CO<sub>2</sub>) emissions
- The estimates of the SCC vary from \$10 to \$200 per tonne of CO<sub>2</sub> (Pindyck, 2013).

# Next steps

- We expect that adopting behavioural models to assess the SCC would generate very different estimates from the existing ones.
- The reason for this is that macro-behavioural models provide distinct perspectives on how economic agents behave in response to shocks to output productivity or capital destruction due to climatic events.

# Next steps

- According to prospect theory, agents may be unwilling to adjust their consumption after a shock, which would leave the economy in a steady state with low capital.
- The more habitual consumers are, the slower adjustments are made towards the steady state because of capital destruction.
- Therefore, in these behavioural-macro models, larger losses due to productivity or capital shocks are expected, which would result in higher estimates of the SCC.

# Conclusions

- If behavioral models are ‘closer’ to the truth, ignoring them may bias the environmental policy
- A Pigouvian tax on pollution is insufficient to bring the economy to the rational equilibrium if consumers are status oriented or loss-averse

# Conclusions

- The probability of the rebound effect is higher in the model with status-oriented consumers than in the rational model
- The probability of the rebound effect under habit formation is very low
- Under ‘loss aversion’, the probability of the rebound effect depends on the weight attached to the ‘reference’ consumption