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The climate beta ☆

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ABSTRACT

How does climate-change mitigation affect the aggregate consumption risk borne by future generations? In other words, what is the ‘climate beta’? In this paper we argue using a combination of theory and integrated assessment modelling that the climate beta is positive and close to unity for maturities of up to about one hundred years. This is because the positive effect on the climate beta of uncertainty about exogenous, emissions-neutral technological progress overwhelms the negative effect on the climate beta of uncertainty about the carbon-climate-response, particularly the climate sensitivity, and the damage intensity of warming. Mitigating climate change therefore has no insurance value to hedge the aggregate consumption risk borne by future generations. On the contrary, it increases that risk, which justifies a relatively high discount rate on the expected benefits of emissions reductions. However, the stream of undiscounted expected benefits is also increasing in the climate beta, and this dominates the discounting effect so that overall the net present value of carbon emissions abatement is increasing in the climate beta.

Introduction

Because most of the benefits of mitigating climate change arise in the distant future, the choice of the rate at which these benefits should be discounted is a crucial determinant of our collective willingness to reduce emissions of greenhouse gases. The discount-rate controversy that has emerged in economics over the last two decades shows that there is still substantial disagreement about the choice of this parameter for cost-benefit analysis. One source of controversy comes from the intrinsically uncertain nature of these benefits. It is a tradition in economic theory and finance to adapt the discount rate to the risk profile of the flow of net benefits generated by the policy under scrutiny. The underlying intuition is simple. If a policy tends to raise the collective risk borne by the community of risk-averse stakeholders, this policy should be penalised by increasing the discount rate by a risk premium specific to the policy. On the contrary, if a policy tends to hedge collective risk, this insurance benefit should be acknowledged by reducing the rate at which expected net benefits are discounted, i.e. by adding a negative risk premium to the discount rate.

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This simple idea can easily be implemented through the Consumption-based Capital Asset Pricing Model (CCAPM) of Lucas (1978). An investment raises intertemporal social welfare if and only if its Net Present Value (NPV) is positive, where the NPV is obtained by discounting the expected cash flow of the investment at a risk-adjusted rate. This investment-specific discount rate is written as

$$r = r_f + \beta\pi,$$

where r_f is the risk-free rate, π is the systematic risk premium and β is the CCAPM beta of the specific investment under scrutiny. It is defined as the elasticity of the net benefit of the investment with respect to a change in aggregate consumption. This means that a marginal project, whose net benefit is risky but uncorrelated with aggregate consumption, should be discounted at r_f, because implementing such a project has no effect at the margin on the risk borne by the risk-averse representative agent. A project with a positive β raises collective risk and should be penalised by discounting its flow of net benefits at a higher rate, and *vice versa* for a project with a negative β.

The objective of this paper is not to offer a new contribution to the debate about the choice of the risk-free rate, or of the systematic risk premium: there have been many of these in the recent past (see Kolstad et al., 2014, for a recent summary). Rather, the aim of this paper is to discuss the CCAPM β that should be used to value climate-mitigation projects. This 'climate β' should play an important role in the determination of the social cost of carbon (i.e. the present social value of damages from incremental carbon emissions), just as an asset β is known to be the main determinant of the asset price. Indeed, in the United States over the last 150 years, financial markets have exhibited a real risk-free rate of around 1.6% and a systematic risk premium of around 4.8 percentage points. Thus assets whose CCAPM betas are respectively 0 and 2 should be discounted at very different rates of 1.6% and 11.2% respectively.[1]

Howarth (2003) was one of the first to examine this question. He pointed out that the net benefits of climate-mitigation projects should be discounted at r_f, provided those net benefits are certainty equivalents (thereby containing a risk premium). He went on to suggest that the climate β is negative, but did not offer detailed analysis to back up the suggestion.[2] Weitzman's Weitzman (2007a) *Review of the Stern Review* also emphasised that the appropriate discount rate for climate-mitigation projects depends on the correlation between mitigation benefits and consumption, although he did not offer detailed analysis of this correlation either. He was contributing to a debate about discounting in the wake of the *Stern Review* (Stern, 2007), in which some scholars' views of what is an appropriate rate at which to discount mitigation benefits were in effect anchored against r_f, while others were anchored against r for standard investments, such as a diversified portfolio of equities. As Weitzman pointed out, there is no guarantee the features of climate mitigation match either of these cases.

Sandsmark and Vennemo (2007) provided the first explicit investigation of the climate β. They constructed a simplified climate-economy model, in which the only stochastic parameter represents the intensity of damages – the loss of GDP – associated with a particular increase in global mean temperature. Given this set-up, large damages are simultaneously associated with low aggregate consumption and a large benefit from mitigating climate change. Hence this model yields a negative climate β. Weitzman (2013) extended the idea that emissions abatement is a hedging strategy against macroeconomic risk, invoking potential catastrophic climate change and its avoidance, while Daniel et al. (2015) also find a negative climate β in the more general context of Epstein-Zin preferences, since their estimation of the social cost of carbon is increasing in the degree of risk aversion of the representative agent.[3]

On the other hand, an alternative channel driving the climate β may exist. Nordhaus (2011) concludes from simulations with the RICE-2011 integrated assessment model (IAM) that "*those states in which the global temperature increase is particularly high are also ones in which we are on average richer in the future*." This conclusion implicitly signs the climate β and is compatible with the following scenario. Suppose that the only source of uncertainty is exogenous, emissions-neutral technological progress, which determines economic growth. In this context, as long as growth is in some measure carbon-intensive, rapid technological progress yields at the same time more consumption, more emissions, more warming and, under most circumstances, a larger marginal benefit from reducing emissions. This would yield a positive correlation between consumption and the benefits of mitigation, i.e. a positive climate β. This channel is present in neither Sandsmark and Vennemo (2007) nor Daniel et al. (2015), because they assume a sure growth rate of pre-climate-damage production and consumption.

In this paper, we provide an overarching analysis of the sign and size of the climate β, which encompasses the aforementioned two stories, as well as other drivers. Our analysis is in two complementary parts. First, we explore analytical properties of the climate β in a simplified model. As well as serving to develop intuition, the model allows us to explore the role of the structure of climate damages, in particular whether they are multiplicative, as standardly assumed, or additive. We then estimate the climate β numerically using a dynamic IAM with investment effects on future consumption. We perform Monte Carlo simulations of the DICE model, introducing ten key sources of uncertainty about the benefits of climate mitigation and future consumption. We use these simulations to estimate the climate β for different maturities of our immediate efforts to reduce emissions. We find that in our version of DICE the positive effect on β of uncertain technological

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[1] See Shiller's dataset: http://www.econ.yale.edu/~shiller/data.htm.

[2] Aalbers (2009) situated the climate β within a broader set of theoretical conditions, according to which climate-mitigation investments might be discounted at a lower rate than other investments.

[3] Our paper sits within a large literature on uncertainty and climate policy (see Heal and Millner, 2014, for a review). Recent papers relevant to our analysis include Bansal et al. (2015) and Lemoine (2015).

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