On Carbon and the Economy

The environment is the lifeblood of the economy, yet it often takes a backseat to humanity's thirst for economic growth. In the 21st century, most have accepted the alarming existence of climate change, yet policy makers and economists have struggled to arrive at a consensus on the climate problem: the magnitude of climate change and the appropriate policy response.

Economic Risks of Climate Change

Infrastructural damage to roads, bridges, and buildings can be caused by frequent extreme weather events induced by climate change, incurring significant economic costs, from repair and reconstruction (IPCC, 2012). For example, global economic costs of natural disasters have risen, from around $50 billion per year in the 1980s to over $150 billion per year in the 2010s (Munich Re, 2018).

Agricultural productivity and food security are negatively impacted by climate change through a combination of changes in temperature and precipitation patterns, and increased frequency and severity of extreme weather events (IPCC, 2012). Schlenker & Roberts (2009) found that a 2°C increase in global temperature could lead to a 6% decrease in global crop yields, while Lobell et al. (2008) contend that climate change could reduce global crop yields by as much as 10% by 2100.

Loss of biodiversity is another impact of climate change, as certain species are unable to adapt to increased temperatures and changing conditions (IPCC, 2014). Williams et al. (2007) posit that a 2°C increase in global temperature could lead to the extinction of up to 18% of plant and animal species. Since biodiversity plays a key role in supporting ecosystems such as pollination and water purification, and industries like tourism, the loss of biodiversity incurs heavy costs in the economy (IPCC, 2012).

Human productivity may also be reduced by climate change, as increasing global temperature could accelerate the spread of diseases, and increase heat-related morbidity and mortality (IPCC, 2014). Diffenbaugh et al. (2013) found that a 2°C increase in global temperature could lead to a 50% increase in the frequency of extreme heat waves in some regions, while Curriero et al. (2002) found that a 2°C increase in global temperature could lead to an additional 38,000 deaths per year in the United States due to heat-related causes. Overall, the impacts of climate change can lead to supply chain disruptions, changes in consumer behaviour, and the loss in resources and productivity (IPCC, 2014). But how do we quantify such impacts?

Economic growth and the environment

The Dynamic Integrated model of Climate and the Economy (DICE) uses a cost/benefit approach to quantify the economic damages of climate change. DICE builds on intertemporal neoclassical growth theory: instead of only focusing on labour, capital, consumption and investment, it considers changes to a stock of 'natural capital' where a tradeoff is made by decreasing present consumption to increase abatement to decrease damages and increase future consumption (Integrated assessment models of climate change*,* 2017). DICE uses empirical socioeconomic and physics modules to predict emissions from consumption, and damages from emissions (Nordhaus & Sztorc, 2013).

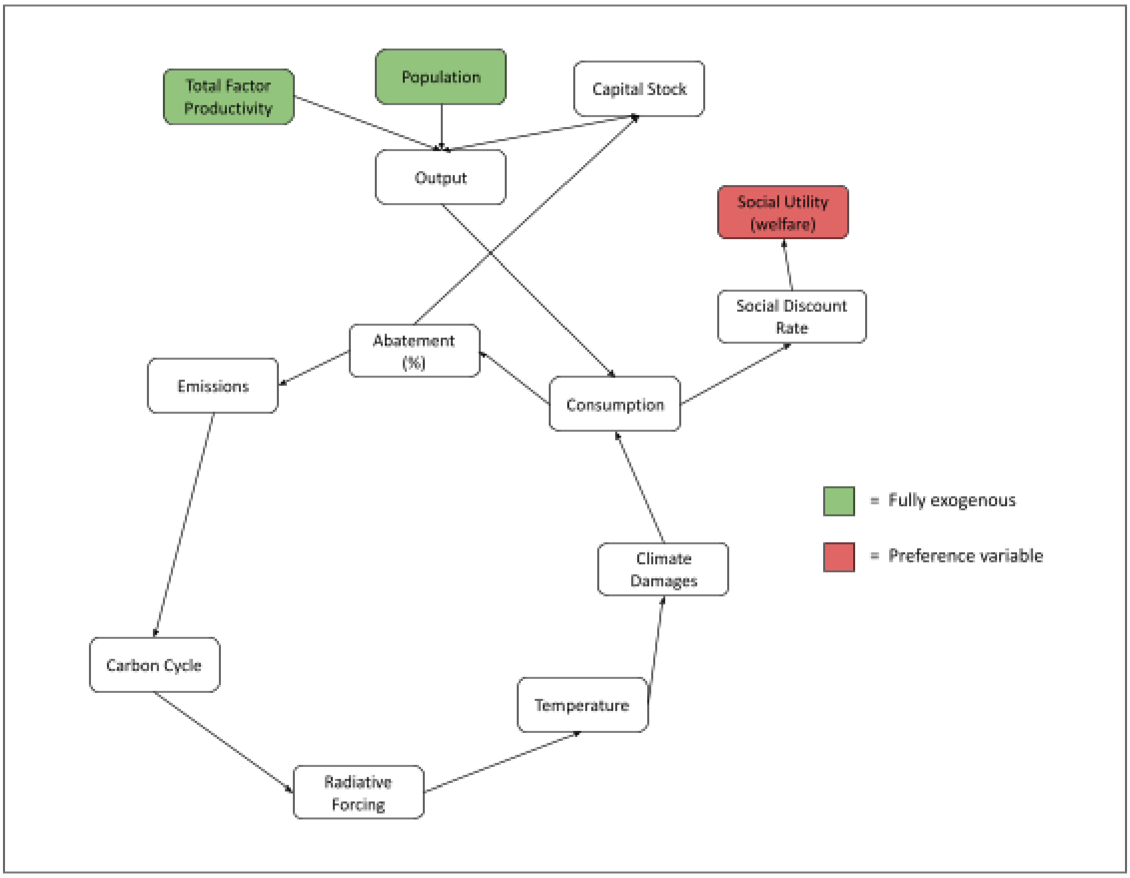


Fig 1. Simplified diagram of DICE

Crucially, DICE makes two important contributions to determining the appropriate tradeoff between economic growth and a healthy environment: welfare optimisation, and determining the Social Cost of Carbon (SCC). DICE discounts welfare using a social rate of time preference (STP), which is society's 'impatience' and willingness to sacrifice current utility for future utility (Nordhaus & Sztorc, 2013). By optimising total welfare of a consumption stream, DICE projects the expected abatement and SCC. The SCC quantifies the estimated damages to welfare caused by the emission of an extra unit of carbon dioxide in terms of consumption in a given period. The rate of change of the SCC depends on the rate of growth of world output, the removal rate of carbon and global market interest rates (Nordhaus, 2017).

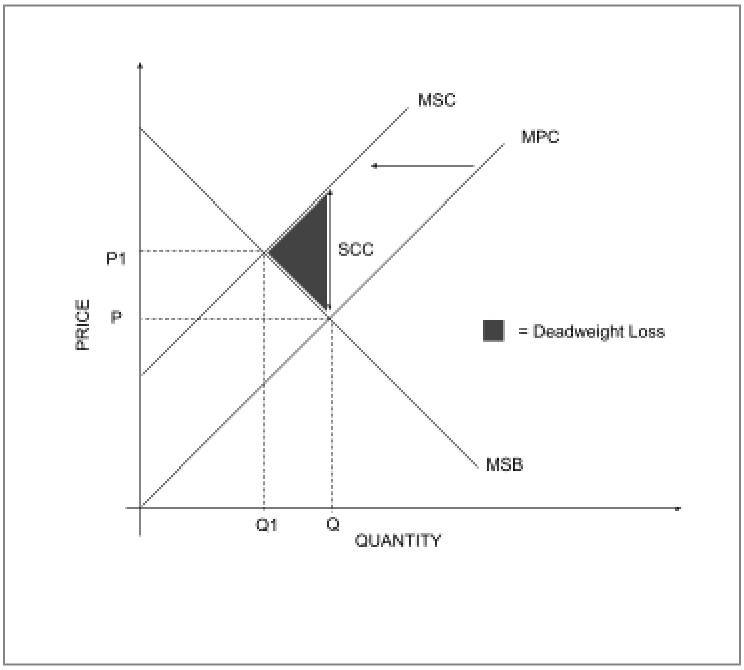


Fig.2 Carbon illustrated as a negative externality

DICE results with Nordhaus' standard assumptions of 1.5% STP and exogenous technological advancement at constant-returns-to-scale estimate that the IPCC's target of a temperature limit of 1.5°C is impossible without the existence of carbon neutral technology, while limiting warming to 2°C requires full abatement efforts (Nordhaus, 2018). An optimal path would involve a SCC of around $30/ton (2010 USD) in 2015 and rise gradually to $100/ton by 2050, so the temperature increase would reach 3.5°C by 2100 (Nordhaus, 2017). This is achieved by contributing 20% of net world output to abatement upfront and slowly increasing abatement as more efficient technology develops, generating a $6 trillion surplus by 2100 in world output when compared with a 'business as usual' projection (Nordhaus, 2018). However, limiting temperature change to 2.5°C will require a SCC of $184/ton in 2015 rising to $1008/ton in 2100 (Nordhaus, 2017). Critics of Nordhaus' estimates point to the underestimated climate incurred costs, due to a high STP (Stern, 2007), exogenous technology modelling (Newell & Pizer, 2003), and lack of consideration of tipping points and tail events in the damage function (Weitzman, 2007).

Hitherto, we have discussed the economic risks as well as stylised Integrated Assessment models to quantify the SCC; it is quite clear when comparing the predicted impacts of 2-3°C of warming and the modest expected economic burden needed to limit the temperature below 2.5°C in DICE that economic growth asymmetrically coincides with a healthy environment.

Climate Policy

The future finances present consumption as global markets fail to internalise the SCC. Internationally, the 'free rider problem' prevents cohesive climate solutions, as countries pursuing independent macroeconomic goals can benefit without contributing to the global effort thereby leading to a tragedy of the commons (Schneider, 2002). In particular, the inaction from voluntary treaties such as the Copenhagen Accord and the Kyoto protocol could be attributed to the lack of incentive for developed countries to take on the carbon burden of developing countries, and the lack of incentive for developing countries to stop developing. Nordhaus (2015) proposed The creation of a 'Climate Club' where non-members are penalised with harsh tariffs exceeding the expected cost of abatement initiatives. This artificially creates a dominant strategy for countries where they incur the least cost by partaking in abatement, thus arriving at a pure strategy Nash equilibrium and reaching long-run socially optimal outcomes. Nordhaus (2021) finds that temperatures can be kept at 3-3.5°C range by 2100 with modest club policy, using a variation of the DICE model.

Nationally, the climate problem lies in the market failure; negative externalities of carbon are not reflected in markets. Policies such as carbon pricing and innovative incentives can be used to correct the market failure. Carbon pricing involves setting a price on greenhouse gas emissions, either through a carbon tax or a cap-and-trade system, with the goal to shift MPC to MSC representing the SCC (Fig.2). Prominently, the EU Emissions Trading System (ETS), the world's largest cap-and-trade program, has been successful in reducing greenhouse gas emissions, with emissions from covered sectors falling by around 21% between 2005 and 2017 (EEA, 2019). Another success story is Germany's feed-in tariff program which provides financial incentives for renewable energy electricity production, such as solar, wind, and hydroelectric power. The feed-in tariff program has been successful in increasing the deployment and uptake of renewable energy sources from 6.3% in 2000 to over 40% in 2019 (IRENA, 2020). Furthermore, non-market based policies such as establishing energy efficiency standards can inform consumers and lead to the use of more efficient technologies (LBNL).

Overall, there are a variety of abatement policies that governments can enact to protect the environment whilst minimising the impact on economic efficiency. Mckinsey (2009) estimated the carbon potential (ability to remove carbon from the atmosphere) and the cost of aggressively pursuing various abatement schemes compared to a 'business-as-usual' case and compiled them into a marginal abatement cost curve (MACC).

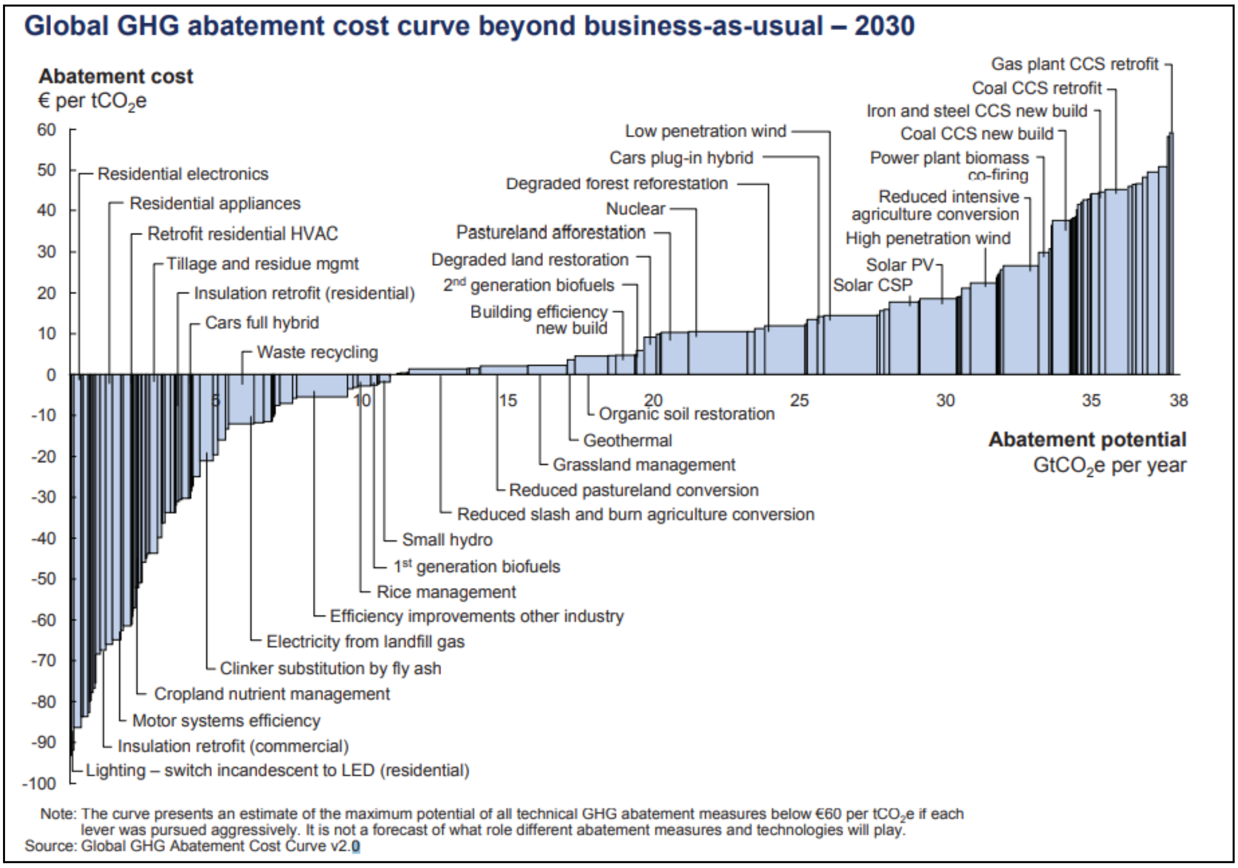
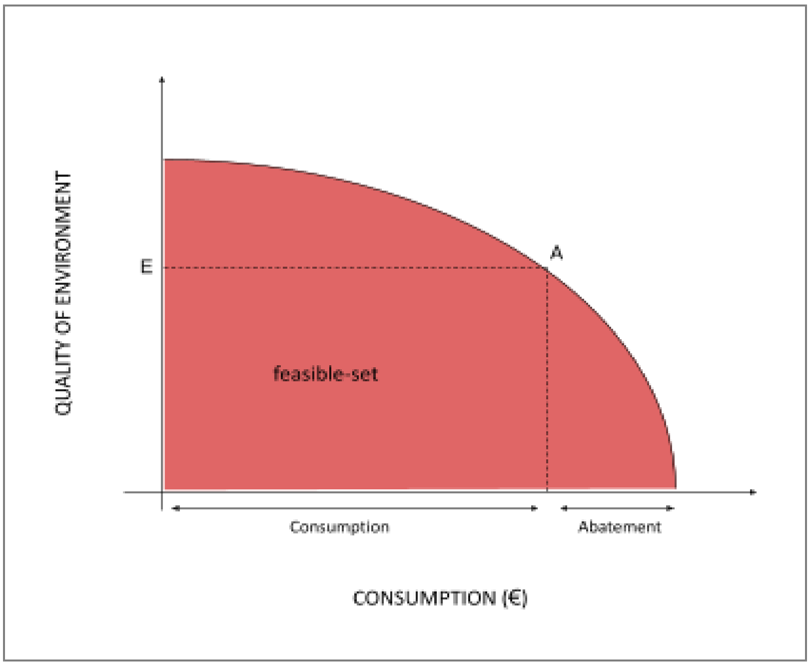


Fig.3 MACC[1] Curve

[1]Sourced from:
https://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/sustainability/cost%20curve%20pdfs/pathways_lowcarbon_economy_version2.ashx

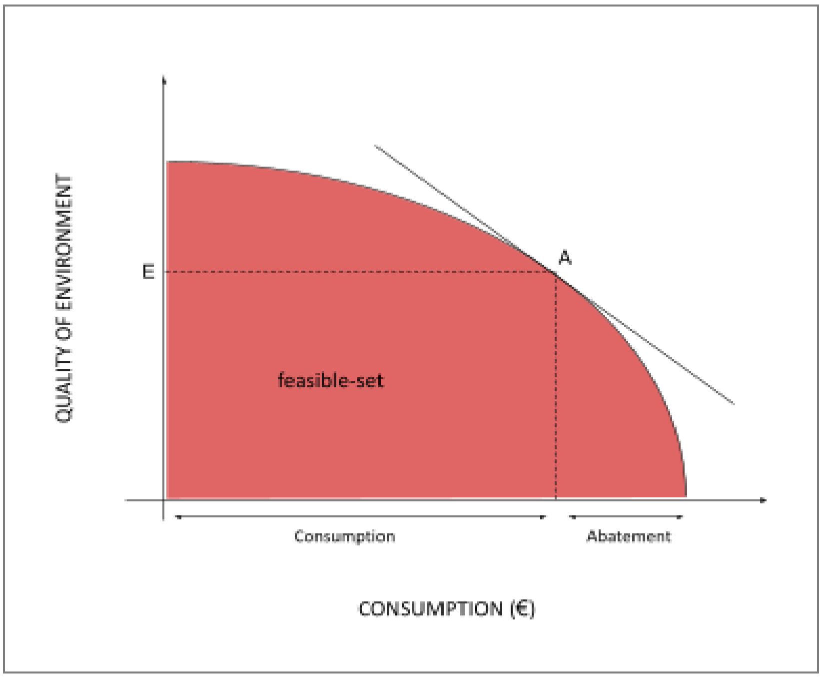
With the section of positive costs on the MACC, we can construct a frontier for possible abatement to consumption ratio at a given output:



Given the aggregate Marginal Rate of Substitution and Marginal Rate of Transformation of each country:

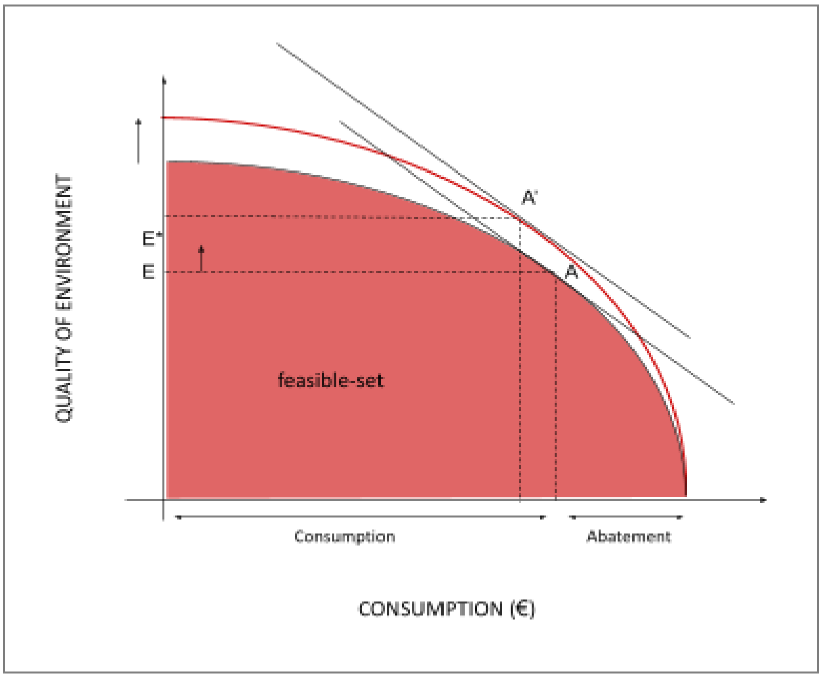
$$MRS = \frac{marginal\ utility\ of\ consumption}{marginal\ utility\ of\ environment\ quality} \qquad MRT = \frac{increase\ in\ environmental\ quality}{decrease\ in\ consumption}$$

We can find optimal policies using indifference curves[2] (CORE-ECON, n.d.):



[2] For simplicity, marginal utility of consumption and the marginal utility of environmental quality are assumed to be constant, resulting in straight indifference curves.

The point A is where MRT = MRS given the utility preference of the country. Technological advancements increase abatement efficiency and lower opportunity cost of abatement. This results in a steeper frontier, and shift from point A to A':



This shows the possibility of sustainable growth being consistent with higher environmental quality.

Closing Remarks

DICE has shown that unsustainable economic growth is inconsistent with a healthy environment; MACC analysis shows that it is imperative to pursue abatement and innovation in order to achieve sustainable economic growth. Internationally, a successful solution to the climate problem requires countries to be less mercenary as national incentives often conflict with global interests. And while consumption often leads to higher levels of social welfare, a wise economist would take a step back and take care of the lifeblood humanity so desperately relies on.

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