CLIMATE CHANGE

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Carbon Pricing and the Precautionary Principle

Author:

John Quiggin

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Schools of Economics and Political Science

The University of Queensland

St Lucia

Brisbane

Australia 4072

Web: www.uq.edu.au

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John Quiggin

School of Economics

University of Queensland

EMAIL j.quiggin@uq.edu.au

PHONE + 61 7 3346 9646

FAX +61 7 3365 7299

http://www.uq.edu.au/economics/johnquiggin

Carbon pricing and the precautionary principle

Introduction

The problem of climate change has been described as ‘a unique challenge for economics: it is the greatest and. widest-ranging market failure ever seen’ (Stern 2007, p. i). Among the factors that make climate change a difficult, the most important, arguably, is uncertainty about the future course of climate change, and the effect of policies aimed at mitigating climate change.

Although there is a large literature on the economic analysis of choice under uncertainty, many crucial issues are poorly understood by policymakers and the general public. In particular, uncertainty about climate change under ‘business as usual’ policies is commonly seen as a reason for inaction. On the other hand, the widely-used ‘precautionary principle’ is generally interpreted as suggesting that early action is desirable. To resolve the conflict between these intuitions, it is necessary to consider in more detail the principles for choice in the face of environmental uncertainty and, particularly, the interpretation of the precautionary principle.

The concept of the ‘precautionary principle’ has been the subject of vigorous debate. As with other contested concepts in environmental theory and policy, most notably that of ‘sustainability’, the debate has proceeded in the absence of an agreed definition. As a starting point, it is useful to consider the definition implicit in this statement by Christine Todd Whitman, then governor of New Jersey and later Administrator of the U.S. Environmental Protection Agency, quoted in Appell (2001)

> Policymakers need to take a precautionary approach to environmental protection.... We must acknowledge that uncertainty is inherent in managing natural resources, recognize it is usually easier to prevent environmental damage than to repair it later, and shift the burden of proof away from those advocating protection toward those proposing an action that may be harmful."

As Whitman indicates, the precautionary principle is concerned with the formulation of choices under uncertainty. However, the majority of the discussion has been undertaken without reference to the large literature on the theory of choice under uncertainty, spanning economics, psychology and statistical decision theory. The absence of any formal framework for discussion has contributed to the confused nature of the debate, in which a multitude of definitions of the precautionary principle have been proposed and criticised.

The precautionary principle as a heuristic

Grant and Quiggin (2013) show that the precautionary principle may be considered as an heuristic for making choices when decision-makers are unaware of some of the possible outcomes of their decision.

The heuristic interpretation of the precautionary principle proposed by Grant and Quiggin arises when a decisionmaker is faced with a choice between alternatives, of which one leads to consequences for which the relevant elements of the state space are well-understood and the other leads to consequences that depend to a significant extent on `unknown unknowns'. Under appropriate conditions, the precautionary heuristic is 'ecologically rational', in the sense proposed by Goldstein and Gigerenzer (2002), who define 'ecological rationality' as 'the capacity of the heuristic to exploit the structure of the information in natural environments.'

If most surprises are unpleasant, a risk analysis based only on known risks will underestimate the costs of choices of the second kind. That is, standard risk analysis leads to a bias in favour of taking chances on poorly-understood risks. The precautionary principle may be seen as a rule designed to offset such biases. Grant and Quiggin show how the precautionary principle may be understood as an ecologically rationally heuristic constraint on decisions and consider heuristic approaches for individuals who are unaware of relevant contingencies and understand this to be the case.

Grant and Quiggin present the following stylized decision problem. A boundedly rational decision-maker must choose whether to undertake a project or to maintain the *status quo*.[1]

[1] In an interactive version of the problem, a private project proponent interacts with a public regulator who must decide whether to approve or reject the proposal.

Given the state of her current knowledge about and understanding of the situation, the project is expected to yield positive net economic benefits compared to maintaining the status quo. In the absence of more detailed consideration, the decisionmaker is not aware of any environmental hazards that may be associated with the project that could inflict high damage. However, more detailed study may reveal such hazards if they exist.

From the perspective of an unboundedly rational external observer, it is possible to assign a probability to the event that a high-damage hazard will be discovered, and an expected (dis)utility to the associated loss. However, until and unless further study is undertaken, the awareness of real decision-makers is much more limited. Grant and Quiggin show that decision-makers cannot assign probabilities to events of which they are unaware, but are nevertheless conscious of the possibility that a high-damage hazard may exist.

Grant and Quiggin propose an approach in which the deductive analysis of decision theory is constrained by heuristics derived from inductive reasoning. In particular, given past experience of decisions that have turned out badly because of unconsidered possibilities, the decisionmaker may regard the proposition ‘there may exist hazards I have not considered’ as being supported by historical induction.

In problems where the precautionary principle is considered, inductive reasoning will normally justify the proposition that the choices resulting from the application of a particular heuristic are subject to unfavourable surprises. To make this notion more precise, Grant and Quiggin assume that the decision tree of which the decisionmaker is aware includes a ‘status quo’ or ‘secure’ (behavioural) rule which is not subject to surprises. In the example under consideration, the *status quo* rule is to reject the project without further study.

A simple version of the Precautionary Principle would require choice of the *status quo* in all cases of this kind. However, Grant and Quiggin argue that this version of the principle is too strong, in that it would preclude options that are not badly exposed to adverse surprises. In many cases, there is a ‘fallback’ option available, that limits the loss that can arise from an unfavourable surprise. For example, a detailed evaluation or a pilot project may be sufficient to yield a more complete assessment of hazards, without exposing the decisionmaker to the large losses that might arise from proceeding with the project in the absence of full awareness of the hazards.

Grant and Quiggin propose a modified version of the precautionary principle, which would allow choice of a plan or project subject to unfavourable surprises if there exists a fallback option that would limit losses to a value less than the expected return from the project in the absence of surprises. Grant and Quiggin show that the modified form of the Precautionary Principle is ecologically rational, relative to the Strong Form, if the occurrence of an unfavourable surprise is less likely than not.

In considering how the formulation of the precautionary principle developed above might be applied to the problem of climate policy, we need to ask

- Where are the potential surprises ?
- What is the status quo?
- What are the fallback options?

Possible surprises may be divided into surprises related to climate sensitivity and impacts (roughly, the extent to which emissions of greenhouse gases will change the global climate, and what affects those changes will have on natural systems and human welfare) and surprises relating to the cost of mitigation.

Potential surprises

Sensitivity

The crucial parameter in a global climate model is climate sensitivity, that is, the sensitivity of equilibrium global temperature to a given change in 'forcing', that is, the heating effect derived from changes in the concentration of greenhouse gases or other sources. Sensitivity is conventionally measured as the equilibrium response of average global temperature, to a doubling of the total forcings derived from greenhouse gases, measured in CO_2 equivalent parts per million. This is a useful basis for discussion since continuation of 'business as usual' policies is likely to generate a doubling of CO_2-equivalent concentrations from the pre-industrial level by around the middle of the present century.

It is important to interpret climate sensitivity carefully. On the one hand, it is an equilibrium measure, so the estimated change in temperature will not take place immediately, due to lags in the carbon cycle and the atmospheric system. On the other hand, under business as usual, there is no reason to expect that CO_2 concentrations will stabilise at twice the pre-industrial level. Projections suggest that the ultimate concentration could exceed 800 ppm or three times the pre-industrial concentration (IPCC 2007a).

A variety of estimates of climate sensitivity have been presented, some as point estimates and some with a range of uncertainty. Two issues are particularly relevant. First, there is the need to take account of aerosols. Most aerosols operate to reduce warming, and thus have an opposite effect to that of emissions of CO_2.

For much of the historical period on which estimates have been based, both concentrations of CO_2 and concentrations of other pollutants generated by industrial production (collectively referred to as 'aerosols') were growing. Hence these variables display collinearity over most of the data period. However, since around 1960 concentrations of aerosols have declined as a result of legislation restricting air pollution, while concentrations of CO_2 and other greenhouse gases have continued to increase.

The combination of collinearity and opposite effects mean that the larger is the estimated effect of aerosols, the larger is the estimate of climate sensitivity, working in the opposite direction to produce a given change in temperature. It follows that a wide range of pairs of parameter values can fit the observed movement in global mean temperature, particularly over the period when aerosol and CO_2 concentrations were highly collinear. This source of parameter uncertainty can be reduced by the use of more recent data and by comparing trends in the Northern Hemisphere (where industrial pollution has produced high levels of aerosols) with those in the Southern Hemisphere (where aerosol levels were lower) (Harvey 2000).

Another important issue is the choice between classical approaches to parameter uncertainty, which have dominated the literature, and Bayesian approaches that allow the incorporation of relevant information from a variety of sources. Bayesian methods generally imply less uncertainty about parameter values than classical methods, since they incorporate various forms of prior information. Stainforth et al (2005), using a classical approach suggest that sensitivity may be as high as 11 degrees C, whereas Annan and Hargreaves (2006) argue that the correct value almost certainly lies between 1.5 and 4.5 degrees C.

A variety of surprises are possible with respect to climate sensitivity. The most important are possible feedback effects that may amplify or reduce sensitivity, and the prospect of discontinuous, and possibly catastrophic, changes in global systems.

The direct forcing effects of increased atmospheric concentrations of carbon dioxide can be determined fairly accurately from simple physical models. However, the final impact of any given level of CO_2 emissions, and the speed with which the global climate system reaches a new equilibrium depend on a complex set of feedbacks, sinks and lags (IPCC 2007a). Climate models take account of feedbacks and lags operating within the atmosphere and, to some extent, the capacity of oceans and other global systems to absorb CO_2.

Even more uncertainty surrounds feedbacks arising from interactions between the climate and the biosphere. For example, higher temperatures may increase the frequency, and severity of bushfires, creating a positive feedback on CO_2 emissions. The magnitude and significance of these feedbacks is poorly understood.

Unfavourable surprises may also arise from discontinuous changes in global systems. One possible discontinuous change would arise from a shutdown of the thermohaline circulation which drives currents such as the Gulf Stream. The effects of such a change might include localised cooling in the North Atlantic, due to the loss of the Gulf Stream and an increase in sea level. Other effects are unpredictable. For example, the the threats of discontinuous change caused by the possible quick release of methane from either deep oceans or tundras. Moreover, given our limited understanding of global systems, it seems likely that there are other possibilities that have not yet been considered. The discussion of the precautionary principle presented above suggests that policy choices need to be made on the basis that such unconsidered possibilities are likely to be relevant.

Potential surprises regarding the cost of mitigation

The economic implications of carbon pricing, whether through taxation or through the creation of tradable emissions permits are fairly well understood. Hence, surprises regarding the cost of mitigation are unlikely. We may illustrate this point in more detail using analysis developed by Quiggin (2012) of the policies required to reduce emissions by 90 per cent between 2010 and 2050, implying an annual rate of decline of 6 per cent. A Business As

Usual (BAU) allows for 1 per cent growth over the period 2010-2050, so the policy must then induce an annual 7 per cent decline relative to BAU.

Any emissions trajectory must satisfy the accounting identity

(1) $C = P*(Y/P)*(S/Y)*(E/S)*(C/E)$

where

C is carbon dioxide emitted to produce energy

P is population

Y is aggregate income

S is energy services

E is energy consumption

In analyzing changes in emissions, it is useful to convert this into (natural) logarithmic terms

(2) $\Delta c = \Delta p + \Delta y + \Delta s + \Delta e + \Delta i$

Here

Δc = d log C/dt is the rate of growth of (energy-related) emissions

Δp = d log(P)/dt is the rate of growth of population

Δy = d log(Y)/dt - d log(P)/dt is rate of growth of income per person

Δs = d log(S)/dt - d log(Y)/dt is the rate of change in the share of energy services in total income

Δe = d log(E)/dt - d log(S)/dt is the rate of change in the ratio of energy use to energy services produced (the inverse of energy efficiency)

Δi = d log(C)/dt - d log(E)/dt is the proportional change in carbon intensity, that is, the ratio of CO_2 emissions to energy services produced

This identity includes no explicit role for prices. Consideration of income and price elasticities of demand, and of elasticities of substitution between energy and capital, and between energy from carbon and other sources, is crucial in understanding the likely impact of price based policies. For simplicity, consider the case where the price of carbon-based fuels is increased by 50 per cent (the effect of\ $100/tonne carbon price would be higher than this for coal, but lower for oil). On the assumption that fuel costs constitute 50 per cent of the price of energy, this would entail a 25 per cent increase in energy costs, and assuming energy accounts for 40 per cent of the costs of energy-related services, a 10 per cent increase in the cost of those services.

Assuming that Δp and Δy are exogenous, the effect of a carbon price is given by the sum of changes in $\Delta s + \Delta e + \Delta i$, which as argued above, must sum to -0.07. A plausible combination would be annual Δi=- 0.04, Δe=-0.02, Δs= -0.01. The implied elasticities over 10 years are below 1 in each case.

An estimate of the welfare loss associated with a reduction in energy demand driven by an increase in the shadow price may be obtained from the consumer surplus associated with a constant-elasticity demand curve. We have

(3) $\Delta = -(1+m^{(1/k-1)})/((k-1)(1-m\wedge^{(1/k)}))$ $\quad k\neq 1$

(4) $\Delta = \log(m)$ $\quad$ k=1

where

Δ is the welfare loss, expressed as a proportion of initial expenditure

m is the desired proportional reduction, set equal to 50 per cent

k is the elasticity of demand

For values of k in the range 1 to 2, Δ ranges from 0.7 down to 0.3. Assuming energy accounts for 6 per cent of GDP, the implied welfare loss is between 1.8 and 4.2 per cent of GDP, with a median estimate of 3 per cent of GDP, approximately equivalent to one year's economic growth.

Australia's experience since the introduction of the carbon price, that is, the absence of any perceptible aggregate impacts, is consistent with this analysis. The increase on the price of electricity resulting from carbon pricing has been around 10 per cent. Calculation of Δ as above yields estimated welfare losses of the order of 0.1 per cent of national income, which are within the margin of error of national accounting estimates, and may therefore be described as negligibly small in a macroeconomic context.

These estimates are highly robust to surprises. Two potential sources of error may be considered. First, the elasticity of demand for energy services may be lower than assumed. However, even for values of k that are well below 1, the welfare loss remains small. Second, there may be unconsidered income effects and other general equilibrium effects. However, these general equilibrium effects are normally second-order. That is, if the cost of reducing emissions is small in relation to aggregate income (say, less than 10 per cent), the error associated with neglecting GE effects is likely to be negligible by comparison with other sources of uncertainty and error.

Summary

To sum up, the responses of the global climate to emissions of greenhouse gases is not well understood. There are a range of model estimates of climate sensitivity. Some feedbacks, particularly those involving the biosphere, are poorly understood. There is a poor understanding of possible catastrophic shifts. Although they occur with low probability, the potential damage is such that taking account of catastrophic risks leads to a substantial increase in mean estimates of losses from uncontrolled climate change.

By contrast, the costs of mitigation and stabilization are fairly well understood. Although there is a range of debate regarding demand elasticities and elasticities of substitution in production, large-scale surprises are unlikely.

What is the status quo?

The phrase *status quo* may be interpreted in many different ways in relation to climate change. First, we might consider the policy *status quo*, that is BAU. Unfortunately, BAU implies continued growth in emissions, resulting in substantial and unpredictable changes in climate. In economic terms, it is hard to define a meaningful notion of the *status quo*. Existing consumption and investment plans are predicated on continued economic growth. Moreover, as long as technological progress continues, the economy continues evolving. The most relevant concepts of a *status quo* are those derived from the sustainability literature, which would require constant stocks of renewable natural resources, and some sustainability criterion for non-renewable mineral resources. In the current context, this leads naturally to considerations of the *status quo* in terms of stabilisation of the global climate and atmospheric system.

In climatic terms, the *status quo* is most naturally interpreted to mean maintenance of the existing climate. This is not feasible, since global temperatures have yet to equilibrate to the effects of the greenhouse gases already emitted into the atmosphere.

Next we might consider stabilization of greenhouse gas concentrations at or near existing levels. In practice, however, even with radical policies to reduce emissions, greenhouse gas concentrations are bound to continue for some decades. It may be possible to reduce concentrations in the second half of the 20th century. Conceivably, technological innovation could permit a return to pre-industrial concentrations.

None of these correspond naturally to a literal interpretation of the phrase *status quo*. Rather than focusing on semantics, it is necessary to look at the interpretation of the *status quo* in the model of Grant and Quiggin (2013). The crucial idea here is that the *status quo* option is the surprise-free choice, if it exists.

As has been argued above, the economic costs of stabilization are well understood, while business as usual policies are vulnerable to severe and unpredictable surprises. Hence, the *status quo* option is stabilization of the climate at a level low enough to allow a fallback option in the event of unfavourable surprises.

Fallback options

A stabilization program involves reducing net emissions of greenhouse gases to zero, with the result that the atmospheric concentration is stabilized at some level such as 450 ppm. Given our limited knowledge of the global atmospheric system, and the fact that atmospheric concentrations are already outside the range of historical experiences, it is possible that we will observe some unfavorable surprise. This might be, for example, an unexpectedly large feedback from temperature to methane emissions, leading to a risk of runaway global warming.

In response to such a surprise, and assuming it was not sudden and catastrophic, it would be necessary to shift rapidly to a trajectory with a lower level of stabilization, and perhaps to one in which atmospheric concentrations of most greenhouse gases are falling. Options that might be considered are:

Crash program of decarbonization, combined with large scale tree-planting to promote sequestration

Geo-engineering plans to reduce temperature by injecting aerosols into the stratosphere

An informal analysis suggests that such policies might be able to reduce the effective atmospheric concentration of greenhouse gases and particles by around 50 ppm of CO_2 equivalents, in the short run and up to 100 ppm in the medium term. Given a initial target of 450 ppm, these fallback options could achieve a return to levels around 350 ppm, generally considered safe. However, the cost would be high and there would be a risk of unforeseen side effects.

For targets greater than 450 ppm, the capacity to deal with unforeseen surprises through fallback options is steadily diminished. Thus, the precautionary principle favours the adoption of a lower target.

For the sake of symmetry, it may be worth considering the response to some favourable climate surprises. Suppose that climate sensitivity turns out to be much lower than is now believed, or alternatively that a simple and low-cost method of carbon sequestration is developed.

In either of these cases, the optimal response is to lower the carbon price and increase the use of carbon-based fuels. *Ex post*, the resulting trajectory of carbon prices will be sub-optimal. However, the welfare loss in this case will not be large. The only effect is to delay the extraction of fossil fuel resources, which remain available for use, and to invest in alternative generation technologies which will turn out, in retrospect to have been more expensive than necessary

Implications for carbon pricing and emissions trading

The precautionary principle has some important implications for the design of carbon pricing systems and, in particular for the choice between carbon taxes and emissions trading schemes. Although they are sometimes seen as being quite different, Australian experience shows that a carbon tax may be implemented as a fixed-price emissions trading scheme. Conversely, a carbon tax with a variable rate can be used to target any desired level of emissions. The proportion of revenue kept by the government, returned to households or allocated to emitters is likewise independent of the choice of scheme.

Nevertheless, it is convenient to think of an emissions trading scheme as involving fixed quantities of emissions and of a carbon tax as being levied at a fixed rate. With these conventions, the precautionary principle suggests that an emissions trading scheme, with some capacity to vary the target in the light of new evidence, is the better choice.

Unpredicted variations in the unit cost of mitigation will imply similar variations in the economic cost of stabilization at a given level, but these are, as has already been shown, relatively small in to national income. By contrast, with a fixed tax rate, there is a significant risk that emissions will exceed dangerous levels.

Concluding comments

The precautionary principle, understood as a heuristic, can help guide better policy choices. Careful consideration of the vulnerability of policies to adverse surprises, and of the availability (or unavailability) of fallback options can lead to more robust policy choices.

In the case of climate change, the precautionary principle implies more concern with avoiding dangerous climate change, and less with economic costs. The stated aim of international policy, to stabilize concentrations of greenhouse gases at 450 ppm of CO2-equivalent, appears justified on the basis of the precautionary principle.

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