THE ECONOMICS OF LIMITATIONS[1]

Climate change and the limitation on fossil fuels through geopolitics or inherent resource constraints are often described together[2], both because they are connected in cause (both are associated with the combustion of limited fossil fuels) and both are examples of issues of sustainability, intergenerational equity, and living on a finite planet earth. This article investigates both the economic similarities and differences between the difference cases.

The article consists of three parts:

- The first part explains the science of climate change and fossil fuel depletion.
- The second part describes the similarity between fossil fuel and climate change – both deal with a scarcity. I introduce the elementary economics of scarcity and the associated payment to owners of scarce resources, known as the scarcity rent.
- The third part distinguishes between two different sorts of constraints: 'hard constraints' (which cannot physically be exceeded) and 'soft constraints' (which can be exceeded but at a cost).

The distinction between 'hard' or 'soft' constraint is clearly conceptually different from whether an economic action entails an external spillover effect on another economic agent or ecological system (in economics this is known as an 'externality'). It is argued that externalities are potentially much more serious when they relate to 'soft' rather than 'hard' constraints. In regard to 'hard' constraints,, economic and political questions relate to the efficient and equitable use and distribution of resources – important but second order concerns relative to the constraint itself. 'Soft constraints' share these concerns but also entail the first-order question of whether the constraint itself is breached (and the severe costs that could incur). If a 'Malthusian' is someone who predicts human and environmental disaster unless human behaviour is adjusted to take account of environmental constraints, these arguments explain why it may be possible to be consistently 'Malthusian' with regard to 'soft' constraints such as the emission of greenhouse gases and 'anti-Malthusian' with regard to 'hard' constraints such as the availability of fossil fuels. This reasoning also explains why it is necessary to view the study of human economic behaviour as part of a larger field, which includes the ecological system. Simplified representations of the natural systems involved are encouraged.

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2 See, for example, Mackay (2009)

Economic Features of Climate Change & Fossil Fuel Scarcity

Climate Change

Emissions of carbon dioxide and other well mixed greenhouse gases (such as methane, nitrous oxide and fluorinated gases list of fluorinated gases could go in glossary) are commodities (a tonne of CO_2 emitted at ground level has the same effect, wherever it is emitted). These emissions are often called 'stock externalities' because they add to a long-term global stock, and greenhouse gases are global public 'bads' (by virtue of their negative effects on global climate and ocean acidity) .

Carbon dioxide emissions and consumption of fossil fuels can be measured either in tonnes of carbon or in terms of tonnes of carbon dioxide. The relative molecular mass of carbon is 12 and that of carbon dioxide is 44. Therefore, 1 tonne of Carbon is equal to 3.67 tonnes of CO2; €1 per tonne of Carbon equals €0.27 per tonne of CO_2.

The characteristics of the main well-mixed greenhouse gases are:
a) they are well mixed; that is that their effect is a global one, not a local one.
b) they are relatively long-lived[3]

The economic characteristics of these greenhouse gases are as follows:

a) They are commodities: A tonne of Carbon Dioxide has a similar effect wherever on the surface of the Earth, and however it is emitted[4]
b) They are stock externalities: From a stock externality it is meant that fundamentally it is the concentration of CO_2 that does the damage rather than rate of emissions.

Unlike many other pollutants, Carbon Dioxide does not degrade but continues to reside in the biosphere.[5] [6] The current level of ocean sequestration ($7GtCO_2$ pa) can be a rough order-of-magnitude estimate of a global carbon budget which would stabilise greenhouse gas concentrations. An outline of the relevant science has been outlined (Stern 2008)[7].

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3 As defined as the atmosphere plus the oceans plus the land-biosphere (plants and soils on land)

4 If the future is discounted then the damage of a tonne of CO_2 emitted today is greater than that of a tonne of CO2 emitted in the future.

5 About half of the human-caused emissions are taken out of the atmosphere to another part of the biosphere, but these removals are not necessarily permanent, cannot be relied on at the same scale indefinitely. Only atmospheric carbon dioxide causes the greenhouse effect. However, CO_2 stored in the oceans also causes the independent and also serious problem of ocean acidification. The land also contains a carbon sink in the form of forests and trees; this flow is however, very much reversible (from deforestation and from future climate change), and the total carbon stored here is a function both of land use patterns and of temperature. We should therefore not count a flow of carbon to forest and soils as being a permanent removal. The most important sink is the oceans, which sequester 7 Gigatonnes of CO_2 per year. This carbon dioxide is buffered by the presence of carbonate and bicarbonate ions, although the efficiency of this sink is likely to decline over time.

6 The upper oceans are in a rapid chemical equilibrium with the atmosphere. It is beyond this authors competence to know whether global warming itself is likely to cause significant out gassing from the very large natural CO2 sink in the deep oceans. Should CO_2 emissions peak and then decline (a scenario which is, to say the least, politically distant) there is a concern over the .

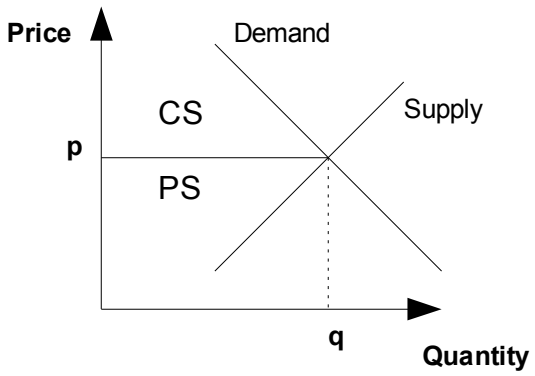
7 In this paper Stern outlines the following '*key elements of a global deal on climate change':*
1. In order to Reduce to 20 Gigatonnes by 2050 ($2TCO_2eq$ each) and then less than 10 Gt ($1tCO_2eq$ each). (This can be compared to the Kyoto baseline of 41GtCO2eq/yr and global emissions in 2005 of 45 GtCO2eq/yr.)
2. Developed countries must reduce emissions 80% by 2050. Electricity must be decarbonized

To stabilise greenhouse gas concentrations at levels which would avoid a *high* risk of *dangerous* climate change (2°Celsius) requires very rapid action. The current warming commitment (the warming that would happen if greenhouse gas concentrations were stabilized) is approximately 2°Celsius[8] above the pre-industrial level with an additional commitment of 0.4°Celsius per decade; although there is a credible risk of greater warming (IPCC 2007), (Hansen et al. 2008). In terms of economic theory, greenhouse gas emissions are a global public bad, because they create problems for human likelihood.

Fossil Fuel Scarcity

Of the three main fossil fuels, COAL is the cheapest, the most plentiful and the most environmentally damaging. Although coal prices have risen in recent years they have not gone up as much as oil and gas, and the difference between the cost of energy in the form of gas or oil and coal energy has increased. Coal is now the cheapest method for generating electricity. At current oil prices, coal could yet be used to make liquid fuels too. The return to coal threatens the credibility of any goal to stabilise greenhouse gas concentrations. Without higher carbon prices or taxes on fossil fuels and on coal in particular, the world is likely to return to coal, resulting in a more rapid increase in emissions, and the use of an energy source capable of adding 1000ppm of CO2 to the atmosphere. In short, coal gives the planet enough rope to hang itself.

Diagram (v)



Energy choices made now will have long term consequences. Coal is found to be both the cheapest fuel and the fuel with the largest climate impact; furthermore it is the most plentiful. In electricity generation in particular, the present costs will lead to a switch from gas to coal. A rush to construct new coal power stations now has significant long term consequences: it makes current and future targets much more expensive to meet.

3. 500ppvCO2e is key target
4. Reductions in greenhouse gas emissions of 80-90% by 2050 with credible interim targets.
5. Simple arithmetic implies: 'No scope for significant deviation'

8 Long-lived greenhouse gases (Kyoto gases+CFCs) have radiative forcing of of 2.6W-m2 (IPCC 2007a); or equivalent to 450ppm CO2. This corresponds to a warming commitment of 2 .1Celsius (using a best guess estimate of 3 Celsius). However, due to other air pollutants, the short term radiative forcing is 1.6Wm-2 or 1.3Celcius. The difference between this and observed 0.7Celcius warming is explained by the 'prudent' estimate of about 2.6Celsius (Climate sensitivity).

Rent!

Introduction

Scarcity rents are associated with restrictions of various types, for example:

1. a real geographical restriction associated with limited supplies of the good;
2. a cartel arrangement among the producers of a good;
3. a restriction imposed by the governments in the supply of the good.

All three of these restrictions could exist in the case of the extraction of oil:

1. governments could restrict the demand for oil;
2. there could (and is) be a geographical restriction on the supply of oil;
3. there could be (and in fact is) a cartel arrangement to restrict the supply of oil.

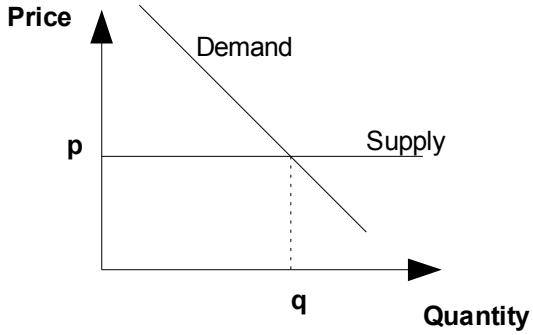
Where this profit goes, depends on how the cap on the good is enforced.

In the case of governmental restrictions on the supply of carbon dioxide emissions (case 1)

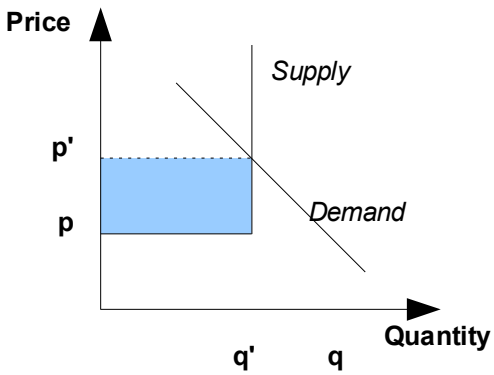
a) If the government is able to *sell* a limited number of permits to companies, the profit will go to the government.
b) If the right to produce the goods is given away (e.g. to the incumbent), the profit will go to the recipient of these rights (e.g. the incumbent companies).

Scarcity Rent for Goods Under Perfectly Competitive Supply

First consider a perfectly competitive market. A good has marginal cost *p* to produce. At any market price greater than c, there are companies willing to supply an infinite amount of that good. At a price below c, no companies will supply the good.



Suppose now we place a restriction on the supply of the good. The following diagram describes the new situation:



The price of the good has risen to p* and the quantity produced has fallen to q*. The revenue taken is now given by q'p' and this is greater than the cost of production which is q'c. The excess revenue is denoted by (p'-p)q' which is the economic rent associated with the restriction in supply.

Scarcity Rent in the General Case

Diagram (i) shows the equilibrium of supply and demand before a restriction is imposed:

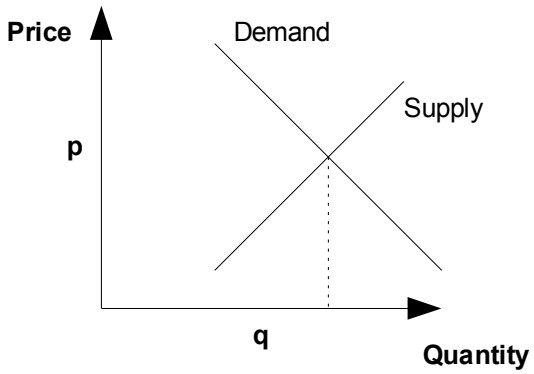


Diagram (i)

Diagram (ii) shows the reduction in quantity from q_0 to q_1 and the price of permits t required. It also shows the revenue generated by the permits, area A.

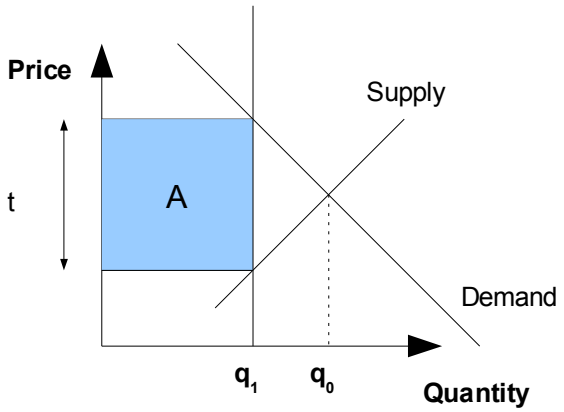


Diagram (ii)

Diagram (iii) shows the required reduction in quantity, instigated by a shift in supplier behaviour (a shift in the supply curve).

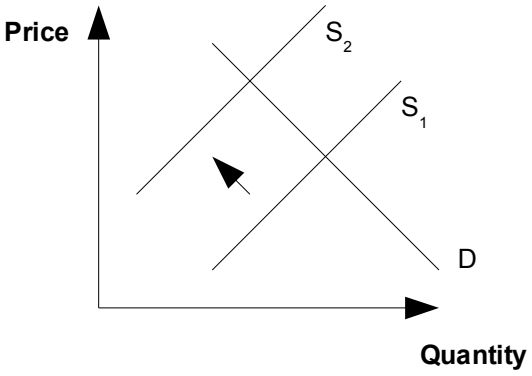


Diagram (iii)

Diagram (iv) shows the same reduction, induced by a reduction in demand from D1 to D2.

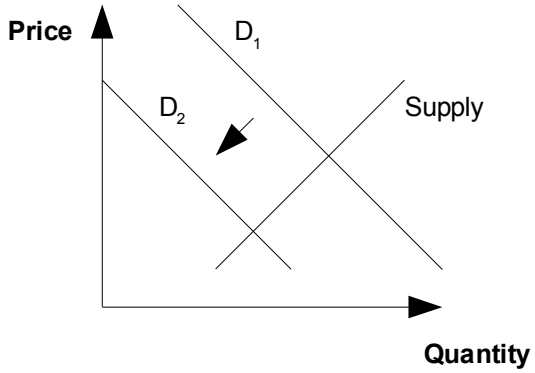


Diagram (iv)

The following diagrams describe the changes in welfare for the different participants. CS denotes the consumer surplus; PS denotes the producer surplus.

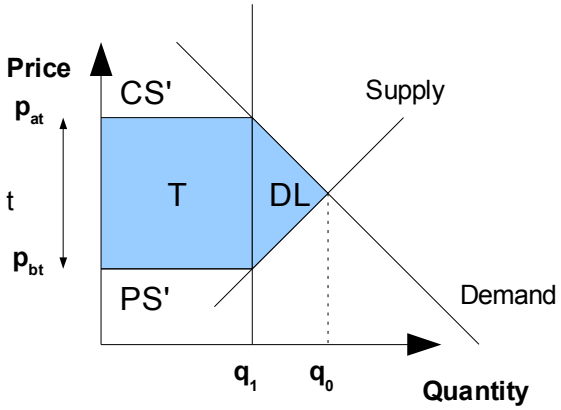


Diagram (v) describes the situation before the restrictions are put into force.

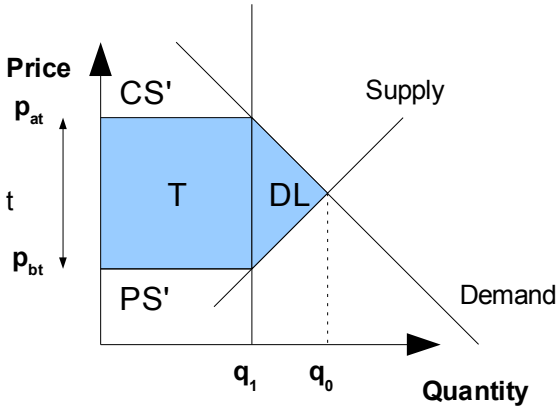


Diagram (vi)

Diagram (vi) describes the situation after the restrictions are put into force. Both consumer surplus and producer surplus are reduced. This loss in surplus takes two forms: revenue (T) and deadweight loss (DL). The scarcity rent T is appropriated either by whoever imposes the restriction: producer or the supplier, or the tax-raising power. The deadweight loss is value lost from the economy as a whole. The customer does not tend to benefit from restrictions.

Discussion

As has been demonstrated, the restriction of supply of a commodity (either by externally-imposed law, by geography or by cartel) leads to an excess profit or 'economic rent'. This rent can be claimed by producer, consumer or by tax-raising authority. There therefore exists a game as to who is to captures the rents. The players are

- On one side the oil consumers, principally the EU, Japan, China.
- On another side, the oil producers, principally OPEC and Russia.

Either side can restrict the amount produced by, in effect, adding a tax to the oil sold.

Producers and consumers are in a game. Essentially, there is a choice between different parties as to who receives the gains from trade. Carbon taxation will cause a change in the terms of trade. Economic rent (i.e. profit) that would have been captured by countries exporting energy, would instead be taken by the richer countries. For more information see Stoft (2008).

Resource Versus Environmental Constraints

Introduction

There are in general two sorts of constraints that may face us, which I will term 'hard' and 'soft'. Hard constraints are inviolable, whereas soft constraints can be exceeded, at the cost either of significant reduction in the capacity to produce the good or service, or of damage to other environmental or human systems. Either type of constraint may or may not be included in the economic decision made by agents: these constraints can be part of the economic decision, or they may be 'externalities' which are not properly priced.

'Hard constraints are that that are physically impossible to exceed - there is no choice over the matter. Examples of 'hard' constraints might include the total amount of oil remaining in a particular oil field. Resources subject only to hard constraints can be underused, but they cannot (by definition) be overused - there is simply a limited amount of them to go around.

'Soft' constraints are those that can be breached – but at some cost. For example there may be a maximum sustainable yield that is consistent with maintaining a certain stock of fish. It is possible to fish above this rate, but if one does so the total breeding stock would decline. Breaching soft constraints may cause hard constraints to become more onerous.

Externalities

The examples of constraints expressed earlier may relate to the idea of an externality. An externality or 'spillover' is an effect of an economic transaction on parties not involved in the transaction. Externalities can be positive, such as the benefits of technological advances, or negative, such as the effects of pollution. Negative externalities can be controlled in various ways, including criminalization, tort law, taxes or permits.

Note that behaviour involving hard or soft constraints may or may not entail externality; the two concepts are in principle independent and all four logical options are possible. An example of a hard constraint which *does* entail an externality is the following: if I take a space on the bus; someone else may be too late in the queue to be physically able to get on the bus. Similarly, it is possible to have a soft constraint that *does not* involve an externality: the construction time of a major piece of infrastructure usually takes a certain amount of calendar time to build; however it is possible to 'hurry up' construction by paying people overtime, and recruiting workers that are willing and able to work faster.

From an environmental perspective whether constraints are or are not exceeded may be more important than the distribution. This implies that problems of externalities involving a 'soft' constraint are different in kind and potentially much more serious than those that involve a 'hard' constraint. In the case of 'hard' constraints, it is not physically possible to exceed the constraint, so that the economic issues are 'second order'; involving the efficient and equitable distribution of resources between people and in time, and not, in general, the overall constraint. In the case of 'soft' constraints the *very constraint* is in question. There is no natural or decentralized reason why a 'soft' constraint would be respected, without central government or some other moral, social or political process to impose a constraint. Severe damage is therefore possible in regard to situations when agents act and are not constrained.

Economics of Hard Constraints

Hard constraints cannot (by definition) be exceeded. We argue that, as a general rule, any economic system deals quite well with hard constraints. In addition, a free market system will ration the constraint efficiently. We will consider whether this initial judgement is true in more detail below.

Economics of Soft Constraints

Soft constraints are less easy to deal with than hard constraints. Because soft constraints can be exceeded, it is very important that they are priced correctly. If soft constraints are not taken account of in economic pricing arrangements, then the violation of soft constraints can be extremely costly. The lack of pricing of soft constraints is therefore a particular example of the general problem of externalities; where the violation of soft constraints causes severe damage, this mispricing may be extremely significant.

A soft constraint might be the number of seats on the bus. Above this number, some passengers must travel in discomfort, with discomfort increasing significantly as capacity is reached. It is not clear what the efficient solution is in this situation: Can a free market determine whether buses should travel with standing people or not?

Where the damage cost of soft constraints is severe, it may be that the damage of exceeding the soft constraint is greater than the price needed to cut off demand. In this case, it seems that the additional price needed to ration the good is the greater of the damage cost and the cost needed to ration demand to the natural limit.

The question of the overall constraint relates only to soft constraints – and must be imposed by social processes, such as taxes or cap.

Rationing Between People and In Time

Whereas the question of the overall constraint relates only to 'soft' constraints, questions as to how limited resources constraint are rationed among people and over time relate to both hard and soft constraints.

We can imagine more than one method of rationing the *use* of resources among people.

1. by price (most goods and services in a market economy)
2. equally per capita (e.g. in wartime)
3. by merit (e.g. in applying to university)
4. by queue (e.g. when waiting for bus)
5. by whoever is stronger - 'rule of the jungle'

Economists tend to argue that rationing by price is the most *efficient* measure; however, other considerations may entail a different rationing scheme. For example, the rationing of scarce resources entails important consequences as regards distribution of income..

In the case of rationing by price, the additional price needed to bring demand below supply (the *rent*) constitutes a permanent additional charge over and above the costs of production. Given that rationing takes place by price, there remains the question as to who will charge the additional rent needed to keep supply below the fixed constraint. Those who charge the rent, get to keep it. Therefore, the way that the rents are distributed from the limited amount of hard constraints is an important question.

Price rationing can take place by the owner of the resource or service (the seller), by the *buyer* of the resource, or by an intermediary such as the government. If buyers ration their behaviour then they can reduce the price paid for the scarce item. In effect, the scarcity rent required is taken by the

buyers. Otherwise, the goods will be rationed by the *sellers, who will take the profit.* A third option, proposed by, among others, Confucius and Henry George, is for the government to impose a tax, so rationing demand.

The 'default' position, in the absence of specific interventions, is for the sellers or owners of the resources to impose the rent. These rents can be very significant; they are a permanent 'supernormal' profit. The economics of poor but resource-rich countries is often dominated by so-called 'rent seeking behaviour', which can lead to conflict: a situation known as the 'resource curse'.

The inter-temporal rationing of resource-use is also an important question. If a non-renewable resource is extracted too fast, it may not leave enough for future generations. If there are agents that have long time perspectives and can store the resource, then it's likely that the outcome will not be a major economic failure. Because of its scarcity value, those who invest in the resource could make money by speculating on future price rises. Therefore we expect that inter temporal rationing should be taken care of by the market; but the distribution of rents is an important question that needs careful consideration.

Conclusion

Constraints in environmental and resource economic problems are generally of two types

1) a physical limit on something (e.g. resources) that it is physically impossible to exceed or
2) environmental limits that we can cross but at the cost of severe damage.

Economic issues in relation to physical limits are a matter of *distribution (*of resources between individuals at a particular time, and *between* generations). A free-market economic system works to allocate scarce resources amongst competing needs – even across generations; but the distribution between agents may still be a matter of concern. In regard to environmental limits, humanity must limit itself: a free market system will cross economic limits unless some constraint (such as a tax or cap) is imposed. In regard to the satiation of human needs through limited *resources*, there is little prospect of a Malthusian crisis, famine is more likely to be caused by the distribution of resources, than by a lack of food. In regard to *environmental* problems by contrast, however, the limitation on our behaviour is not enforced by nature – society must enforce the constraints itself, or face irreversible damage.

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