THE EFFICIENCY, EQUITY AND POLITICS OF EMISSIONS PERMIT TRADING

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The efficiency, equity and politics of emissions permit trading[1]

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ABSTRACT: This paper illustrates that an international permit trading system may hurt relatively poor countries by making associated economic activities unaffordable. A model is constructed in which the free market solution is Pareto inefficient as a result of pollution. The introduction of tradable permits allows pollution to be internalised, and brings about an increase in the total social surplus. But when incomes vary, this may not lead to a Pareto improvement; those in poor countries stop the polluting activity because they cannot afford to do otherwise. Only those in relatively rich countries are made better off. This may explain why poor countries are reluctant to ratify the Kyoto Protocol, itself advocating a permit trading scheme. The politico-economic implications of permit trading are also examined. We show that the democratic requirements for ratification impose a lower bound on pollution reduction that can be achieved through a system of pollution permits with trade.

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1 Introduction

The Kyoto Protocol, negotiated in 1997, represents international efforts to reach agreement on a policy regime that will reduce and ultimately reverse global warming. Yet the Sixth Conference of the Parties to the United Nations Framework Convention on Climate Change (COP6) failed in its stated objective of moving The Parties towards ratification of the Protocol in their domestic legislatures[4].

The purpose of this chapter is to understand one particular aspect of current resistance to ratification of the Kyoto Protocol. We focus on objections by developing countries, whose concerns appear misplaced when set against predictions that they stand to gain under implementation of the Kyoto Protocol. According to studies using large scale economic models cited by the Organisation of Economic Co-operation and Development (OECD 2000) the flow of "green" funds to the developing world is projected to be between US$5bn and US$17bn by 2010. However, we present a simple analytical framework and examples in which less wealthy countries may be made worse off under the sort of regime being proposed.

As it stands, the way that developing countries would be involved with the regime set out in the Kyoto Protocol is through the Clean Development Mechanism (CDM). Under this system, it is envisaged that firms from developed countries would be able to build plants that embody more environmentally friendly technology than was used at the time in the developing country, and thereby earn 'carbon credits' that could be offset against emissions at home. There are no emissions restrictions currently imposed on developing countries. At face value, it is difficult to see how a developing country could be harmed under such a scheme, particularly as it can always reject a proposed deal under the CDM. (Further details on this, and other background information on the Kyoto Protocol, can be found in Moomaw *et al* 1999).

Arguably, concern amongst developing countries really lies with anticipated developments under the Kyoto Protocol, particularly with proposed caps on future emissions levels. Al-

[4]COP6 was held in the Hague during November 2000 and at the time of writing is the most recent.

ready, a number of developed countries are refusing to ratify the regime until developing countries are made subject to emissions targets, even if these are above current emissions levels. In recognition of this, we model a scheme that limits pollution by introducing a permit requirement applied across all countries, and analyse the efficiency and equity implications of the scheme. Income varies across countries, with those at the bottom end of the distribution representing 'The South' and those at top referred to as 'The North'. We are able to show that while the scheme might increase total social surplus by reducing pollution, not all countries across the income distribution benefit. These results are established against a backdrop of trade between the two regions.

The model draws on earlier work by Kaneko and Wooders (1994) and is based on car use by a continuum of (infinitely small) consumers, and the resulting exhaust emissions. This may seem a little incongruous, given that emissions permits are usually discussed in the context of limiting pollution by large producers, who emit tons per year of greenhouse gases such as CO_2 as a by-product of industrial processes. In fact, the story of car use is told as a parable for the interaction between market equilibrium in the global economic activity that generates CO_2 emissions and the externalities resulting from CO_2 emissions themselves. However, in taking this approach two issues must be addressed, one being whether the appropriate focus can be on consumption rather than production, the other being whether it is appropriate to assume that agents are small[5].

On the first point, consumption is modelled rather than production deliberately to emphasise that the abatement decision depends ultimately on consumer preferences and the individual's budget constraint. Consumer preferences reflect the balance between the benefit of consumption, in this case private car use, and the disutility from pollution. This would continue to be the case if pollution resulted from production rather than consumption. The

[5]It is also worth noting that car use itself is estimated to contribute about 15 percent of overall global CO_2 emissions to the earth's atmosphere (WRI 1994, 1999). And while car ownership has probably reached saturation point in the US (at least in terms of the numbers of cars per person), at 750 cars per 1000 polulation, markets in India and China are far from saturated, at 7 or 8 per 1000. Therefore, in the future, policies to control car use may be a very important part of a global strategy to control car use, and a permit trading scheme may be one way of achieving this result. But this is not the central focus of the present paper.

consumer budget constraint accounts for the increased cost of driving when permits must be purchased in addition to a car. If the permit cost were borne by the producer, who then passed this on to consumers through the price mechanism, the effect would essentially be the same but less clearly visible. On the second question of whether agents may appropriately be modelled as small, this is consistent with the assumption of a widespread externality. That is, each individual consumer's impact on the total stock of pollution is insignificant and thus the consumer does not take account of the effects of his own actions on levels of pollution.

Turning to supply considerations, previous research by Hahn (1984) and by Borenstein (1988) has identified efficiency losses that arise when a new market for tradable permits is created. This inefficiency is driven by incentives of strategic interaction between firms. Hahn (1984) derives inefficiencies from the fact that firms' private profits are not necessarily equal to the surplus that they generate, motivating too much or too little entry, leading to the inefficient use of pollution permits. Borenstein (1988) analyses the ability of a monopolist to manipulate the price of permits to its own advantage. By assuming that firms behave competitively, we deliberately suppress such strategic issues, distinguishing the nature of the inefficiencies that we highlight from those identified in the earlier literature. It should be noted, however, that while we make the assumption of price-taking behaviour by firms, we could obtain analogous results with strategic behaviour. Introducing strategic behavior would merely complicate the analysis and make it more difficult to untangle the sources of deviations from efficiency.

Of course, the modelling of agents as small does not necessarily suppress all strategic interaction, as a finite number of (small) agents could in principle form a coalition. However, the competitive equilibrium that we demonstrate is equivalent to the f-core (the set of feasible states of the economy that cannot be improved upon by any coalition containing only a finite number of economic actors) which, in the presence of widespread externalities, may not be Pareto-optimal. Our approach allows us to highlight the problems of widespread externalities[6].

[6] See, for example, Hammond, Kaneko and Wooders (1989), Kaneko and Wooders (1989), and Hammond

As a final remark on the set-up of the model, it must be made clear that our analysis assumes lump-sum redistributions to be impossible or simply not made. There appears to be support for this assumption in the literature on international policy making (see, for example, Bagwell and Staiger 1999 and Dixit and Norman 1980 page 192), reflecting recognition that in practice international redistributions are not large enough to increase Pareto efficiency significantly. In research in progress we show that in fact when pollution permits are introduced it is not always possible for the gainers to compensate the loosers.

How does the introduction of the permit trading scheme make the South worse off? In our model, the intuition is simple and stark. When incomes vary across countries, in equilibrium it is the poor South that abates car use for the simple reason that it cannot afford both the cars and the permits required under the regime to be allowed to drive them. The North benefits from lower overall car use while being able to go on using cars as before. Perhaps the application to production has even greater resonance. Set up in these terms of production, our model would say that the South could not afford to build plant and purchase the pollution permits required to produce. In actual fact, this appears to represent the South's greatest anxiety over the Kyoto Protocol.

How can the CDM be thought of in the context of a permit trading system? The carbon credits earned by a Northern firm that builds a plant in the South can essentially be thought of as pollution permits in the context of a permit trading scheme. Under one version of the system currently being proposed, pollution permits are bundled with plant in the South and cannot be separated. We adopt the much more straightforward assumption that permits are assets that exist in their own right and can be traded internationally. This is the system currently being advocated by the "umbrella group" of countries, which includes the US, Canada, Japan and Australia, but it is not at present clear whether it will actually be adopted. But even if not, our framework could be adapted to consider 'bundling' under the CDM as well.

The implications of permit trade in the context of international trade have also been

(1999).

studied by Copeland and Taylor (1995, 2000). The first of their papers studies the endogenous allocation of pollution permits by governments as a strategic variable. Therefore, the total emissions allowed are not the result of an international agreement of the kind envisaged under the Kyoto Protocol, but the outcome of individual government's decisions. Copeland and Taylor abstract from the usual equity issues that arise in the Heckscher-Ohlin type framework on which their model is based by assuming that a single representative individual in each country holds all the resources. The second of these papers focuses on aspects of the Kyoto Protocol, and does highlight income effects from permit trading, but these are driven by price effects resulting from the opening of international trade, and therefore are different from the income effects that we focus on. Our model deliberately suppresses terms of trade effects due to trade in goods, and highlights instead income effects that arise from variation in the underlying income distribution[7].

The paper proceeds as follows. In the next section, the basic model is set up. A free market equilibrium, in which there are no policy interventions, is demonstrated to be Pareto inefficient. This outcome is then used as a benchmark against which to measure the impact of a permit trading regime. In Section 4, we analyse a scheme whereby individuals are endowed with permits, but additional permits are required in order to drive a car. It is here that we demonstrate how, because it results in all rationing of car use being undertaken by them, poor countries are harmed by the introduction of such a policy. In this section, however, we also show that variation in permit allocation can redress the income imbalance. Giving more permits to the South than to the North tends to reverse this outcome, but means that only the relatively rich in each region are able to drive.

In Section 5 politico-economic considerations are introduced. Political effects arise because different income groups are affected differently by pollution permit allocation and trade. We show that a minimum permit allocation, implying a minimum level of pollution,

[7] Proposition 7 of Copeland and Taylor (2000) states that when no terms of trade effects arise by goods trade then permit trade can have no adverse (Pareto) efficiency implications in their model. It is precisely under these circumstances that we show adverse efficiency implications can in fact occur when income varies across countries.

is required in each region for the scheme to receive democratic support. The key implication is that some environmental targets may be too demanding, in other words require too large a reduction in pollution, to receive democratic support. This may apply, for example, to the prediction that a 60% reduction in greenhouse gas emissions is necessary for a halt to global warming (Hadley Centre 2000)[8]. Section 6 concludes by relating this work to complementary research that we are undertaking on the general efficiency implications of permit trade in the presence of income variation and a widespread externality (Wooders and Zissimos 2001).

2 The basic model

2.1 Car production, trade, emissions and welfare

The world is divided into two regions, North and South. Suppose that every point on the (semi-open) unit interval represents a country. To define the regional dimension, let $0 < b < 1$ and suppose that those points on the interval $[0, b)$ represent the South, with the North constituted by the interval $[b, 1)$. The welfare effects of pollution are felt entirely through the use of cars. The utility function of consumer i (the representative consumer in country $i \in [0, 1)$) is given by

$$u_i(z_i, m_i, \pi) = m_i + \frac{\alpha z_i^{\frac{\alpha-1}{\alpha}}}{\alpha - 1} - \kappa\pi$$

where α is a parameter greater than one, m_i is a perfectly divisible composite good that we can think of as money, and z_i is the consumption level of cars. We have chosen this particular utility function since it is monotonic increasing in money and cars and, in equilibrium, consumers who purchase cars will each purchase one unit; in ongoing research this allows

[8] The politico-economic implications of permit trading have also been studied by Howe (1994) and Farrow (1995). However, these earlier contributions focus on the political feasibility of different policies - tax versus permit trading - and means of permit allocation - auctions as against grandfathering (allocation in proportion with past emissions), given an environmental target. Our focus is different, holding the regime constant and examining a range of targets, showing some of them to be politically infeasible.

us to consider the effects of variable car use and to compare the results with those of this paper. The pollution level is given by $\pi = \int_{[0,1)} z_i \, d\mu$, where μ is Lebesgue measure and κ is a parameter.

The budget constraint for individual i is given by

$$m_i + pz_i = Y_i,$$

where p is the consumer price of a car and Y_i is i's income. The budget constraint can be used to substitute for m_i in the utility function. Solving for car demand, we assume that the externality is widespread, so that consumers do not take it into account in their consumption decisions. Differentiating with respect to z_i;

$$\frac{\partial u_i}{\partial z_i} = z_i^{-\frac{1}{\alpha}} - p.$$

Setting the first order condition equal to zero and solving for car demand by an individual, we have

$$z_i = p^{-\alpha}.$$

As the car price rises, demand falls, an effect that is modulated by α.

The production technology for cars is assumed to be subject to constant returns, with free entry, at a per-unit cost of $c = 1$. Therefore, the location of car production and trade is not important in this model, neither from the perspective of terms-of-trade effects nor in terms of the pollution externality[9].

In this analysis we model the decision of whether or not to purchase a car. A car is assumed to be indivisible; it is not possible to buy a fraction of a car. In Section 3 and

[9] Production is not modelled explicitly; this paper presents a partial equilibrium analysis. Production could be introduced, however, and the spirit of the conclusions of our results would continue to hold.

sub-section 4.1 this assumption is of no consequence at equilibrium since consumers only demand cars in single units at equilibrium. This assumption becomes important in sub-section 4.2, where income varies across individuals. Any relatively poor individual unable to afford a car is assumed to be unable to purchase part of a car (say by leasing or hiring). This might seem like a bold assumption, but in practice there is always some level at which purchasing a car, or the services provided by a car, cannot be divided further. Car rental for a limited period may be feasible, and desirable given that the marginal utility of consumption is very high for small quantities, even if car purchase is beyond the budget constraint. But at some level even car services through rental are indivisible; a car cannot be rented for less than a day. And in the real world there are some individuals for whom a day's car hire is unaffordable. It is in order to highlight the equity issues that arise in this type of situation that our assumption regarding the indivisibility of car purchases is made. A drawback to the assumption of indivisibility of cars is that the widespread externality is associated with the number of cars on the road, rather than how much each one is used. In mitigation it could be assumed that all individuals use their cars the same amount, or that we are concerned with average damage per car. Either of these approaches require the additional simplifying (and reasonable) assumption that per-capita car use does not increase as the level of car ownership falls. In related analysis of permit trading (Wooders and Zissimos 2001) we lift this assumption, analysing perfect divisibility of car services.

3 A free international market for cars

The purpose of this section is to show the Pareto inefficiency of the free market solution when the impact of the widespread externality on welfare is large and negative. This motivates the introduction of tradable permits in subsequent sections.

We assume $Y_i > 1$ for all i. (Thus, there are assumed to be no regional systematic or significant differences in income.) This assumption ensures that all markets clear and trade is balanced in equilibrium. In the absence of intervention, a competitive equilibrium in this economy is

$$
\begin{aligned}
p &= 1 \\
z_i^* &= p^{-\alpha} = 1 \text{ for all } i \in [0,1).
\end{aligned}
$$

This just says that when no individual is constrained by income in their choices of z[10], then each individual will choose to buy one car at the competitive price. Given perfect competition in production, sufficient quantities of cars are produced to meet world demand at a price $p = 1$.The utility of the competitive outcome for consumer i is

$$
\begin{aligned}
u_i(z_i, m_i, \pi) &= Y_i + \frac{\alpha z_i^{\frac{\alpha-1}{\alpha}}}{\alpha - 1} - z_i^* p - \kappa \int_{[0,1)} z_i \; d\mu \\
&= Y_i + \frac{1}{\alpha - 1}\left(\frac{1}{p}\right)^{\alpha-1} - \kappa \int_{[0,1)} \left(\frac{1}{p}\right)^{\alpha} d\mu,
\end{aligned}
$$

and, setting $p = 1$,

$$
\begin{aligned}
u_i(z_i, m_i, \pi) &= Y_i + \frac{\alpha z_i^{\frac{\alpha-1}{\alpha}}}{\alpha - 1} - z_i^* - \kappa \int_{[0,1)} z_i \; d\mu \\
&= Y_i + \frac{1}{\alpha - 1} - \kappa \int_{[0,1)} d\mu,
\end{aligned}
$$

For $\kappa > 1$ the average damage from pollution is greater than the average benefit. This can be seen more clearly by setting $\alpha = 2$. In the competitive outcome, utility enjoyed by consumer i is

$$
u_i^*(z_i, m_i, \pi) = Y_i + 1 - \kappa
$$

Given the competitive outcome, any reduction in demand would raise welfare. However, the consumers in each country are too small to have a significant impact on pollution. For the remainder of this paper we continue to assume $\kappa > 1$.

[10] We follow Jane Austen in our use of the plural to avoid the use of “he” or “she”.

4 'Giving up the car' with tradable permits

Those who want to portray environmental regulation in its starkest terms often talk in terms of being forced to 'give up the car'. In this section we look at a scheme where pollution is reduced because a proportion of individuals choose to give up their cars voluntarily through the introduction of a tradable permit scheme; that is, a proportion of individuals are indifferent between having to purchase permits and a car on the one hand and selling the permits allocated to them by the scheme on the other. We show an equilibrium in which welfare for each individual, whether they choose to have a car or not, is higher under the scheme than under the free market outcome of the previous section.

Suppose that an international agreement is reached whereby the representative consumer in each country is endowed with 2 permits, but required to have 4 permits in order to purchase a car. International trade in permits is allowed, making it possible to obtain 4 tickets if desired. It is immediately evident that the permit regime is set up so that car use is reduced by a half. That is, instead of the entire world's population owning and using a car, only half does so. This is admittedly a very simple scheme, and in practice, the allocation of permits is likely to much more complex and contentious. But two purposes are served in taking this approach. First, whilst the regional distribution of permit allocations will be varied in the analysis of this section and the next, the restrictiveness of the regime in reducing car use by a half is held constant, helping to highlight the differences between the regimes. Second, denoting by C the set of car users, the analysis is simplified because we know *a priori* that $\pi = \int_{i \in C} z_i = \frac{1}{2}$.

4.1 Efficiency considerations

Suppose that individuals in all countries have income $Y_i > 2$. This is sufficient for a new equilibrium to be attained under the tradable permit scheme where all consumers are indifferent between having the income from the sale of permits and having the use of a car.

Utility when an individual uses a car is given by

$$u_i = Y_i + \frac{1}{\alpha - 1}\left(\frac{1}{p}\right)^{\alpha-1} - 2t - \kappa \int_{i \in C} \left(\frac{1}{p}\right)^{\alpha} d\mu$$

where t is the price of a permit. The second term reflects the utility from car use, and the third shows disutility from having to purchase two permits. When a car is not bought, utility is given by

$$u_i = Y_i + 2t - \kappa \int_{i \in C} \left(\frac{1}{p}\right)^{\alpha} d\mu,$$

where utility is derived from sale of the permit endowment. At an equilibrium permit price, every consumer is indifferent between using a car and buying 2 permits on one hand and selling 2 permits on the other. Equating utility levels for purchasers and nonpurchasers of cars, we have

$$\frac{1}{\alpha - 1}\left(\frac{1}{p}\right)^{\alpha} - 2t = 2t.$$

The competitive supply price of a car is the same as before; $p = p_c = 1$. Therefore,

$$t^* = \frac{1}{4(\alpha - 1)}$$

For t^* to clear the permit market, half of all consumers must sell their permits and forgo the right to drive a car. This reduces car usage to half the level under the free-market outcome of Section 3. The level of welfare can be compared across regimes. Imposing the same parameter values as in the previous section, that is $\alpha = 2$ and $\kappa > 1$, we have

$$u^{**} = Y_i + \frac{(1-\kappa)}{2} > Y_i + 1 - \kappa = u^* \text{ for all } i \text{ in } [0, 1),$$

with $t^* = \frac{1}{4}$. This shows that welfare for each individual is higher under the controlled market solution, for those in North and South alike. A Pareto-improvement requires that no individual be reallocated any positive amount of the right to drive a car.

For reduction of car use to be welfare improving from the free market solution, each consumer in every country must have enough income so that in equilibrium the consumer is indifferent between purchasing the permits required to drive a car and selling their endowment of permits. If this is not the case, the outcome may change significantly, bringing about important redistributional repercussions.

Note that the present example is constructed around $\alpha = 2$. When $\alpha < 2$, we require a larger value of κ to make reduction of car use welfare improving in equilibrium. For example, when $\alpha = \frac{3}{2}$, we must have $\kappa > 2$ for reduction by a half to be Pareto superior to the free market outcome. Symmetrically, for $\alpha > 2$, reduction of car use by a half can increase welfare for $\kappa < 1$. One way to proceed would be to investigate fully the relationship between parameters and the ranking of outcomes under the respective regimes. However, our purpose here is rather to indicate the possibility that, for some values of α, a given reduction in car use brings about a Pareto improvement. We then demonstrate that when the income distribution varies across individuals this result can break down. This we now do, basing our example on the value $\alpha = 2$.

4.2 Equity considerations

To illustrate possible equity implications of introducing a market for tradable permits, we now modify the model so that countries in the South are poor relative to those in the North.

Let the income distribution Y_i be given by

$$Y(i) = 1 + \frac{\gamma}{(1-i)} \text{ for all } i \text{ in } [0,1), \tag{1}$$

where $\gamma < \frac{1}{8}$. The poorest country is at $i = 0$. Incomes increase with i at an increasing rate[11]. The dividing line between North and South - the equator - is placed at $b = \frac{1}{2}$, so that half of the world's population resides in the North and half in the South. All countries in the South are poorer than those in the North (see Figure 1).

Once again, we have an equilibrium where half of the consumers buy two permits and a car, with the rest selling their permits. But now, it is those in the relatively poor South, where income is given by (1) and i is in the interval $[0, b)$ that sell their 2 permits and those in the North (the interval $[b, 1)$) that buy the permits and use a car (see Figure 2). The marginal consumer $i = \frac{1}{2}$ uses all his endowment to buy a car and two permits at $p = 1$; $z_i = p^{-\alpha} = 1$. He pays $\frac{\gamma}{(1-i)} = 2\gamma$ for two permits; $t^* = \gamma$. Now consider a consumer to the left of $i = \frac{1}{2}$ on the interval $[0, 1)$. If he buys two permits at price $t^* = \gamma$ each, he will not be able to afford to buy a car ($z_i = 1$) at $p = 1$.

Under this outcome, assuming $\alpha = 2$ and $1 < \kappa < \frac{3}{2}$, we have[12]:

$$\begin{aligned} u_i^{**} &= Y_i + 2\gamma - \frac{\kappa}{2} < Y_i + 1 - \kappa = u_i^* \text{ for all } i \text{ in } [0, b), \\ u_i^{**} &= Y_i + 1 - 2\gamma - \frac{\kappa}{2} > Y_i + 1 - \kappa = u_i^* \text{ for all } i \text{ in } [b, 1). \end{aligned}$$

Thus, the utility level u_i^{**} for consumers in the North $[b, 1)$ is higher than u_i^* in the original competitive equilibrium without traded permits, but for those in the South welfare is actually lower. Notice that the smaller is γ, the lower is the compensation that those in the South receive for their permits, and the lower is their welfare in equilibrium. In summary, those in the rich North are still able to use cars under the controlled market, while also benefiting from the fact that overall car use has been reduced. It is those in the South that are excluded from car use all together.

[11] The functional form of the world income distribution given by (1) guarantees an interior solution. It also implies that the richest countries have an infinite income. The analysis still goes through for a finite cap on income levels, providing that, given parameter values, the cap is high enough for an interior solution. We thank an anonymous referee for drawing our attention to this point.

[12] Strictly speaking, for these inequalities to hold, we require only that $\frac{1}{2} < \kappa < \frac{3}{2}$. However, we continue to assume that $\kappa > 1$, thus ensuring that the controlled market solution increases total social surplus.

4.3 A larger Southern permit allocation

A natural question arises over what happens when the South is given a larger permit allocation relative to the North. We find that this does indeed improve the welfare of the relatively rich consumers in the South, enabling them to drive a car. This occurs at the expense of welfare of relatively poor consumers in the North, who cannot afford permits.

To illustrate this, suppose that each country in the South is given 39 permits, with 40 being required to drive a car, while each Northern country is given just 1 permit. Set the dividing line between North and South at $b = \frac{1}{2}$ as before, so that the country at $i = \frac{1}{2}$ is the poorest country in the North.

In the previous example, the poorest consumer in the North was the marginal consumer. With the current parameter values, we shall see that $i = \frac{1}{2}$ cannot afford to own a car in equilibrium. To see this, suppose that $i = \frac{1}{2}$ is the marginal consumer. Then consumer i must use his entire endowment to purchase a car and 39 permits; thus, $\gamma/(1 - \frac{1}{2}) = 2\gamma$ must be the total cost of 39 permits. Therefore, $t = 2\gamma/39$. But the richest consumer in the South has to purchase only a single permit at this price, and this is affordable. Thus, all Northern consumers and at least one Southern consumer purchase permits at this price, which implies that there must be excess demand for permits. Therefore, $t = 2\gamma/39$ cannot be a market clearing price. This price must rise to clear the permit market, which would mean that $i = \frac{1}{2}$ cannot afford the 39 permits required, and will not be able to own a car under the new equilibrium. It also suggests that some Southern consumers will be able to afford the single permit required to have a car.

To make this precise, first work out the market clearing condition for permit demand. Let b_1 and b_2 be the measure of Southern and Northern consumers respectively who buy permits. If the intention behind the tradable permit scheme is to reduce car use by a half, then set

$$b_1 + b_2 = \frac{1}{2}.$$

b_1 is given by the distance from the point $b = \frac{1}{2}$ to the marginal Southern consumer i_S; $b_1 = \left(\frac{1}{2} - i_S\right)$. In the same way, b_2 is the distance from the supremum at 1 to the marginal Northern consumer i_N; $b_2 = (1 - i_N)$. See Figure 3 for an illustration. Using these in the above identity,

$$i_S + i_N = 1.$$

The marginal Southern consumer uses their entire endowment to purchase a car and a single ticket, while the marginal Northern consumer has to purchase a car and 39 tickets. Thus

$$\frac{\gamma}{1 - i_S} = t \text{ and} \frac{\gamma}{1 - i_N} = 39t$$

From these two preceding equations, we can solve for the equilibrium ticket price and marginal Southern and Northern consumers;

$$\begin{aligned} t^* &= \frac{40\gamma}{39}, \\ i_S &= \frac{1}{40}, \\ i_N &= \frac{39}{40}, \end{aligned}$$

from which $b_1 = \frac{19}{40}$ and $b_2 = \frac{1}{40}$. This tells us that all but the very poorest in the South are able to buy a car and a permit, while all but the very richest are excluded from using cars in the North. Suppose $1 < \kappa < \frac{3}{2}$ as before, but now let $\gamma < \frac{1}{160}$. Thus, as in the previous example, γ is small relative to κ. Then the following ranking on outcomes can be established, given that $\alpha = 2$:

$$\begin{aligned}
u_i^{**} &= Y_i + 40\gamma - \frac{\kappa}{2} < Y_i + 1 - \kappa = u_i^* \text{ for all } i \text{ in } [0, b_1), \\
u_i^{**} &= Y_i + 1 - \frac{40\gamma}{39} - \frac{\kappa}{2} > Y_i + 1 - \kappa = u_i^* \text{ for all } i \text{ in } [b_1, \frac{1}{2}), \\
u_i^{**} &= Y_i + \frac{40}{39}\gamma - \frac{\kappa}{2} < Y_i + 1 - \kappa = u_i^* \text{ for all } i \text{ in } [\frac{1}{2}, b_2), \\
u_i^{**} &= Y_i + 1 - 40\gamma - \frac{\kappa}{2} > Y_i + 1 - \kappa = u_i^* \text{ for all } i \text{ in } [b_2, 1).
\end{aligned}$$

That is, those from both regions who are excluded from driving cars are worse off than under the free market solution, while those from both regions who are able to buy cars and benefit from reduced pollution are made better off under the permit system.

5 Politico-economic implications of permits

One of the key implications of our analysis is that the allocation of permits across regions is likely to determine the political support for the scheme as a whole. The permit allocation of the previous section would have been very popular in the South, and if held to a referendum would almost certainly have been supported by a democratic majority. In the North, by sharp contrast, where only the very richest could afford to purchase the permits required to drive a car, the scheme would be very unlikely to receive a democratic mandate.

We can use the model to set up a framework for thinking about the political constraints on the adoption of permit trading schemes for the solution of environmental problems. The approach that we will take is to assume that the representative citizen in a country supports the scheme if it benefits them, and votes against if it does not. This is admittedly a simplistic assumption. It may not always be appropriate to think of national support being given to an environmental regime simply on the basis of whether it is in direct national interest. For example, at COP6 countries such as Sweden rejected the US proposal to include forests as carbon sinks as part of the regime, even though it was in their direct national interest to do so because, accounting for their own sizable domestic forests they would be able to increase emissions, rather than reduce them as under currently binding requirements (see Houlder 2000). The reason given was said to be that this proposal risked undermining efforts to achieve global carbon emissions reductions, suggesting that pure short-run national interest is not always the right way to evaluate support for schemes to improve the environment. This objection notwithstanding, we will use exactly this criteria as a relatively simple way to show how political constraints can restrict the set of environmental economic regimes that are viable, leaving more complex political considerations for future work.

Suppose that in order to be introduced the permit trading scheme must receive popular democratic support from both regions. Let each region vote as a whole on whether the permit trading scheme should be introduced. Furthermore, suppose that a majority of fifty percent is required within each region for overall regional support to be declared. We seek a permit allocation in North and South that will bring this about. Continue to assume that the intension behind the tradable permit scheme is to reduce car use by a half; then as before we have $b_1 + b_2 = \frac{1}{2}$. But now for democratic support within the South we require $b_1 = \left(\frac{1}{2} - i_S\right) \geq \frac{1}{2}b = \frac{1}{4}$; the equivalent democratic constraint in the North is $b_2 = (1 - i_N) \geq \frac{1}{2}b = \frac{1}{4}$.

The unique equilibrium solution to this problem is given by the following

$$\begin{gathered}\text{30 tickets allocated to each } i \text{ in } [0, b),\\ \text{10 tickets allocated to each } i \text{ in } [b, 1),\end{gathered}$$

$$t^* = \frac{4\gamma}{30}.$$

The marginal Southern consumer uses their entire endowment on the purchase of a car and 10 tickets, while the marginal Northern consumer has to purchase 30 tickets. Thus

$$\begin{aligned} i_S &= \frac{1}{4} \\ i_N &= \frac{3}{4} \end{aligned}$$

giving $b_1 = b_2 = \frac{1}{4}$. Half of those in each region buy a car. We now need to verify that the half of the population in each region who buy a car are indeed better off than in the absence of the scheme, and can therefore be expected to give it their support. Imposing the same restrictions as before on parameter values ($1 < \kappa < 3/2$ and $\gamma < 1/160$) the following ranking on outcomes can be established:

$$\begin{aligned}
u_i^{**} &= Y_i + 4\gamma - \frac{\kappa}{2} < Y_i + 1 - \kappa = u_i^* \text{ for all } i \text{ in } [0, b_1), \\
u_i^{**} &= Y_i + 1 - \frac{4\gamma}{3} - \frac{\kappa}{2} > Y_i + 1 - \kappa = u_i^* \text{ for all } i \text{ in } [b_1, \frac{1}{2}), \\
u_i^{**} &= Y_i + \frac{4\gamma}{3} - \frac{\kappa}{2} < Y_i + 1 - \kappa = u_i^* \text{ for all } i \text{ in } [\frac{1}{2}, b_2), \\
u_i^{**} &= Y_i + 1 - 4\gamma - \frac{\kappa}{2} > Y_i + 1 - \kappa = u_i^* \text{ for all } i \text{ in } [b_2, 1).
\end{aligned}$$

This ranking shows that the half of the population in each region that buy a car are better off than without the scheme, and are therefore assumed to vote for it. This is sufficient to give it an overall democratic mandate.

An important point to note is that democratic support could not be obtained for a reduction in car use greater than 50 percent, even if this were deemed necessary, say by some objective scientific criterion. For example the Henley Centre (2000) have estimated that even with green house gas emission cuts of 60 percent over the next decade, the rise in the Earth's temperature will not be halted, but may be restricted to 2C by 2100. Suppose, purely for the purposes of illustration, that a 1 percent reduction in car ownership were associated with a 1 percent reduction in greenhouse gas emissions. The results of our model suggest that the reductions called for may in fact be politically infeasible under the regime being advocated in the Kyoto Protocol.

6 Conclusions

This chapter has taken as its main motivation developing country concerns over the Kyoto Protocol. It has rationalised these in the form of a simple theoretical model which shows how, under one particular configuration of the scheme, poorer countries are made worse off under a market controlled by pollution permit trade than they would be otherwise.

To do this, we first show how unregulated car use, which creates a widespread externality, leads to a Pareto inefficient outcome. We then demonstrate how pollution can be internalised through the introduction of a tradeable emissions permit system. This regime leads to a reduction in the pollution level, and therefore an increase in social surplus. But when income is unevenly distributed, this may not bring about a Pareto improvement. The permit requirement effectively makes a car purchase more expensive. When permits are allocated (equitably) across all countries but income varies so that those in the North are richer than in the South, only countries in the South reduce car use. They are forced to do so, because they cannot afford a car and the necessary permits. As a result, Southerners are made worse off by the scheme, while those in the North benefit, both by reduced world car use and by continuing to use cars themselves. If the South is given more permits than the North, then it is the relatively rich within each region that gain, but the relatively poor in each region that lose through the rationing of their car use.

This framework was used to examine the politico-economic requirements for a permit trading scheme to be introduced. If each individual equates being made better off by the scheme with giving it their democratic support, then the scheme will not be supported if it requires more than 50% of people in each region to give up their right to drive a car. This result may have sobering ramifications. It suggests that certain environmental targets, even if they are sanctioned scientifically, may fail to get political support. Suppose, for example, that we were told car use must fall by 60% in order to halt global warming. According to the predictions of our model, such a reduction could not be achieved by the type of tradable permit scheme that we analyse here.

What does this analysis imply for the future of permit trading under the Kyoto Protocol? In reducing overall pollution, the scheme has some merit. But our analysis shows that without careful attention to the design of the system it may have significant pitfalls for poorer countries as well. Recall that a key assumption was that cars could only be purchased as discrete units, and the permit trading system is associated with the purchase of cars. Results presented in a related paper, Wooders and Zissimos (2001), show that when car services are infinitely divisible and there are no fixed costs associated with driving a car (the cost of going to the car rental office, for example, and paying a minimum fee) under permit trading this problem is resolved. Wooders and Zissimos (2001) find that indeed the permit trading system actually benefits relatively poor countries, a conclusion much more in line with conventional wisdom. However, the results of this present paper can by no means be dismissed. As it stands the system currently being proposed, under the CDM for example, seems to exhibit some of the key features of indivisibility that underpin the deleterious equity implications reported here. Pollution permits, or carbon credits as they are sometimes referred to, are associated with building plant (akin to buying a car), rather than undertaking a marginal amount of the polluting activity (akin to driving the marginal mile, as analysed by Wooders and Zissimos 2001). The design of the system in this respect could make a crucial difference to its ultimate equity implications.

The framework of this paper could also be extended to support arguments for better provision of public transport. One way to offset the difficulty in dividing the services provided by a car into smaller units is through improving public transport, particularly by increasing the frequency of services, so that it becomes more closely substitutable with private car use.

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Figure 1: World income distribution

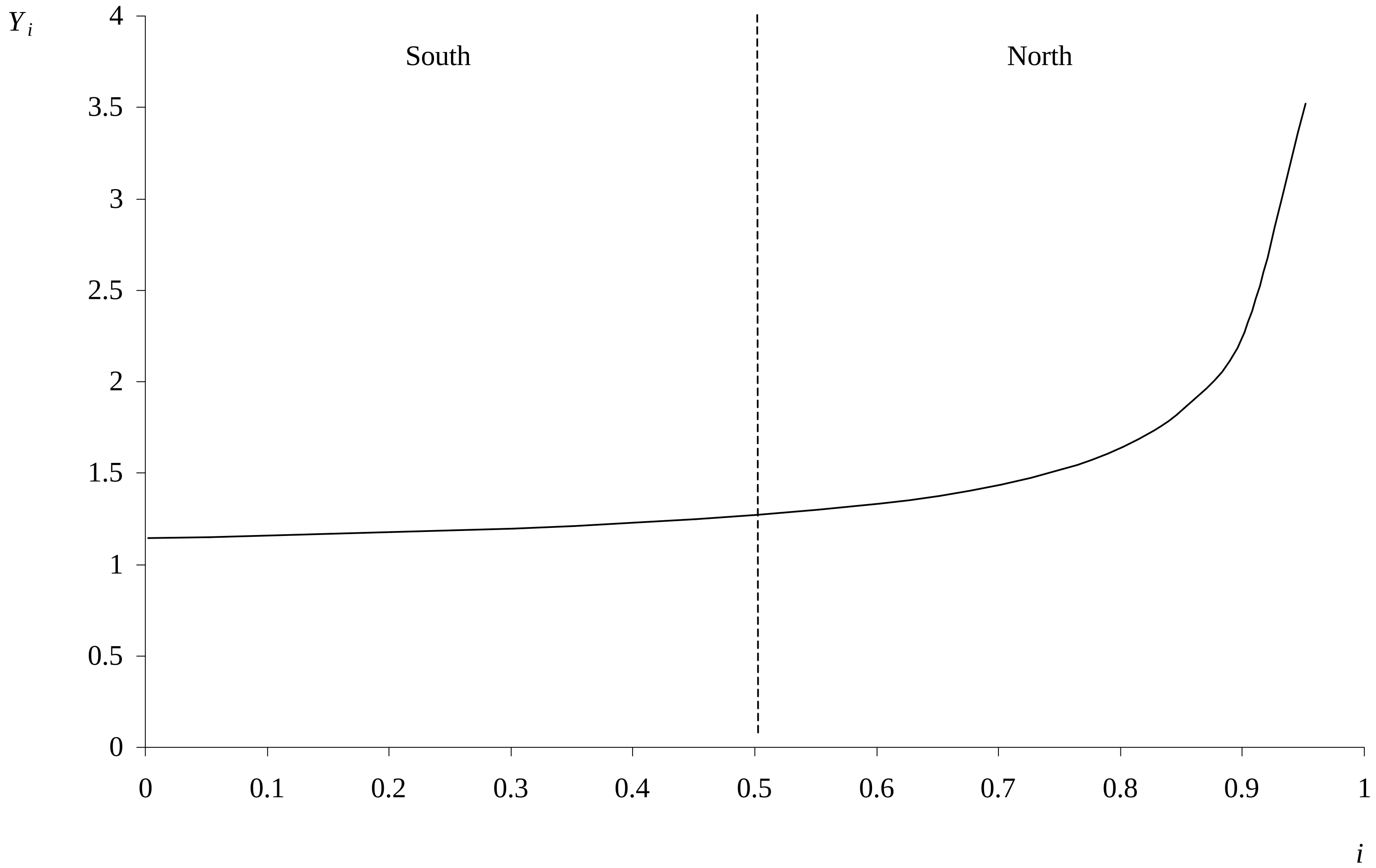

Figure 2: Car use with permits
when the South is poor relative to the North

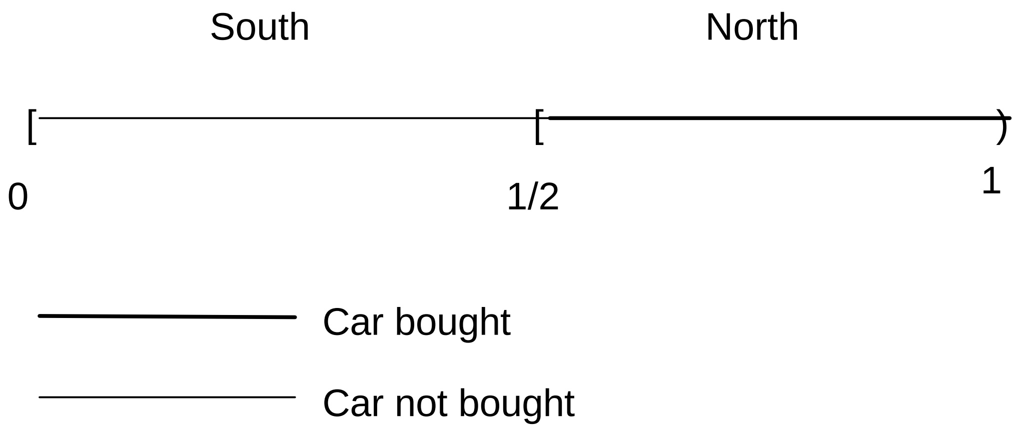

Figure 3: Car use across regions
when South has more permits