Neither the rock nor the hard place: using payment thresholds to balance the politics and the economics of emissions control

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Abstract: To maximise the economic benefits of tradable emission permits or emission taxes, while keeping these emission pricing mechanisms politically acceptable, requires the use of payment thresholds. There is no other way to avoid the "rock versus hard place" dilemma posed by the standard, polar forms of these pricing mechanisms that are generally discussed by economists, namely auctioned permits, free permits, or a pure tax. This means that in total, the government should auction permits only beyond some payment threshold, and should levy a tax on emissions only beyond a similar threshold. For full symmetry, the latter would mean treating emission taxes like tradable emission permits, with the tax threshold thus a de facto property right, though thresholds less like property rights can still be useful. The importance of a payment threshold is shown empirically for the case of global greenhouse gas abatement, where we use emission pricing to maximise welfare subject to a political constraint on the total control and revenue costs directly paid by emitters. This shows how using a payment threshold allows abatement to be much higher, and welfare to be higher, than with the standard forms of emission pricing.

Keywords: tradable emission permits, emission tax, payment thresholds, political acceptability

TABLE OF CONTENTS

1. Introduction

The economic analysis of two key mechanisms of emission pricing − tradable emission permits and an emission tax − is apparently stuck between a rock and a hard place. More precisely, this is true for tradable emission permits; while for an emission tax, analysis is stuck solely in a hard place. The "rock" is the need for an emission pricing scheme to be revenue-neutral at source, in order to maximise political acceptability. The "hard place" is the opposite need, for an emission pricing scheme to raise as much revenue as possible, in order to maximise economic welfare by using the revenue to lower existing, distortionary taxation.

For a system of tradable emission permits, the rock is the choice initially to distribute all permits free, also known as "grandfathering" them all; and the hard place is the choice initially to sell all permits, usually by auction. To a remarkable degree, the economic literature depicts these as the only choices, when clearly that is a false dichotomy. Neither the rock nor the hard place need be chosen: any proportion between 0 and 1 of permits can be sold, with the rest being free. For an emission tax set at a "full incentive rate", that is, at a rate that would yield the same emissions reduction as tradable permits, the literature depicts a false "monotomy", that is, a tax must always be pure, charged on every unit of emissions. But this "hard place" is not the only choice: by using a tax threshold, any proportion between 0 and 1 of emissions can be charged.

In this paper I argue that it is vital for the future success of emission pricing, for economists to suggest to policymakers a full range of pricing mechanisms, including all the space between the rock and the hard place. I use the term "payment threshold" to mean the emission level above which *in total* emissions are paid for, and below which emissions are not paid for;

it can be either the level of free permits, or the threshold above which the tax applies. My claim is that only by using a payment threshold can policymakers balance the otherwise irreconcilable demands for emission pricing to be politically acceptable and economically optimal, and thus realise the considerable benefits that emission pricing can bring. I support this claim by both briefly reviewing the history of key emission pricing schemes to date, with a special focus on the example of controlling global emissions of greenhouse gases (GHGs), which is used throughout the paper to illustrate key issues. I support the claim that a payment threshold is vital also a new technical contribution, which shows the difference it makes to a simple, empirically calibrated model of maximising the global welfare of GHG emission pricing that is subject to a political constraint.

Before setting out my case, in Section 2 I first rehearse just how considerable the benefits of emission pricing can be, by briefly comparing it with some alternatives of command-and-control regulation. Section 3 describes in principle how a payment threshold balances politics and economics for tradable permits, and reviews how strongly, though by no means universally, the literature promotes the false dichotomy of all free versus all sold permits. Section 4 paints a similar picture for an emission tax, after first reviewing the little-known but important idea of emission tax thresholds. Section 5 offers selected episodes from the history of both tradable permits and taxes to show that payment thresholds are indeed necessary, and discusses the many simplifying assumptions, both visible and hidden, made elsewhere in the paper. Section 6 gives the empirical model of politically constrained welfare maximisation. Section 7 makes an important digression to suggest principles for how to distribute the payment threshold among sectors within one country, and Section 8 concludes.

2. The cost-effectiveness of emissions pricing

The cost-effectiveness of using emission pricing to achieve any given target level of abatement is well known in principle. Using either (competitive) emission permit trading or an emission tax to create a uniform price allows all emitters to reach the same marginal abatement cost, which in turn allows the overall short-run cost of meeting the target to be minimised (Baumol and Oates 1971). The alternative of a command-and-control regulation can impose markedly different marginal abatement costs, and so much higher overall costs. The incentive also leads to dynamic efficiencies in encouraging both an efficient industry size and adequate innovation in abatement, as recently surveyed by Requate (2005), but we focus here on the short-run cost savings from emission pricing. These depend on the variability of marginal abatement costs, the particular regulatory alternative to which they are compared, and whether they are measured looking back at implemented pricing schemes, or forward to potential ones. Careful calculations have revealed substantial savings in practice, as reviewed for example by Hahn (2000) who reported achieved cost savings of 25-35% actually achieved by the US sulphur trading programme.

Predicted savings from emission pricing under a hypothetical global climate treaty can be much greater. A useful example comes from the global emissions trading model developed by Jotzo and Pezzey (2005), which divides the globe into 18 regions or countries (hereafter just "countries") and has a roughly 5-fold range of marginal abatement costs, highest in Japan and lowest in China. For an emission price of about 15 \$/t, where all \$ costs are in US 2000 dollars and t means a tonne of CO2-equivalent emissions, total abatement is 12% compared to business-as-usual emissions in 2020; endogenously calculated abatement targets range from

0% for China to 17% for Japan; and the model predicts that *not* allowing emissions trading would raise the global abatement cost by about 150%, from about 50 to 125 G$/yr. For a higher emission price of 37 $/t, the increase in total abatement costs from not allowing trading would be absolutely larger but proportionately smaller (from about 290 to 510 G$/yr, or about 75%). The potential costs savings of course vary with the distribution of targets across countries that is chosen within a given emissions total, but the order of magnitude is clear.

It is much harder to find similar evidence for the degree to which emission pricing can lower total abatement costs within a single country. This is presumably because of the inherent arbitrariness in defining what are different emitting sectors of the economy, and therefore how each sector should be treated under a plausible, regulatory alternative to emission pricing.[1] However, given the large proportion of greenhouse gas emissions coming from energy use, and the millions of small energy users (as well as many large ones) in a modern economy, it is very likely that any regulatory policy will incur much higher total abatement costs than using tradable permits or a tax to transmit a uniform price incentive throughout the economy.

1. Reviewing the evidence here will appear in a later version of this paper.

3. The case in principle for a payment threshold with tradable permits

3.1 How a payment threshold works for both permits and a tax

Before arguing the case for using a payment threshold with tradable permits, we need first to explain in general how it works. From Pezzey (2003), for *either* tradable permits *or* a tax, it means that total collection of all emitters pays the government's pollution control authority (henceforth just "the authority") a net sum of the emission price (say t in dollars/tonne), multiplied by the difference between actual total emissions (say $E(t)$ in tonnes/year, determined by abatement in response to the price) and the total threshold (say $E^\dagger$, also in tonnes/year):

$$\text{payment} = t[E(t)-E^\dagger]. \qquad [3.1]$$

Two further details are important to explain both how the threshold works, and the broad scope of this analysis. The first detail is that [3.1] also applies algebraically to an individual emitter. That is, even if total emissions are above the total threshold (as needed to prevent a fiscal drain on the authority), the opposite might be true for some individual emitters, so that those emitters receive, rather than make, a payment.[2] With permits, this would mean a firm makes money by selling spare permits, and with a tax, it would be paid by the authority for each unit that its emissions fall below its threshold. This gives the same incentive to abate each unit of emissions, no matter how low they are.

The second detail is that even though, for the sake of illustration, the

2. Label individual emitters by $i = 1,...,n$, with i's emission being e_i and its part of the threshold being $e_i^\dagger$, where $E = \Sigma_i e_i$, $E^\dagger = \Sigma_i e_i^\dagger$. Then i's payment to the authority is $t(e_i-e_i^\dagger)$, and it could be that $e_i < e_i^\dagger$ for several emitters even though $E > E^\dagger$.

units above were static, flow measures, they could instead be chosen as the *present discounted value* of the total financial flows over the lifetime of an emission pricing scheme. This means that many dynamic proposals for more sophisticated schemes are not different from the simple one represented by [3.1], but are contained within it. For example, with proposals that permits should be initially free, and then later taxed (Grafton and Devlin 1996) or phased out, one can calculate what proportion of the present value of all permits will thus be transferred to the authority, and this is then $E^{\dagger}/E$. A similar calculation can be done with any proposal (as in the hybrid plan of McKibbin and Wilcoxen 2002) to create a mixture of short-term permits denominated in tonnes and long-term permits denominated in tonnes per year, with different distribution principles for each permit type.

3.2 The case for a payment threshold with tradable permits

What then is the political case for a full threshold, $E^{\dagger} = E$, so that all permits are initially free, yielding no revenue *at source* (the meaning of "revenue-neutrality" in this paper, as opposed to spending all revenue raised from emission pricing on something else)? It comes from the observation from Olson (1965) that, because emitters are generally much fewer in number than households, they have more power over the shape of the permit system. Any permits they have to pay for are just a loss of wealth, so emitters are naturally in favour of paying nothing, so all free permits probably maximises political acceptability.

The economic case for no threshold, $E^{\dagger} = 0$, is more subtle because it relies on two market interactions. One is the well-known effect that raising \$1 of revenue from existing taxes imposes an excess burden of (say) \$*M*, where a benchmark value typically chosen for *M* is 0.3 (Goulder et al.

1999). So an extra $1 of revenue raised by emission pricing allows a *revenue-recycling benefit* of about 30c by funding a reduction in income tax; so the more revenue raised, the better; so setting the threshold to zero and selling all the permits maximises economic welfare. The second market interaction is ultimately one of equity rather than efficiency. When total emissions are cut by any emission pricing scheme, the result would often be a rise in the price of the emitter's goods output. (This is especially true for the biggest source of Australian GHG emissions, namely coal-fired electricity generators.) This gives the emitter a *rent* (surplus over production cost) for each unit of output, which may well add up to heavily outweigh the corresponding emission control costs. If so, making all permits free would seriously overcompensate the emitter. Conversely, selling them all guarantees maximum political opposition to tradable permits.

Having the choice to use any intermediate payment threshold from the full range $0 < E^{\dagger} < E$ obviouslys allow the policymaker whatever freedom is needed to reach the delicate balance of maximising economic welfare *subject to the constraint* of keeping permits politically acceptable. Ignoring any intermediate threshold creates the false dichotomy between the polar cases of all free and no free permits, and hence an irreconcilable conflict between political and economical criteria. Yet a surprising number of influential papers either consider only the polar cases (see for example Edwards and Hutton 2001), or leave the strong impression that the only important cases are the polar ones, even if in passing the possibility of partially free permits is mentioned (see for example Cramton and Kerr

2002).[3] Other papers include both permit and tax instruments, and are reviewed in the next section.

3. Many more papers will be cited here in a later version of this paper, to reinforce my claim about the main message found in the literature.

4. The case in principle for a payment threshold with a tax

The arguments about the importance of using an intermediate payment threshold with an emissions tax are nearly symmetrical to those for tradable permits. Why do we keep interest in emissions taxation alive, despite the increasing popularity of tradable permit schemes? Because under uncertainty, controlling the emission price by a tax can still be theoretically superior to controlling the emission quantity by permits (Weitzman 1974), and this will be true in practice for control of a long-lived stock pollutant like GHGs (Pizer 2002). Pezzey (1992) and Farrow (1995) showed that if a tax threshold is treated as a quasi-property right like a free permit (effectively a new variant of a government bond, as visualised below), then a tax has the same long-run efficiency as a system of partly-free tradable permits using the same values in the revenue formula, equation [3.1].

Anyland Government
The Treasury

EMISSION TAX THRESHOLD

for 5,000 tonnes/year of CO2-equivalent

The Anyland Government will pay the bearer, on 1 July each year forever, a sum equal to 5,000 tonnes/year, multiplied by the CO2 tax rate in $/tonne set for that year by the Anyland Environmental Protection Agency.

However, variants of a tax threshold which are not quasi-property rights − for example, a rule that no emitter gets paid by the authority − should also be considered. Their loss of cost-effectiveness (in this example, by not properly encouraging emitters to leave an industry) may well be outweighed by their increased legal, administrative or political acceptability.

Though the above papers on tax thresholds are moderately cited, their implication is generally ignored in the literature on instrument choice for emissions control, perhaps because the prohibition against production-dependent emission control subsidies in Baumol and Oates (1988) is still considered to apply. Analyses of GHG taxes typically still consider only pure taxes, continuing the tradition set by landmark authors such as Buchanan and Tullock (1975) and Hahn (1989). And in literature considering both tradable permit and tax schemes, almost always only polar alternatives are considered; see for example Parry (1997, 2003), Parry, Williams and Goulder (1999), Goulder, Parry and Burtraw (1997), Goulder et al. (1999), and Wiener (1999).

Once we recognise the possibility of using a payment threshold to make an environmental tax revenue-neutral at source in principle − if not in practice, because of the uncertainty in how total emissions will respond to any given emission price − then the case for using an intermediate threshold becomes the same as with tradable permits. The authority can choose anywhere along the continuum between a pure tax and a revenue-neutral tax-and-threshold, so as to reach the best balance of politics and economics. Sticking with a pure tax is a self-defeating hard place.

5. Evidence and three important caveats about payment thresholds

5.1 Evidence

Here we consider evidence from the history of emission pricing policy which will support the key claim in the two previous sections, that interest group resistance to pure emission taxes or fully auctioned tradable emission permits makes them politically infeasible. Resistance goes back a long way. A common argument, as for example used by the UK Chemical Industries Assocation in its evidence to RCEP (1972), is that emissions allowed under an existing regulatory standard (and there always is one: in practice, emission pricing is never created in a void of no control) are "socially acceptable", and so should not be taxed. Essentially, a de facto property right is thereby claimed to continue emitting, free of charge, at levels already legally permitted.

Freely allocated permits also "offer a much greater degree of political control over the distributional effects of regulation, facilitating the formation of majority coalitions", as noted a generation later by Stavins (1998) is a commentary on the 1990s US sulphur trading scheme, wherein the vast bulk of permits (98%) are indeed free; see also Joskow and Schmalensee (1998).

More key evidence of the impossibility of using no payment threshold at all comes from the fate of widespread proposals for carbon taxes in the early 1990s in response to suddenly increased scientific publicity of global warming in the late 1980s. The most notable proposal was made by the European Commission, and considered only pure taxes and ignored the possibility of tax thresholds. Political resistance to the amounts of revenue that would be raised by pure taxes, if set at anything like full incentive rates, was too great to be overcome. So the 1997 Kyoto Protocol instead adopted tradeable permits as the economic instrument of choice, because of the "obvious" option using free permits to avoid raising revenue. The tradition of using permits, and giving most of them away free, continues in the 2005 European Trading Scheme for CO_2 control in the European Union.

A further, very recent and telling example, comes from the rapid rise and fall of the New Zealand proposal for a carbon tax in 2005. In May, the government proposed a carbon tax to start at New Zealand$15/tCO2 in April 2007 and capped at New Zealand$25/t thereafter, with no threshold and all revenue recycled into reducing existing taxes. Crucially, only CO_2 would be taxed, so agricultural methane and nitrous oxide, and methane from the waste sector, would not be taxed, thereby (in the peculiar case of New Zealand) exempting over half of the country's emissions from pricing control. Moreover, firms would get full or partial exemption from the tax by "moving to world's best practice in emissions control" and signing a Negotiated Greenhouse Agreement. But in the very next month, new forecasts predicted New Zealand would be 36 Mt/yr above its Kyoto Protocol target in 2008-2012, in contrast to the 50 Mt/yr below target that was expected when the government agreed to ratify the Protocol and made its plans for the carbon tax.

So a detailed review was commissioned, and reported in November, after an election campaign in August in which the carbon tax plan was strongly criticised by some parties, and the government ended up with only minority control of the parliament. The review scrapped the carbon tax plan, and the main reasons given were its unfairness and ineffectiveness, stemming from its large exemptions to agriculture and to firms with Negotiated Greenhouse Agreements. It is highly plausible (subject to further research) that these exemptions were included in the first place to improve political acceptability, *given the lack of payment threshold* in the tax plan. So adopting a politically impossible, pure tax has arguably contributed to the immediate downfall of emission pricing, and the efficiency benefits it might have brought to the New Zealand economy.

5.2 Three important caveats

Many detailed assumptions have already been built into this paper, but three are worth highlighting here: the first two so as to avoid recommending an oversimplified form of emission pricing in practice, and the third to avoid claiming too much for the political economy problems that payment thresholds can solve. The first built-in assumption is that *emissions are well-mixed*. By definition this is true for greenhouse gases, otherwise their climate effect would not be global, but many other pollutants are much more regional or global in nature, and the worry then is always that spatially uniform emission pricing will lead to excessive damage from local pollution "hot-spots". This need not be a problem if the total amount of abatement is big enough, as in the US sulphur trading program, but needs to be remembered as a possibly important complication.

The second built-in assumption is an aspect of apparently timeless, static treatment. This means that *adjustment costs* have been ignored. Because of adjustment costs, short-run control costs are much higher than in the long run. So in practice it is important not to jump straight to a long-run optimum emission price, either directly via a tax, or indirectly via a chosen permit total. There will be great savings from phasing in an emissions price gradually, though this must be distinguished from phasing out free permits, which does nothing to lower the emission price.

The third assumption has implicitly been that there is a single government in charge of emissions control. This ignores the problem of *international competition*, both in the policy arena between sovereign governments, and in product markets between firms in different countries, which obviously forms a key obstacle to GHG emissions control. Can a payment threshold protect trade-sensitive, GHG-intensive industries against unfair competition from countries where GHGs are uncontrolled. It depends. To the extent that political resistance from such industries can be bought off by transfer of wealth, then Yes. Otherwise, such industries, often the very emitters with the cheapest opportunities for emissions control, end up being exempted. But to the extent that political resistance stems from loss of employment and output needed to reduce emissions (from E_0 to E in our model) then No. There is no easy answer to the latter problem (hence the pressure for technological fixes, currently well reflected in federal Australian GHG policy).

6. Abatement and welfare gains from using a payment threshold for GHG pricing

6.1 Modelling the welfare gain from emissions pricing

In contrast to the rest of this paper, this section makes a new, technical contribution about the economic benefits of payment thresholds, rather than arguing the general case for using them. We use a simple linear model, from Goulder et al. (1999), of the effect of an emissions price on emissions and welfare, and apply it to the case of greenhouse gas (GHG) control in 2020, using calibrated global figures from Jotzo and Pezzey (2005). The model assumes complete certainty in all variables here, so there is no distinction between tradable permits and a tax as market mechanisms, and we talk in general terms of an "emissions price", denoted *t* \$/t. We assume that global emissions *E* Gt/yr are abated below some business-as-usual level E_0 Gt/yr by a multiple β Gt/yr per \$/t of the emissions price, which we will call the (global) *abatement potential*:

$$E(t) = E_0 - \beta t, \quad \beta \text{ G(t}^2\text{)/\$.yr a constant;} \qquad [6.1]$$

We now sum the overall welfare gain of emission pricing, including both environmental and economic effects. The first, positive part of this sum, motivating the whole of this paper, is the *damage-avoided benefit* of the abatement β*t*, also taken to be as a simple multiple of the emissions price, being some damage rate *D* \$/t times abatement:

$$\Delta W^D = D\beta t. \qquad [6.2]$$

We avoid calling this just "environmental" benefit because *D* might include status as well as environmental effects, as discussed later. From this we subtract the *primary cost of abatement*. This includes costs of both the abatement effect of spending on end-of-pipe abatement technologies, and the output-substitution effect of people shifting their consumption patterns towards cleaner goods and leisure; and it is measured by the triangular area under the rising abatement line βt plotted against the emission price t; :

$$\Delta W^A = ½\beta t^2. \qquad [6.3]$$

The "gross net benefit" of emissions pricing, $\Delta W^D - \Delta W^A = D\beta t - ½\beta t^2$, is of course maximised by setting the price t equal to the damage rate, D, but this is not the end of the story. We also include two terms reflecting the dominant "double dividend" consensus of the second-best interactions between emissions pricing and pre-existing taxation (see Goodstein 2003 for a critical review and Parry and Williams 2004 for a robust defence of this consensus). First we add the *revenue-recycling benefit* to economic efficiency of raising revenue from emission pricing. This is the marginal excess burden of taxation, M, times the revenue, which in turn is the price t times the post-pricing emissions base $E - E^\dagger$ that is actually charged, after allowing for the payment threshold $E^\dagger$:

$$\Delta W^R = Mt(E - E^\dagger) = Mt(E_0 - \beta t - E^\dagger). \qquad [6.4]$$

Then we subtract the *tax-interaction cost* of distorting consumption choices towards leisure, which Goulder et al. compute as the area under the line of $ME(t)$ plotted against the price t:

$$\Delta W^I = Mt(E_0 - ½\beta t). \qquad [6.5]$$

Together, the tax-interaction cost minus the revenue-recycling benefit $(\Delta W^I - \Delta W^R)$ add an extra cost of $M(½\beta t^2 + tE^\dagger)$, namely the marginal excess burden M times the sum of the the abatement cost $½\beta t^2$, and the revenue forgone by using the payment threshold $tE^\dagger$. Subtracting this from the gross net benefit gives the *welfare gain* of emissions pricing,

$$\Delta \boldsymbol{W}(t, E^\dagger) = D\beta t - ½\beta(1+M)t^2 - MtE^\dagger. \qquad [6.6]$$

Simple differentiation of [6.6] then shows the marginal response of welfare to the emissions price t:

$$\partial \Delta \boldsymbol{W}(t, E^{\dagger})/\partial t = \beta[D - (ME^{\dagger}/\beta) - (1+M)t]. \quad [6.7]$$

The role of the double dividend terms (those in M) is thus crucial. Setting $t = 0$ in this response formula shows that if the damage rate D is less than the marginal excess burden M times the threshold $E^{\dagger}$ divided by abatement potential β, increasing the price t from zero *lowers* welfare, not raises it. This matters greatly for the benchmark GHG parameters we use, which are (from Jotzo and Pezzey 2005 for E_0 and β, and from Goulder et al. 1999 for M):

$$E_0 = 54 \text{ Gt/yr}, \quad \beta = 0.426 \text{ G(t}^2\text{)/US2000\$.yr}, \quad M = 0.3. \quad [6.8]$$

Under a very small price which gives very small abatement, a full payment threshold will be close to BAU emissions ($E^{\dagger} = E \approx E_0$), so that

$$ME^{\dagger}/\beta \approx ME_0/\beta = 38.0 \text{ \$/t}. \quad [6.9]$$

From [6.7], this means the damage rate D must be *at least* 38 dollars a tonne of CO2-equivalent before emissions pricing *with a full payment threshold* − for example, tradable emission permits that are fully grandfathered − will raise rather than reduce welfare. Alternatively, with a damage rate of D = 20 $/t, it means that the payment threshold must be less than half, otherwise environmentally pricing will be harmful rather than helpful.

In current policy debates, a figure of about 20 $/t for the *climate damage* from GHG emissions would be regarded as being much more politically possible than about 40 $/t. However, this does not necessarily mean that, if auctioning at least half of emission permits is considered politically impossible, then emission pricing should not be tried until the higher damage figure has become possible. There is also solid evidence of systemic overconsumption caused by self-defeating status races. Because GHG emissions are so closely linked to energy production, hence to GDP and to consumption, emission pricing then gives an extra, real benefit from reducing overconsumption, and this effect has been estimated as being worth at least 19 $/t (Howarth forthcoming). So adding this to estimates of the climate damage makes a total damage rate of over 38 $/t much more plausible.

6.2 Adding a political constraint on financial cost of emission pricing

Here we assume, in line with the evidence above in Section 5.1, that in terms of what is politically achievable, there is a strict limit on the *financial cost to emitters* which emission pricing can impose. Financial cost ΔF is defined as the primary abatement cost ΔW^A from [6.3], plus the revenue that emission pricing transfers from emitters to government, namely the price t times the portion of emissions that must be paid for overall, $E-E^\dagger$:

$$\Delta F(t,E^\dagger) := \tfrac{1}{2}\beta t^2 + t(E-E^\dagger) = E_0 t - \tfrac{1}{2}\beta t^2 - tE^\dagger. \qquad [6.11]$$

We assume that this financial cost is politically constrained to be some small fraction k of the total damage done by business-as-usual emissions, DE_0:

$$\Delta F(t,E^\dagger) \le kDE_0, \quad k > 0. \qquad [6.12]$$

Parameter k is highly debatable, variable and hard to pin down − might it be 5%, 10% or 20%? − but it is undoubtedly real.

What happens to maximising welfare when this constraint is imposed? Technical details are given in the Appendix. They include the parameter restrictions needed to make the maximising of one quadratic function of price t, $\Delta \boldsymbol{W}(t,E^{\dagger})$, subject to a constraint on another quadratic function, $\Delta F(t,E^{\dagger})$, a well-defined problem. It turns out we need

$$ME_0/\beta < D < E_0/\beta \quad \text{and} \quad k < 1/(1+M) - 1/2(1+M)^2, \qquad [6.13]$$

and for the benchmark parameters in [6.8], this boils down to restricting the damage rate D and political constraint factor k as follows:

$$38.0 < D < 126.8 \text{ \$/t} \quad \text{and} \quad k < 0.473. \qquad [6.14]$$

The latter poses no problem, but as discussed the former may be important. For purposes of illustration we choose

$$D = 50 \text{ \$/t} \quad \text{or} \quad 75 \text{ \$/t}, \quad \text{and} \quad k = 0.1. \qquad [6.16]$$

In Table 1 we report results for the effects of the constraint, without and with a payment threshold, for these two levels of damage rate. The first line of results gives the optimal constrained tax rate selected, in comparison to the optimal unconstrained rate $D/(1+M)$, obtained from setting marginal welfare to zero in [6.7] with a zero threshold $E^{\dagger}$.

Note from these results that using a payment threshold clearly improves abatement a lot, and welfare by a lesser amount; but that the extent of these improvements depends greatly on the damage rate D. A 50% higher damage rate leads to the threshold rising from 59% to 92% of emissions, and to abatement being increased by a factor of about 5 rather than 2.4, with welfare increased by a factor of about 1.8 rather than 1.1. This reflects the influence of the double dividend terms. Only when damage is serious enough, can the abatement benefits of politically acceptable emission pricing, which inevitably involves a fairly high percentage threshold, overcome the tax interaction costs that pricing generates.

Table 1 Effect of payment threshold on abatement and welfare achievable by politically constrained emission pricing for global GHG control

Common parameters	E_0 = 54 GJ/yr, β = 0.426 G(t^2)/\$.yr, M = 0.3, k = 0.1			
Damage rate D, \$/t	50		75	
Payment threshold	None (full permit auctioning / pure tax)	Optimal (some auctioning / tax threshold)	None (full permit auctioning / pure tax)	Optimal (some auctioning / tax threshold)
Payment threshold cf. emissions, $E^{\dagger}/E$	0%	59%	0%	92%
Tax, t (\$/t)	5.1	12.0	7.7	37.0
Tax cf. unconstr. optimum, $t(1+M)/D$	13%	31%	13%	64%
Abatement cf. BAU emissions, $1-E/E_0$	4%	9%	6%	29%
Abatement cost, $\frac{1}{2}\beta t^2$ (G\$/yr)	6	30	12	292
Revenue transfer, $t(E-E^{\dagger})$ (G\$/yr)	264	240	388	113
Welfare gain, $\Delta \boldsymbol{W}(t,E^{\dagger})$ (G\$/yr)	101	112	228	413

7. How might a national GHG payment threshold be distributed among sectors?

Here we briefly consider how a nation's greenhouse gas control policy might be shaped if the central arguments put forward above are accepted. Who should get what share of free permits or tax thresholds in the GHG case? In one sense this is a digression, as one could regard the precise distribution of permits as a purely political issue to be decided by the national government. However, the issue has proved important enough in seminar presentations of this paper to warrant inclusion here; otherwise the argument for a payment threshold is too easily dismissed as an academic pipedream that can never be implemented in practice. So I give a rough proposal set in the Australian context, where over a third of GHG emissions come from electricity generation, and over four-fifths of electricity generation is coal-fired. Key complications to take account of are the monopoly rents created by emissions control, and the need for upstream acquittal by primary fuel extractors and importers in order to avoid the huge administration costs of directly controlling the CO2 emissions of millions of households and vehicles.

My proposal starts by assuming that the national levels of both controlled emissions (E) and the payment threshold ($E^{\dagger}$) have been agreed, though as we will soon see, the exact size of the threshold may prove fuzzy for reasons of administration costs. As a fair, and one hopes politically plausible distribution principle, I suggest that *the threshold should be distributed in proportion to the net economic costs caused by emissions control*. The trick is then to estimate what these *net* costs are, taking into account the degrees to which emitting firms end up paying less to their suppliers and charging more to their customers as a natural (not necessarily exploitative or price-gouging) part of the economy's new equilibrium under emission pricing. Such estimation could be attempted by computable general equilibrium modelling, but the numbers, as well as their translation into threshold distribution, will always remain contestible.

It will be tempting to suggest very simple distribution schemes, and those who would benefit from simple schemes are not shy in promoting them. But the unvoidable complexity of calculating net costs can best be illustrated by pointing out the glaring flaws in two simple distributions:

- Giving out all thresholds in proportion to the effective emissions of upstream acquitters (mainly extractors and importers of coal, oil and gas) will over-compensate them, since the emission price could greatly exceed the fall in price that producers receive.
- Giving out all thresholds to directly emitting firms (predominantly electricity generators) and households and vehicle owners will
  - overcompensate many firms, depending on the degree to which emission pricing ends up lowering their supply costs and raising their output prices;
  - be impractical for millions of households/drivers.

The only fair distribution is a pragmatic mix, whereby some thresholds go to acquitters, some go to emitters, and some go to households and vehicle owners. However, the administration costs for a precise distribution to this last category may prove too great: for example, no one knows how much every vehicle owner recently spent on fuel. So to avoid countless individual arguments, there may well be a case for selling the thresholds allocated to householders and vehicle owners − in which case the payment threshold will appear to be lower − and using the revenue thus raised to provide targeted compensation, for example lower vehicle registration fees.

8. Conclusions

At the heart of what economics has to offer environmental policy is the idea that there are big advantages in using market forces as a dominant force in controlling emissions and other environmental damage. Generations of students have been taught the cost-minimising properties of a common emission price, as created by either tradable emission permits or an emission tax, in both the short and long terms. Yet students are also now taught that emission pricing has been slow to catch on as an accepted policy instrument, that emission taxes at full incentive rates simply never happen, and that applications of tradable permits invariably give almost all permits away free. I have argued that this state of affairs is far below what emission pricing could achieve for society, and hence represents a far too modest achievement of the environmental economics profession.

The solution lies in expanding the menu of pricing instruments beyond the three extreme, polar, asymmetric forms generally on offer. The first two, a pure emissions tax or fully auctioned permits, are universally espoused by economists but rejected as politically unacceptable. The third, all free (grandfathered) permits, is clearly politically acceptable, but increasingly regarded by economists as perhaps doing more harm than good, especially at low permit prices, because of its costly if hidden interactions with the existing tax system. Limiting the menu of policy instruments to just these three forces policymakers to choose between a rock and a hard place, with obviously unsatisfactory outcomes. Yet there is lots of room between the rock and a hard place. The payment threshold − beyond which emitters have to pay for emissions − can be *anywhere between all or nothing* of the controlled level of emissions, rather than just all *or* nothing, as with the rock and the hard place. Only by actively exploring and promoting the potential of these intermediate forms of emission pricing can its full potential be achieved.

My contribution here has been both to present a synthesis of these arguments; and an empirical illustration, for the case of global greenhouse gas control, how a payment threshold can increase the welfare gain and greatly increase the abatement achieved by emission pricing subject to a political constraint on how much it costs emitters overall. This showed the benefits of a payment threshold to be sharply non-linear in the rate of environmental damage. So for the biggest environmental challenge that the human race may face in the next century, that of making deep cuts in greenhouse gas emissions, there is likely to a huge payoff from using a payment threshold to balance the economics and politics of emission pricing.

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Appendix

(Parameter restrictions [6.13] are needed here, and so are assumed to hold.)

1. Welfare maximum with political constraint and no threshold

The constraint binds, so the emission price is given by the lower of the solutions of

$$½\beta t_1^2 - E_0 t_1 + kDE_0 = 0, \qquad \text{[A.1]}$$

which is

$$t_1 = [E_0 - (E_0^2 - 2\beta kDE_0)^{½}]/\beta. \qquad \text{[A.2]}$$

Maximum welfare comes from inserting this into the welfare formula

$$\Delta \boldsymbol{W}(t_1,0) = \beta D t_1 - ½\beta(1+M)t_1^2, \text{ which after manipulation}$$

$$= (1+M)E_0\, \{[D/(1+M) - E_0/\beta][1-(1-2\beta kD/E_0)^{½}] + kD\}, \qquad \text{[A.3]}$$

the formula used in the calculations reported in Table 1.

2. Welfare maximum with political constraint and optimum threshold

We set the derivative of welfare [6.6] w.r.t. the payment threshold equal to zero:

$$d(\Delta \boldsymbol{W})/dE^{\dagger} = (\beta D - ME_0 - \beta t)t/(E_0 - E^{\dagger} - \beta t) = 0, \text{ hence} \qquad \text{[A.4]}$$

$$t = t_2 := (\beta D - ME_0)/\beta. \qquad \text{[A.5]}$$

Assuming the political constraint binds means

$$E_0 t - ½\beta t^2 - tE^{\dagger} = kDE_0, \text{ hence} \qquad \text{[A.6]}$$

$$E^{\dagger}(t) = E_0 - ½\beta t - kDE_0/t \text{ or } E_0 - E^{\dagger} = ½\beta t + kDE_0/t. \qquad \text{[A.7]}$$

Maximum welfare is then found by first inserting t_2 into this to give

$$\bar{E}_2 = E_0 - ½(\beta D - ME_0) - k\beta DE_0/(\beta D - ME_0) \qquad \text{[A.8]}$$

Then insert t_2 and $\bar{E}_2$ into [6.6] to yield, after manipulation,

$$\Delta \boldsymbol{W}(t_2, E_2^{\dagger}) = ½(\beta D - ME_0)^2/\beta + MkDE_0, \qquad \text{[A.9]}$$

the formula used in our calculations.