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Survey

Personal carbon trading: A critical survey Part 2: Efficiency and effectiveness

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ABSTRACT

Equity, efficiency and effectiveness are three key criteria use to assess environmental policy instruments. Part 1 of this survey shows that, in terms of equity, Tradable Energy Quotas (TEQs) – a widely discussed personal carbon trading (PCT) scheme - cannot be differentiated from Cap and Dividend (C&D) or Cap and Share (C&S). Hence, Part 2 explores whether they can be differentiated in terms of efficiency and/or effectiveness. The paper reviews two studies that compare the efficiency of TEQs and C&D. Whilst their estimates of the costs and abatement potential of TEQs differ, neither study considers that there is a case, on efficiency grounds, for its implementation. The paper goes on to sketch two arguments for the implementation of PCT that might, nevertheless, be made on efficiency grounds and one – relating to public acceptability – that might be made on effectiveness grounds. Exploring the various public surveys conducted on the acceptability of PCT, the paper concludes that support for PCT is not obviously greater than for alternative instruments and notes a methodological limitation in the work reviewed. The paper concludes that, to date, the case against implementation of PCT is stronger than the case for.

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1. Introduction

Equity, efficiency and effectiveness are three key criteria for comparing environmental policy instruments. Part 1 of this survey describes a range of personal carbon trading (PCT) schemes and compares, in terms of equity, the two most widely discussed PCT schemes

- Tradable Energy Quotas (TEQs)
- Personal Carbon Allowances (PCAs)

with two proposed alternative trading schemes

- Cap and Dividend (C&D)
- Cap and Share (C&S)

This comparison shows that these schemes can be equally fair: that is, no one scheme is inherently more equitable than another. As the schemes cannot be differentiated in terms of equity, Part 2 examines whether TEQs, C&D and C&S can be differentiated in terms of efficiency and/or effectiveness.[1]

A scheme is *effective* if it can deliver a prescribed emission reduction target. A necessary condition for effectiveness is that a scheme's implementation is technologically feasible, and research indicates that, for all three schemes, there is no technical barrier to implementation (AEA Energy and Environment, 2008; Lane et al., 2008). A scheme is *efficient* if it can deliver the prescribed reduction target at low total cost, with total cost defined here as the sum of implementation, participation and abatement costs. The implementation and participation costs of the three schemes are compared in Sections **2** and **3** whilst Section **4** explores their abatement and total costs. Section **4** concludes by reviewing two UK studies, one by the Department for Environment, Food and Rural Affairs (Defra) and the other by the Institute for Public Policy Research (IPPR) that, on the grounds of efficiency, do not support the implementation of TEQs. In contrast, Section **5** outlines three arguments that might support its implementation. The last of these relates to another necessary condition for effectiveness, public acceptability, which is discussed in Section **6**. Section **7** concludes.

2. Implementation Costs

2.1. TEQs and C&D

2.1.1. Lane et al. Study

In 2008, Defra published its pre-feasibility study into PCT. This comprises four reports: Lane et al. (2008), Defra (2008), Owen et al. (2008) and Thumim and White (2008). The first three are considered in this paper.[2]

Lane et al. (2008) compare implementation costs of Fleming's TEQs and an economy-wide upstream trading scheme. However, this upstream scheme is not C&D, as its auction revenue is not allocated to individuals (Table 1).[3] Dresner (2005) argues that the UK's

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[1] Given its similarity to TEQs, PCAs is not included within the comparison.

[2] The fourth is referenced in Part 1.

[3] Thus, the comparison is not one between two equally equitable instruments (Part 1, Section 5.2).

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Table 1
Variants of PCT and upstream trading assessed by Defra and IPPR.

Feature	Defra			IPPR		
	PCT	Upstream		PCT	Upstream	
	Scope	Scope	Auction revenue allocated to individuals?	Scope	Scope	Auction revenue allocated to individuals?
Implementation	EW[a] (TEQs)	EW	No	EW (TEQs)	EW	No
Participation	IO[b]	IO	No	IO	IO	No
Abatement	IO	IO	No	IO	IO	No
Public acceptability	EW (PCAs)	EW (C&D)	Yes	IO	IO	No

[a] EW = economy wide.
[b] IO = individuals only.

largely integrated tax and benefit system would make the administrative cost of allocating auction revenue to individuals through adjustments to their tax allowances and benefit rates close to zero.[4] Hence, figures for the implementation costs of this upstream scheme can be taken as indicative of those for C&D. Given this, and that its participation costs (Section **3**) would be identical to C&D, this upstream scheme is, for continuity, referred to as C&D.

Lane et al. estimate the set-up costs of TEQs at £0.7–2 billion and the annual running costs at £1–1.8 billion[5] (Table 2), whilst estimating the set-up costs of C&D at £50–100 million and the annual running costs at £50 million. They propose that, under TEQs, high street banks should run individuals' carbon accounts alongside their cash accounts, estimating the annual running cost of a carbon account at £15–20. Lane et al. recognize that not everyone has a bank account but, assuming, for simplicity, that everyone does and that there are 50 million carbon accounts in all, they calculate the annual cost of running individuals' accounts at £0.75–1 bn. This sum – by far the largest component of total annual running costs - covers, amongst other things, the cost of posting individuals a monthly account statement, Lane et al. (2008, p. 45) noting that

> only a minority of the adult population currently uses internet banking services, so it would be imprudent…to eliminate hard copy statements of carbon credit usage.

Lane et al. estimate the remaining annual running costs at £0.2–0.8 bn (Table 2).

Whilst organizations under TEQs have the option of opening a carbon account to engage in Type 1 surrender (S1), Lane et al. (2008, p. 41) assume that all will engage in Type 2 surrender (S2) i.e. surrender at the point of sale.[6]

2.1.2. IPPR Study

In the IPPR's assessment of Defra's pre-feasibility study, Lockwood (2009) accepts Lane et al.'s estimates for the set-up costs of TEQs and C&D and the running costs for C&D but suggests that their estimate for the running costs of TEQs may be too high. According to Lockwood, evidence from Europe suggests that current bank accounts can be run at an annual cost of £14–17.50 and he argues that, as carbon accounts would be simpler to run, their annual running cost would be lower. Furthermore, he suggests that most individuals could access a carbon statement electronically (although a paper statement should be available to those who want or need one). On this basis, he concludes that the annual cost of running an individual's carbon account could be £10–15 which, assuming 50 million accounts, gives a total annual figure of £0.5–0.75 bn (Table 2). Whilst Lockwood's focus is on implementation costs of TEQs as they relate to individuals, he appears to accept Lane et al.'s assumption that organizations under TEQs will engage in S2.

Lockwood, like Defra (2008), takes 2013 as the earliest implementation date for TEQs. Although in 2010, around 75% of UK households were connected to the internet, only around 40% of adults banked online (Table 3). This figure suggests that Lockwood may be optimistic in proposing that, by 2013, "most" individuals would access electronic statements. However, the proportion doing so would grow as computer literacy amongst the population increased, and making paper statements "opt in" would utilize this literacy to reduce costs.

Lockwood further argues that the remaining annual running costs of TEQs will be substantially lower, estimating them at £0–0.25 bn (Table 2).[7] For example, given Lane et al.'s proposal that an individual's carbon account runs alongside their bank account, Lockwood argues that the verification of identity required for that individual to open their bank account is sufficient for them to obtain a carbon account, and that the costly additional verification for carbon accounts proposed by Lane et al. is not required.

Table 2
Estimates of annual running costs for TEQs.

Cost category	TEQs: annual running costs (£m)	
	Lane et al.	Lockwood
Accounting and transactions		
Running carbon accounts	750–1000	500–750
Other	90–350	↑
Overall management	<10	
Enrolment, ID verification and allocation	100–300	0–250
Auction and trading	<20	
Compliance and enforcement	10–100	↓
Total	950–1750	500–1000

Table 3
Internet use and internet banking in the UK.[a]

UK adults and households	2006	2007	2008	2009	2010
Adults using internet (%)	60	67	71	76	77
Internet users banking online (%)	42	45	49	54	54
Adults banking online (%)	25	30	35	41	42
Households connected to internet (%)	57	61	65	70	73

[a] Sources: Office of the National Statistics (2006, 2007, 2008, 2009b, 2010).

2.2. C&S

Whilst C&D involves an upstream auction with revenue allocated through the tax and benefit system, C&S involves posting emissions rights out to individuals, individuals selling their rights at banks or post offices, and these market makers selling them on to fossil fuel suppliers. Thus far, no quantitative comparison of the two schemes' costs has been made but, in its study of C&S, AEA Energy and Environment (2008) reasonably estimates the set-up and running costs of C&S to be higher. However, as C&S neither requires the provision of carbon accounts to individuals nor systems for S1 and S2, its implementation costs will be considerably less than those of TEQs.

[4] Some individuals eligible to be allocated auction revenue will be neither tax payers nor benefit recipients and so some other means of transferring revenue would also be required, which would bring some additional cost.
[5] They note that "The broad range is reflective of analysis conducted at a very early stage of feasibility testing" (Lane et al., 2008, p. 6).
[6] For details of S1 and S2 see Part 1, Section 3.1.
[7] Lockwood does not provide cost estimates for the individual cost categories in Table 2, hence the global figure. However, it seems reasonable to presume that these costs must be greater than Lockwood's lowest estimate of zero.

Table 4
Comparison of total annual cost of TEQs and C&D.

Items	Annual cost and abatement estimates					
	Defra			Lockwood		
	Low	Central	High	Low	Central	High
Annual implementation and participation costs						
TEQs						
Set-up costs[a,b] (£m)	84	163	241	70	135	200
Running costs[c] (£m)	1000	1500	2000	500	750	1000
Participation costs (£m)	500	1000	1500	400	575	750
Implementation + participation costs (£m)	1584	2663	3741	970	1460	1950
Implementation + participation costs per individual[d] (£)	31.68	53.25	74.81	19.40	29.20	39.00
C&D						
Set-up costs[e,f] (£m)	9	9	9	10	10	10
Running costs (£m)	50	50	50	50	50	50
Participation costs (£m)	0	0	0	0	0	0
Implementation + participation cost (£m)	59	59	59	60	60	60
Implementation + participation cost per individual (£)	1.18	1.18	1.18	1.20	1.20	1.20
Difference in implementation + participation cost				910	1400	1890
Difference in implementation + participation cost per individual (£)	£30.50[g]	£52.07	£73.63	£18.20	£28.00	£37.80
Abatement						
Permit price = 2013 shadow price of carbon (£/tCO_2)	29	29	29			
Permit price = 2020 non-traded carbon price (£/tCO_2)				60	60	60
TEQs						
EE^ (%)	0	2.5	5			
E′E^ ($MtCO_2$)	0	5.9	11.9			
Value of EPHE^ (£m)	0	172	344			
Value of EPHE^ per individual (£)	0	3.44	6.87[g]			
C&D						
EE′ (%)	0	0.5	1			
EE′ ($MtCO_2$)	0	1.2	2.4			
Value of EPFE′ (£m)	0	34	69			
Value of EPFE′ per individual (£)	0	0.69	1.37			
Difference in abatement value (E′FHE^) per individual (£)	0	2.75	5.49			
Size of EE^ for TEQs' total cost per ton of abatement to equal permit price (%)	23.1	38.8	54.4	6.8	10.3	13.7
Size of EE′ for C&D's total cost per ton of abatement to equal permit price (%)	0.9	0.9	0.9	0.4	0.4	0.4
Size of E′E^ for TEQs' total cost to be equal to that of C&D	22.2	37.9	53.5	6.4	9.9	13.3

[a] Set-up costs from Lane et al. (2008) amortized over 10 years by Defra with interest rate applied.
[b] Set-up costs from Lane et al. (2008) amortized over 10 years by IPPR with *no* interest rate applied.
[c] Whilst Lane et al. estimate annual running costs at £1–1.8 bn, Defra assume costs of £1–2 bn.
[d] 50 million participating individuals assumed. Under TEQs, each is assumed to have a separate carbon account.
[e] Defra uses only the *central* estimate from Lane et al. (2008). Costs amortized over 10 years *with* interest rate applied.
[f] IPPR uses only the *upper* estimate from Lane et al. (2008). Costs amortized over 10 years with *no* interest rate applied.
[g] Defra notes that, even making the most optimistic assumptions about TEQs (i.e. low implementation and participation costs and EE^ equal to 5%) and the least optimistic about C&D (i.e. EE′ equal to 0%), the amount by which abatement costs under TEQs are lower per individual (£6.87) is 4.5 times smaller than the amount by which implementation and participation costs are higher (£30.50).

3. Participation Costs

3.1. Which PCT Scheme?

Defra's pre-feasibility study does not assess a single version of PCT. For example, whilst Lane et al. (2008) assess Fleming's TEQs, Defra (2008, p. i), in its comparison of the efficiency of PCT and C&D, considers a PCT scheme under which only individuals are allocated emissions rights (Table 1).[8] Defra (2008, p. i) justifies this individuals-only focus as follows.

> Alternative designs have been proposed, including more ambitious economy wide schemes, however considering the net benefit of introducing trading [for individuals] provides an insight into the added value of *personal carbon trading* generally. Downstream trading already covers all energy intensive industries through the EU ETS[9] and after the introduction of the Carbon Reduction Commitment in 2010 will cover large non-energy intensive organizations too. The unique aspect of personal carbon trading schemes is that such downstream trading would be extended to individuals' energy use.

Although Defra analysis focuses only on *individuals'* participation and abatement costs, its acceptance of Lane et al.'s assumption that all organizations engage in S2 means that one can infer its view on what *organizations'* participation and abatement costs would be were its individuals-only scheme extended economy wide to become TEQs (Section **4.8**). For this reason, and for continuity, Defra's scheme is henceforth referred to as TEQs. Although the IPPR similarly focuses only on individuals' participation and abatement costs (Table 1), its apparent acceptance of the Lane et al. assumption means the scheme it assesses is, for continuity, likewise referred to as TEQs.

3.2. TEQs

Defra estimates that individuals would spend between two and six hours each year participating in TEQs, with a central estimate of 4 h. Assuming 50 million participating individuals and a value of £5 for an hour of their participation,[10] the total annual participation cost

[8] These rights cover individuals' energy and aviation emissions. Whilst Defra characterizes this scheme as PCAs, Part 1 notes that, under PCAs, individuals are, in theory at least, allocated rights covering their energy emissions plus all their public transport emissions, whilst organizations are allocated rights via the carbon market.
[9] European Union Emissions Trading Scheme.
[10] This figure is based on the value of £4.94 that, in 2007, the Department for Transport placed on an hour of non-work time for the purposes of cost–benefit analysis.

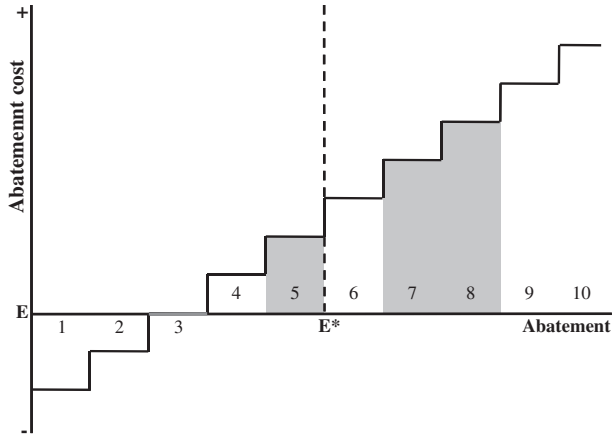

Fig. 1. Stylized marginal abatement cost curve: theoretical potential.

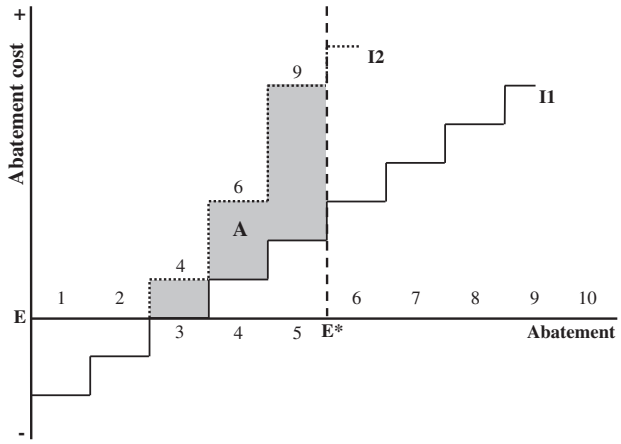

Fig. 2. Stylized marginal abatement cost curves for I1 and I2.

comes to between £0.5 and 1.5 billion with a central estimate of £1 billion (Table 4). Defra (2008, p. 54) notes that, although a "rough estimate", its central value of 4 h per person "underline[s] that the costs associated with the time burden would be non-negligible for a PCT scheme". However, the IPPR (Lockwood, 2009) argues that Defra's estimates are too high and puts annual participation at 1.6–3 h per individual with a central estimate of 2.3 h. Assuming the same number of participants and value for participants' time, the total annual participation cost comes to £0.4–0.8 bn with a central cost of £0.6 bn.

If all individuals engaged solely in S2, then once they had put in place an arrangement for a market maker to purchase their carbon units, annual participation time would be zero. For even though, under S2, they would be purchasing and surrendering units at the point of sale, their transaction would consist of a single monetary payment (for energy + units), that would take no longer than a payment (for energy only) prior to the implementation of TEQs. Thus, both Defra and the IPPR implicitly assume that all individuals engage in S1. Defra and IPPR's assumption that all organizations engage in S2 implies that organizational participation costs are zero.

3.3. C&D and C&S

Under C&D, there would be no participation cost to individuals or organizations for, just as prior to the introduction of the scheme, all purchases of energy would be purely monetary transactions. According to Defra and the IPPR this absence of participation costs and its lower implementation costs, means that the annual implementation and participation costs per individual are from £20–75 lower than for TEQs (Table 4). Under C&S, the only participation time for an individual would be the small amount involved in the sale of rights to market makers.

4. Abatement and Total Costs

Sections **2** and **3** addressed implementation and participation costs. Abatement costs, and the sum of all three costs i.e. total costs are addressed in Section **4**.

4.1. The ENCORE Hypothesis

With regards to emission reductions, various authors have suggested that individuals may respond differently to TEQs than to C&D or C&S.[11] For example, Fleming (2007) suggests that TEQs will engender an increased sense of responsibility for emission reduction. Kerr and Battye (2008, p. 8, 40) similarly suggest that TEQs will give individuals "transparent responsibility" for emission reductions and that one of its likely strengths will be that of "engaging and empowering individuals". Starkey and Anderson (2005) suggest that TEQs may cause them to become more aware of their emissions than under other instruments, that is to become more "carbon conscious" (Starkey, 2008, p. Ev 24). And this may lead them to undertake a more intensive search for emission reduction opportunities, which in turn may lead to them discovering and taking advantage of lower cost emissions abatement opportunities.

Thus, it can be hypothesized that, as the result of a differential psychological impact, namely that of engendering a greater level of engagement, consciousness, responsibility and empowerment (ENCORE) individuals' abatement costs will be lower under TEQs than under C&D and C&S.[12] Section ***4.2*** illustrates how these lower abatement costs might result in TEQs being the most efficient of the three instruments.

4.2. ENCORE and Total Costs

Fig. 1 is a stylized marginal abatement cost curve, showing the ten most efficient measures for reducing individuals' energy emissions, some of which have a negative cost. An emissions cap is set at a level which requires abatement EE*. When implemented, Instrument 1 generates high levels of ENCORE, which in turn results in the five most efficient measures being discovered and implemented. However, Instrument 2 fails to generate such high levels and, as a result, measures 3, 5, 7 and 8 are not discovered and abatement is achieved through the implementation of measures 1, 2, 4, 6 and 9. Fig. 2 shows the marginal abatement costs curves for Instruments 1 and 2, with the increased ENCORE under the former leading to abatement costs that are lower by amount A. In Fig. 3 the curves are further stylized with abatement costs under Instrument 2 equal to A + B + D, abatement costs under Instrument 1 equal to B + C + D and the difference equal to A − C.

The total cost of an instrument is its *abatement* costs (AC) plus the sum of its implementation and participation costs, here referred to as *other costs* (OC). Using this terminology, TEQs will be more

[11] Organizations are discussed in Section ***4.8***.

[12] Fleming and Chamberlin, 2011 propose that TEQs would also engender a (greater) sense of "common purpose". The author remains unconvinced of the intelligibility of this concept. However, a separate analysis is required as, unfortunately, there is not space here for the detailed discussion required.

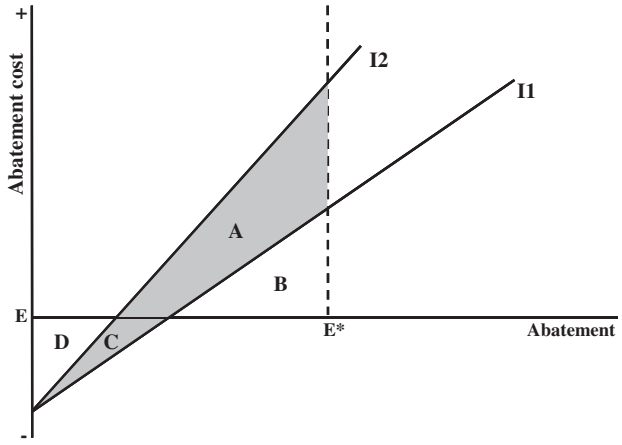

Fig. 3. Further stylized marginal abatement cost curves for I1 and I2.

efficient than C&D or C&S (C&D/S) if

$$AC_{TEQs} + OC_{TEQs} < AC_{C\&D/S} + OC_{C\&D/S}$$

In other words, TEQs will be more efficient if its abatement costs are lower than those of C&D/S by an amount greater than that by which its other costs are higher, that is if

$$OC_{TEQs} - OC_{C\&D/S} < AC_{C\&D/S} - AC_{TEQs}$$

If, in Fig. 3, TEQs and C&D/S are substituted for, respectively, Instruments 1 and 2,[13] then TEQs will be more efficient if

$$OC_{TEQs} - OC_{C\&D/S} < A - C$$

4.3. ENCORE and Irrational Abatement

One of the components of ENCORE is the notion of "responsibility", which Defra (2008, p. 39) discusses as follows.

> A rational approach to trading would include an understanding that the overall level of emissions is set by the cap and that the best way of taking 'responsibility' for ones own level of emissions is to engage in the personal carbon trading market. This is important, as a sense of personal responsibility has been highlighted as a key benefit of personal carbon trading…However, if the sense of responsibility means that individuals see their allocation as a limit or target, or a reflection of what a 'fair' level of personal emissions is, then this will prevent trading from achieving least cost abatement, and this will represent an additional cost arising from the implementation of personal carbon trading.

The additional cost arises from above-allocation individuals engaging in what Defra refers to as "irrational" abatement i.e. reducing their emissions to the level permitted by their carbon unit allocation when it would cost less to emit above this level and purchase units to cover their above-allocation emissions.

Under C&D, there is no individual allocation of emissions rights to treat as an upper limit or target. And whilst C&S does provide individuals with an allocation of rights, it does not provide a mechanism that enables them to ascertain whether and by how much their energy emissions are above or below allocation. However, TEQs does provide such a mechanism, namely S1. Thus, to the extent that individuals engage in S1, there is the potential, not present under C&D and C&S, for them to treat their allocation as an upper limit — and, hence, for irrational abatement.

Whilst irrational abatement is plausible, Defra (2008) does not discuss its likely prevalence and how this is factored into its wider analysis. However, Defra certainly does not argue that such abatement will prevent TEQs' abatement costs being lower than those of C&D (Section ***4.6***). Equally, authors (e.g. Bird and Lockwood, 2009; Fleming and Chamberlin, 2011) who discuss Defra's analysis do not address the likely prevalence of irrational abatement under TEQs.

4.4. More on ENCORE

If, despite any irrational abatement, increased ENCORE under TEQs may result in lower abatement costs, it is important to clarify which of TEQs' features may give rise to increased ENCORE.

When, under TEQs, individuals engage solely in S2, the experience at the point of sale is very similar to that under C&D and C&S, namely a single monetary payment. However, TEQs differs from C&D and C&S in requiring the surrender of carbon units. And as fuel receipts and utility bills under TEQs show the quantity of carbon units surrendered, individuals could, in theory, determine their total energy emissions by summing the emissions on their bills and receipts. However, this difference is not significant as

1. it would be straightforward under C&D and C&S to have emissions associated with an energy purchase printed on fuel receipts and utility bills.
2. calculating emissions from receipts and bills would, in any case, be too laborious for most.
3. there are other ways of determining ones energy emissions (Section 4.5).

If, under C&S, emissions were printed on receipts and bills then, in relation to individual energy emissions, S2 under TEQs would be virtually identical to C&S.[14] That is, under both schemes, individuals would be allocated rights covering their energy emissions, sell them to market makers, transact only in money at the point of sale and receive receipts and bills showing emissions. Thus, if ENCORE is greater under TEQs than under C&S, it can only be because TEQs has the option of S1 and at least some individuals take this option up.[15]

Given that lower abatement costs under TEQs are dependent upon at least some individuals engaging in S1, it is important to understand the factors that favor individuals choosing to engage either in S1 or S2. These are now discussed in a UK context.

4.5. S1 or S2?

At the time of Defra's comparison of TEQs and C&D, it used the shadow price of carbon for policy appraisal, a price based on estimates of the damage costs associated with greenhouse gas emissions. However, due to considerable uncertainties surrounding these estimates, the Department of Energy and Climate Change has introduced a "target-consistent approach" to pricing carbon (DECC, 2009, p. 2). Under this approach, the price of carbon is the estimated marginal abatement cost required to meet a particular emissions reduction target. In fact, the government has developed estimates for two carbon prices: a *traded* price covering abatement under the EU ETS and a *non-traded* price covering abatement in other sectors. As individuals' energy emissions fall into these other sectors, the IPPR uses the non-traded price (Section ***4.7***) which is also used below.

[13] This is not to suggest that TEQs will necessarily result in the lowest possible abatement cost, only that it has a lower abatement cost than C&D.

[14] TEQs and C&S differ in their treatment of COGS and INDIE emissions. See Part 1.

[15] S1 is one reason why ENCORE may also be greater under TEQs than under C&D. C&D also differs from TEQs and from C&S (Section 4.9) in that individuals are allocated auction revenue rather than emission rights.

Three factors favor S1.

1. *Knowledge of energy emissions.* If, under TEQs, individuals are interested to know whether and by how much their energy emissions are above or below allocation, it is only by engaging solely in S1 that they can know this from their carbon statement.
   However, S1 would not be necessary if individuals had alternative means of conveniently determining their energy (i.e. residential + private transport) emissions. Such means may soon be available. The UK government's aspiration is that, by 2017, all households will have a smart meter able to calculate residential emissions and, according to Champion (2008), there is potential for onboard computers to calculate, and for dashboards to display, vehicle emissions.
2. *Bid and offer spread.* Assume that a TEQs scheme covering all gases was implemented in the UK in 2013. Under such a scheme, individuals would be allocated carbon units permitting annual emissions of around 4 tons of carbon dioxide equivalent (t/CO_2e).[16] Assume too that all individuals engage in S2. Finally, assume that individuals' energy emissions are equal to those permitted by the carbon units they are allocated and, thus, that on average, they buy back the same quantity of units they were allocated.[17] In this case, with a non-traded carbon price of £54 t/CO_2 and a bid and offer spread of 5%,[18] individuals would face an average penalty of around £11. In comparison the average penalty under S1 would be zero.
3. *Risk aversion.* For a risk-averse individual, the disutility of a loss is greater than the utility of an equivalent gain. According to Defra (2008, p. 38), when an individual engages solely in S2, she has a roughly even chance of an equivalent gain or loss i.e. that the price at which carbon units are sold at the point of sale will be higher or lower by the same amount than the price at which she sold her units to a market maker immediately upon allocation. If so, then risk-averse individuals would prefer S1.
   However, it has been suggested that risk aversion may be lower when potential losses are low (Erev et al., 2008). Assuming the average carbon price was £54 t/CO_2 and could rise or fall by 30%,[19] individuals would, under S2, face the prospect of a loss or gain of up to around £65. Arguably, for many, this does not represent a significant loss and, if so, may reduce the preference for S1.

Two factors favor a choice of S2.

1. *Understanding.* Some individuals will engage in S2 out of a belief, correct or otherwise, that they will be unable to cope with S1 i.e. with using a carbon card, understanding a carbon statement and trading with market makers.
2. *Time.* As S2 at a petrol station does not involve the use of a carbon card, transaction time will be quicker than under S1. And if all customers engage in S2, queuing time will also be shorter than under S1 (Starkey and Anderson, 2005). Furthermore, under S2, there is no time spent considering carbon statements and trading with market makers. Thus, those individuals who prefer to minimize the time they spend on TEQs will engage in S2.

Ultimately, an individual's choice of S1 or S2 will depend on how they weight these various factors. Whilst Defra (2008, p. 35, 37–38) acknowledges that some individuals may prefer to engage in S2, it makes no assessment of what the S1:S2 split might be (and neither do others who have written on PCT). Instead, in its comparison of TEQs and C&D, Defra assumes, as does the IPPR, that all individuals engage in S1. Under this assumption, abatement costs are at their lowest and so TEQs is at its most efficient. But as not all individuals will engage in S1, Defra and the IPPR compare C&D with an account of TEQs that is implausibly efficient.

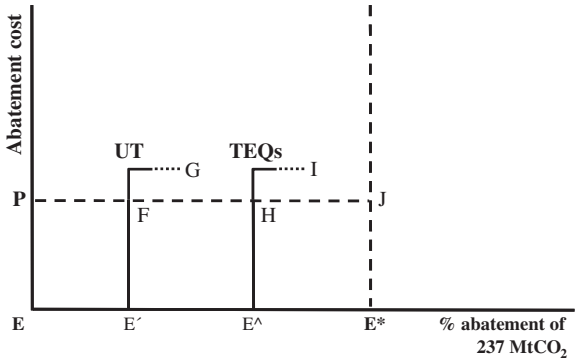

Fig. 4. Marginal abatement cost curves for TEQs and C&D.

4.6. Defra: Comparing TEQs and C&D

For simplicity, Section 4.2 proceeded as if TEQs or C&D was the only existing mitigation instrument and all abatement took place domestically. However, Defra's comparison assumes that TEQs or C&D would be implemented in addition to existing instruments and the UK purchases international credits to assist in meeting its emission reduction targets.[20]

With regard to Defra's analysis, EE* in Fig. 4 represents 2013 abatement achieved through the purchase of international credits in the absence of TEQs or C&D.[21] Defra assumes that the credit price P is the shadow price of carbon (£29/tCO_2) and explores whether implementing TEQs or C&D in 2013 might achieve a portion of abatement EE* at a cost less than P.

Defra suggests that TEQs can raise the visibility of individual energy emissions in three ways.[22] First, TEQs provides *indirect* feedback on emissions at the point of sale. Whereas *direct* feedback occurs in real time (e.g. feedback by a smart meter), indirect feedback is retrospective or prospective (e.g. the display on utility bills or motor fuel receipts under TEQs of the emissions associated with an energy purchase). Second, under S1, an individual's carbon statement provides information on their overall energy emissions. And, third, S1 provides a moment to "stop and think" about one's private transport emissions (Defra, 2008, p. 34–37).

1. *Indirect feedback.* Individuals' energy emissions consist of residential and private transport emissions. Defra argues that the *direct* feedback provided by smart meters will raise the visibility of residential emissions such that no additional visibility would result from the *indirect* feedback under TEQs on utility bills. Defra further argues that requiring petrol pumps and motor fuel receipts to display emissions associated with a fuel purchase would provide the

[16] 3.8 t to be precise. This assumes (1) individuals eligible for rights are those 18 and over (2) eligible individuals number 50.3 million (Office for National Statistics, 2009a) (3) eligible individuals are responsible for the same percentage of energy emissions as in 2008 i.e. 40% (4) UK inventory emissions are 566 Mt/CO_2e (DECC, 2010b) and (5) energy emissions make up the same percentage of total emissions as in 2008 i.e. 85%.

[17] Individuals' energy emissions could be higher (lower) than those permitted by the carbon units they are allocated if, on aggregate, they purchase units from (sell units onto) the carbon market (Part 1).

[18] From Defra (2008, p. 38).

[19] From Defra (2008, p. 39).

[20] Arguably, TEQs or C&D would be best implemented as a sole UK-wide trading scheme. However, in practice, they would have to co-exist with the EU ETS which covers around 50% of UK CO_2 emissions. Thus, implementation of a UK-wide scheme would entail substantial double regulation (Starkey, 2008, p. Ev 22).

[21] Whilst Defra (2008) considers the option of the UK meeting its target solely through domestic abatement, it regards the purchase of credits as more likely. Thus, only this latter option is discussed here.

[22] "Visibility" is a similar concept to the "carbon consciousness" component of ENCORE.

same indirect feedback on private transport emissions as TEQs, but at a fraction of TEQs' implementation costs.

2. *Information on overall emissions.* Under S1, the carbon statement provides individuals with feedback on their overall energy emissions. However, Section **4.5** notes the potential to receive such feedback from alternative sources.
   S1 enables individuals to compare their energy emissions to the national average and Defra argues those who realize they have above-allocation emissions may be motivated to undertake abatement they would not have undertaken had they not been able to make the comparison. However, if this leads to irrational abatement (Section 4.3), the cost of abatement will rise.
3. *"Stop and think" moment.* Defra suggest that surrender by carbon card under S1 will make individuals purchasing motor fuel more aware of the associated emissions than under C&D i.e. they are more likely to stop and think about (reducing) these emissions.

Defra estimates that, by 2013, existing instruments will have reduced individuals' energy emissions to 237 Mt/CO_2 and estimates the portion of EE* that TEQs could, as a result of increased visibility, deliver at an abatement cost less than P as up to 5% of this 237 Mt/CO_2 sum.

> A reduction in personal carbon emissions greater than 5% purely as a result of the raised visibility delivered by personal carbon trading is unlikely. Evidence for effectiveness of indirect feedback provides suggested savings of between 0 and 10% of personal carbon emissions…Given that personal carbon trading would exist alongside other policies that deliver visibility, notably smart metering, and that much of the low hanging fruit in terms of technological measures will already have been delivered by other policies, additional savings, at the high end of this range, are highly unlikely to be realized. A figure of a 5% …can be used as an upper bound for the additional abatement…(Defra, 2008, p. 66).

In Fig. 4, EE′FG and EE″HI represent Defra's marginal abatement cost curves for, respectively, C&D and TEQs. Given Defra's view that much low-hanging fruit will have been picked by existing instruments, no negative-cost abatement is assumed. Instead, under C&D, it is assumed that an amount of zero-cost abatement (EE′) is followed by abatement more costly than P. And, under TEQs, it is assumed that a larger amount of zero-cost abatement (EE^) is, again, followed by abatement more costly than P. Thus, abatement costs under TEQs are lower than those under C&D by E′FHE^. Defra (2008, p. 70) sees much of the additional zero-cost abatement under TEQs resulting from behavior change e.g. switching off lights when leaving a room, and cycling or walking to the local shops instead of driving (Defra, 2008, p. 25).[23]

Defra's low, central and high estimates for zero-cost abatement under TEQs (EE^) are, respectively, 0, 2.5 and 5% (Table 4). However, although Defra (2008, p. 62) argues that zero-cost abatement will also take place under C&D (EE′), no estimate range is offered. A low, central and high estimate of, 0, 0.5 and 1% is assumed here.

Table 4 sets out what size EE′ and EE^ must be for the total cost per ton of this abatement under, respectively, C&D and TEQs to equal P. Abatement under TEQs must then be greater than E′E^ for it to have a lower total cost than C&D. Even taking the low estimate for TEQs' implementation and participation costs, EE^ must be over 23% for the total cost per ton of abatement under TEQs to equal P, and E′E^ must be greater than 22.2% for TEQs to have a lower total cost than C&D. Given it estimates the maximum value of EE^ at 5%, Defra concludes that "it seems unlikely that [TEQs] would be able to past the cost-effectiveness test" (Defra, 2008, p. 70).

4.7. IPPR: Comparing TEQs and C&D

Like Defra, Lockwood (2009) assumes that all individuals engage in S1 and that TEQs and C&D have the same sort of marginal abatement cost curves i.e. zero-cost abatement followed by abatement more costly than P. However, unlike Defra, Lockwood assesses the abatement potential of TEQs in 2020 rather than 2013 and assumes P equals the non-traded carbon price (£60/tCO_2).[24]

Based on a review of behavioral economics and social psychology (Capstick and Lewis, 2008), Bird and Lockwood (2009, p. 22) argue that, in addition to increased visibility, TEQs may give rise to other effects that lead to greater abatement

> through changing preferences by spreading norms about appropriate behavior and through effects associated with perceptions of fairness and co-operation.[25]

Given this, and based on research by the Committee on Climate Change (CCC) and others, Lockwood estimates EE^ (Fig. 4) under TEQs in 2020 at 3.5–8.5%. Under his central (high) estimate for TEQs' implementation and participation costs, Lockwood calculates that EE^ would have to be 10.3% (13.7%) for the total cost per ton of abatement to equal P. However, under his low estimate, EE^ would have to be 6.8%. And for TEQs to have a lower total cost than C&D, E′E^ must be greater than 6.4%. Thus, if (1) Lockwood's low estimate for TEQs' implementation and participation costs is realistic and (2) EE′ under C&D is less than 2.1%, then it is possible for the total cost per ton of abatement under TEQs to be both lower than that under C&D and lower than P. Nevertheless, Bird and Lockwood (2009, p. 46) conclude that

> PCT will be a risky policy in any circumstance, because of the inherently unknowable dimensions of its [additional abatement] effects and the range of possible [other] costs. A government will only consider it seriously if other policies are seen to be failing or to be unable to reach deeper emissions cuts, and when the political pressure to act on climate change increases. This could be some time off, but policymakers should keep open the option of some version of PCT in the future.

Thus, although they reach somewhat different conclusions regarding the potential for the abatement of individual energy emissions under (an implausibly efficient version of) TEQs, neither Defra nor the IPPR supports its implementation.

4.8. Organizations

On the basis of Defra and the IPPR's assumption that all organizations will engage in S2, organizations' abatement costs under an economy-wide TEQs scheme would be no different to those under C&D. Thus, from Defra's perspective, the criticism of Fleming and Chamberlin (2011, p. 42) that it does not consider organizations in its analysis carries little weight. However, Fleming (2007, p. 4) assumes that all organizations will engage in S1 stating, with regard to organizations purchasing carbon units, that

> they will generally do so in the easiest possible way — that is, by

[23] Others view the cost of behavior change as negative (CCC, 2008, p. 226). Of the three ways in which Defra suggests TEQs might raise visibility, only the second has the potential to bring about, for example, greater switching off of lights. (The third relates to transport emissions and the introduction of smart meters mean the first will fail to result in additional visibility.)

[24] Lockwood offers no explanation for his assumption that there are no negative-cost abatement opportunities under TEQs, nor any between £0 and £60/tCO_2.

[25] Unfortunately, the review fails to apply the insights of behavioral economics and social psychology to the important issue of preferences for S1 or S2 (Section **4.5**).

> giving instructions to their bank. Each week, the bank will take part in the Tender[26]...where it will buy enough…units to meet the needs of all its customers.

Given that S2 requires no effort at all, it seems odd to characterize S1 as the "easiest possible way" for organizations to participate in TEQs and implausible to suggest that all will engage in S1. But even assuming they did, what would be the implications for the efficiency of TEQs? Discussion around participation in the UK's CRC Energy Efficiency Scheme (CRC) is instructive here.

The CRC, which began operation in 2010, is a mandatory emissions trading scheme to improve energy efficiency in large public and private sector organizations not regulated by the EU ETS. It has around 5000 participating organizations. Under the CRC, organizations are required to engage in a process similar to S1. It was originally proposed that organizations with a half hourly metered electricity consumption of at least 3000 MWh per year should be required to participate but the threshold was subsequently raised to 6000 MWh so as to exempt small energy users "for whom administrative costs would outweigh energy efficiency benefits" (DECC, 2010a, p. 34). This suggests that whilst S1 under TEQs might reduce the total costs of larger organizations,[27] it might actually increase those of the millions of smaller organizations. Thus, even if in the unlikely event that all organizations were to engage in S1, it is by no means clear that organizational total costs would be lower under S1 than under S2 and, hence, under C&D.

4.9. C&S

As noted in Section 4.5, the experience at the point of sale is the same under both C&D and C&S and, thus, the only difference between them is that, under C&D, individuals are allocated revenue whilst under C&S, they are allocated rights. To date, no comparison has been made of likely abatement costs under the two instruments but C&S will have lower *abatement* costs only if the allocation of rights leads to greater ENCORE than the allocation of revenue. And C&S will have lower *total* costs only if its abatement costs are lower than those of C&D by an amount greater than that by which its other costs are higher. A similar point is made at the Cap and Share website (Cap and Share, 2011) which notes

> [Cap & Dividend] is a simpler system, and hence cheaper…The advantage of Cap & Share over Cap & Dividend is purely psychological....It is for the government and the public to decide whether this is worth the extra complication and cost of C&S over Cap & Dividend.

5. Possible Arguments for TEQs?

In the light of Defra and the IPPR's rejection of TEQs on efficiency grounds, this section outlines three possible arguments for TEQs. To date, none has received a detailed exploration in the literature.

5.1. Higher Carbon Price

The £60/tCO_2 price used by Lockwood is the "central" 2020 non-traded carbon price. If instead the "high" price of £90 was used, then E′E^ would have to be greater than 4.3% (rather than 6.4%) for TEQs to have lower total costs than C&D.[28] Under the UK's target-consistent approach to carbon pricing, the more demanding the emission-reduction target, the higher the carbon price (DECC, 2009, p. 37). Thus, proponents of TEQs might attempt to argue that the UK target should be more demanding, that a "high" carbon price should be used, and that together these would result in E′E^ being sufficiently large to make TEQs cheaper than C&D. However, whilst Fleming and Chamberlin (2011, p. 44–45) note that the comparison of TEQs and C&D is sensitive to the carbon price, they stop short of proposing that a higher price be used.

5.2. Peak Oil

Heinberg (2006) and Hirsch (2008) have argued not only that conventional oil supply will peak in the near future but that, in a post-peak world, developed nations will need to ration oil. Fleming (2007) further argues that, post peak, an electronic allocation system such as that proposed for TEQs will be required to ration *oil rights* and, thus, that the marginal cost of also using the system to allocate *emissions rights* would likely be small. Thus, even if, in the *absence* of an electronic allocation system for oil rights, TEQs is not the most cost-effective means of emission reduction, proponents might argue that it will become so if it operates in the *presence* of such a system.

A detailed study on oil peaking (Sorrell et al., 2009, p. x) concluded that the various uncertainties surrounding oil production make it impossible to predict the timing of the peak with precision but that

> On the basis of current evidence we suggest that a peak of conventional oil production before 2030 appears likely and there is a significant risk of a peak before 2020.

Thus, near-future peaking cannot be ruled out. Nevertheless there has been little discussion to date as to whether, in such an event, oil rationing might be required. This is an important issue into which further research would be valuable.

5.3. Public Support

Chamberlin (2008) suggests that, whilst TEQs, C&D and C&S all set carbon budgets, given the deep cuts in emissions that will be required to effectively tackle climate change, TEQs may be the only instrument capable of maintaining public support for staying within a demanding carbon budget i.e. the only *effective* instrument. Presumably this would be so as a result of TEQs engendering a (significantly) greater level of ENCORE than the other instruments. The next section explores whether there is any support for Chamberlin's hypothesis in the survey work that has been conducted to date on the public acceptability of PCT.

6. Public Acceptability

Five surveys comparing PCT with alternatives are described and discussed below.

6.1. Survey Description

6.1.1. Owen et al.

Owen et al. (2008) conducted a series of 12 focus groups involving 92 participants drawn from the seven segments in Defra's

Table 5
Rating of three instruments in survey by Owen et al.

Options	PCAs	C&D	Tax and share
Very positive (%)	2	1	1
Quite positive (%)	24	7	12
Neither positive nor negative (%)	18	24	29
Quite negative (%)	13	34	24
Very negative (%)	41	34	33

[26] Fleming's terms for the auction of carbon units.
[27] It would be possible to subsume CRC within an economy-wide TEQs scheme.
[28] DECC (2009, p. 65) notes that "The high to low [price] ranges of both the 2030 and 2050 values cover most of the available [abatement cost] model estimates for relevant emissions trajectories".

environmental segmentation model (which classifies the public according to environmental values and attitudes). In the focus groups, participants were asked to compare three instruments: PCAs, C&D and an upstream carbon tax under which revenue is allocated to individuals on an equal per capita basis ("Tax and Share"). The results of this comparison are set out in Table 5 (Owen et al., 2008, p. 46).

Note that, in terms of equity, PCAs is not equivalent to C&D and Tax and Share, as auction revenue is not allocated to individuals on an equal per capita basis (Part 1, Section **5**).[29]

6.1.2. Harwatt

Harwatt (2008) compared a PCT scheme and a carbon tax as alternative means of reducing personal road emissions. Under Harwatt's *Tradable Carbon Permit* (TCP) scheme, emissions rights covering personal road emissions are allocated to individuals on an equal per capita basis. However, under her fuel price increase (FPI), the tax revenue is not allocated on the same basis but is, instead, hypothecated for investment in public transport. Thus, again, the schemes compared are not equivalent in terms of equity. Harwatt (2008, p. 24) conducted interviews with 60 individuals and found that

> Respondents were much more positive about the TCP scheme than the FPI. In addition, the average ratings revealed the TCP scheme to be more favorable in every aspect. Hence, whilst fuel price increases and tradable permit schemes are very similar in theory, the public response revealed stark differences in terms of how the policies were perceived.

6.1.3. Bristow et al.

Bristow et al. (2008, 2009) conducted a computer-based stated preference exercise with 208 participants. Each was asked to compare two versions of PCT and then one version of PCT and one version of a carbon tax, with the versions compared varying from participant to participant. The versions of PCT varied in terms of, for example, how emissions rights were allocated and the versions of the carbon tax varied in terms of, for example, how the tax revenue was used. Thus, an insight could be gained into the design features of both instruments favored by participants. For example, with regard to PCT, participants preferred an option of "children receiving an allowance and extra support for those with greatest needs"[30] and, with regard to a carbon tax, participants preferred revenue recycling into measures that would further reduce emissions either through spending on technology or on measures to make behavioral change easier (Bristow et al., 2008, p. 55).

Again, the versions of PCT and a carbon tax with which each participant was presented are not equivalent in terms of equity.

6.1.4. Bird et al.

Bird et al. (2009) conducted an online survey of 1081 individuals who were asked to compare three instruments: a PCT scheme, a carbon tax and upstream trading covering individual emissions (Table 1). Participants were asked their views on the introduction of each instrument ("initial") and again once all three had been introduced ("final"). Their views are set out in Table 6 (Bird et al., 2009, p. 17).

Once again, the instruments compared are not equivalent in terms of equity as, under the carbon tax and upstream trading scheme, the revenue is not allocated to individuals. The authors state that

Table 6
Rating of three instruments in survey by Bird et al.

Options	Initial			Final		
	PCT	Carbon tax	Upstream trading	PCT	Carbon tax	Upstream trading
Tend to support/strongly support (%)	31	19	23	25	20	24
Neither support nor oppose (%)	20	17	23	29	24	29
Tend to oppose/strongly oppose (%)	40	58	41	42	53	44
Not sure (%)	8	6	12	4	3	4

> In our research, we did not suggest that revenue from taxation or upstream trading would be returned in this way. We believe that based on existing policy and attitudes within the Treasury that this represented a politically realistic comparison for respondents to consider (Bird et al., 2009, p. 16).

However, if the authors believe the Treasury would be prepared to countenance an instrument as novel as PCT, one wonders why they hold it would not countenance allocating revenue to individuals when doing so is arguably less novel and would be equivalent, in equity terms, to implementing PCT.

6.1.5. Jagers et al.

Jagers et al. (2010) asked 2000 Swedes whether they would prefer to keep the current Swedish carbon tax or shift to a PCA scheme. 66% stated they would prefer to keep the current tax. The authors found this unsurprising noting that "people have a tendency to favor the state they are currently in" (Jagers et al., 2010, p. 415). Once more, the two schemes compared are not equivalent in terms of equity.

6.2. Survey Discussion

In Jagers et al.'s survey, an actual carbon tax is preferred to a hypothetical PCT scheme but in the surveys conducted by Owen et al., Harwatt and Bird et al., support for a hypothetical PCT scheme is equal to or higher than for a hypothetical upstream trading and/or a carbon tax.[31] However, the initial support for TEQs falls off slightly over the course of the survey conducted by Bird et al. and slightly more participants are very negative about PCAs than upstream trading or a carbon tax in the survey conducted by Owen et al. But, whilst these surveys yield some interesting insights into public attitudes, the comparisons offered to participants are not able to yield any insight into a crucial research question.[32]

Alternative instruments can be equivalent in terms of equity. For example, TEQs-EAR, a variant of TEQs under which auction revenue is allocated to individuals is equivalent to C&D, C&S and Tax and Share (Part 1). In other words, any particular conception of equity can be delivered using alternative instruments. And, thus, if survey participants are presented with a selection of instruments that are equivalent in terms of equity and which they understand to be so equivalent, then an insight can be gained into which particular instrument they favor to deliver *a particular conception of equity*. However, this insight cannot be obtained from any of the above surveys as the instruments presented do not have equivalent allocations.

In terms of equity, the instruments compared by Owen et al. are the most nearly equivalent and the fact that they are not exactly so would, arguably, not matter had participants perceived them to be

[29] In his description of PCAs (Part 1), Hillman makes no mention of what is done with the auction revenue. Owen et al. (2008, Appendix 15) told participants only that the revenue "would allow the government to reduce the level of taxes in the economy".

[30] By this the authors mean parents receiving an additional allowance because they have children (Bristow et al., 2009, p. 1826).

[31] As each participant, in Bristow et al.'s survey was presented with a different version of both PCT and a carbon tax, straightforward comparisons are not possible.

[32] The survey by Wallace et al. (2010) also provide useful insights into public attitudes to PCT but is not discussed in detail here as it does not compare PCT with other instruments.

exactly so. However, Owen et al. (2008, p. 50) note that some participants felt that PCT "may be more equitable than the other two options", when, in fact, C&D and Tax and Share are, from an egalitarian perspective at least, more equitable.

Furthermore, in none of the surveys were participants given information about the comparative implementation and participation costs of the instruments. It is interesting to speculate how participants would respond if they were asked to compare TEQs-EAR and C&D and it was made clear to them that (1) the instruments were equally equitable and (2) the implementation and participation costs of TEQ-EAR might be fifteen times those of C&D. Finally, from the survey work done to date, there appears little obvious support for Chamberlin's hypothesis.

7. Conclusion

Part 1 of this survey shows that TEQs, C&D and C&S can be equivalent in terms of equity. Thus, Part 2 seeks to establish if these instruments can be differentiated in terms of their efficiency or effectiveness. Sections **2–4** show that, whilst the studies by Defra and the IPPR reach somewhat different conclusions regarding the efficiency of TEQs, neither endorses its implementation. In the light of this, proponents of PCT might seek to make a case for implementation by developing an efficiency or effectiveness argument such as those set out in Section **5**. However, to date, proponents have not, at least in the view of this author, made a compelling case for the implementation of PCT.

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