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White certificate schemes: Economic analysis and interactions with the EU ETS

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ABSTRACT

This paper examines the economic, environmental and distributional impacts of an idealised tradable white certificate (TWC) scheme and shows how the impacts are modified when the scheme operates in parallel with the EU emissions trading scheme (EU ETS). It uses simple graphical techniques to assess whether a TWC scheme will increase, decrease or have an ambiguous effect on electricity demand, wholesale and retail electricity prices, carbon emissions and investment in energy efficiency, paying particular attention to the interpretation of 'additionality'.

Following a comparable analysis of the impact of the EU ETS, the paper examines the implications of introducing a white certificate scheme in a country that is already participating in the EU ETS. It compares the effect of this combination of instruments to that of the EU ETS operating in isolation. It concludes that there is no necessary link between the price of white certificates and marginal cost of energy efficiency investment, the price of electricity or the ability of the suppliers to eliminate free riders from their subsidy schemes. Also, a TWC scheme will make no contribution to reducing global carbon emissions unless and until it leads to a tightening of the EU ETS cap.

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1. Introduction

This paper addresses two questions. First, what does basic economic theory tell us about the economic, environmental and distributional impacts of an idealised tradable white certificate (TWC) scheme? Second, how are these impacts modified when the scheme operates in parallel with the EU emissions trading scheme (EU ETS)? These questions are explored through elementary graphical models of the markets for electricity and energy efficiency.

The paper abstracts from the empirical details of individual schemes and makes a number of standard but radically simplifying assumptions regarding the operation of the relevant markets. In particular, much of the analysis assumes that markets operate without any significant 'barriers' or market failures. This approach may seem odd to readers familiar with energy efficiency policy, since the multiple and reinforcing barriers to energy efficiency form the *raison d'etre* for white certificate schemes and related instruments (Sorrell et al., 2004). Nevertheless, while these barriers influence the response to market and regulatory signals and are relevant to both the design and justification of policy interventions, they do not significantly affect the economic impacts of those instruments that are the main focus of this paper (described below). We therefore consider that much insight can be gained from a simplified approach, which can then form the basis for more detailed investigation of particular schemes, including economic modelling.

TWCs are attracting increasing interest within the EU as a cost-effective means of encouraging investment in energy efficiency by energy suppliers (Farinelli et al., 2005; Harrison et al., 2005; Langniss and Praetorius, 2006; Oikonomou et al., 2007; Vine and Hamrin, 2008). Variations of this instrument are currently in operation in Italy and the UK, about to be introduced in France and under serious consideration in Denmark and the Netherlands.[2] In this context, the interactions between such schemes and the EU ETS become a key policy concern (Sorrell, 2003). These interactions may occur through a number of routes, but most importantly through the operation of electricity markets. The paper, therefore, investigates the behaviour of an idealised national TWC scheme that is aimed solely at improving the efficiency of electricity use. To provide an

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[2] A number of non-European countries are also expressing interest in this type of instrument, with schemes in operation in Australia (New South Wales) and the United States (Connecticut) (Vine and Hamrin, 2008). White certificates are termed 'energy saving certificates' in the US.

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Box 1–Key variables

Price variables:

- wholesale electricity prices,
- retail (consumer) electricity prices,
- EU ETS allowance price and
- white certificate price.

Quantity variables:

- electricity demand,
- renewable electricity generation,
- non-renewable electricity generation,
- carbon dioxide emissions,
- investment in end-user energy efficiency and
- investment in new renewable energy generation.

Distributional variables:

- impacts on electricity producers,
- impacts on producers of energy efficient equipment and
- impacts on electricity consumers.

organising framework, the paper focuses on a small number of *price*, *quantity* and *distributional* variables, which are summarised in Box 1. The impacts of the policy instruments on each variable are explored using simple graphical techniques, with distributional impacts being assessed through the standard measures of consumer and producer 'surplus'.

The paper first examines the potential effect of a TWC scheme operating in isolation and then examines the effect of the EU ETS in isolation. The TWC scheme is treated in more detail than the EU ETS, since its impacts are both less familiar and more complex. The paper then examines how these effects may be modified when both instruments operate in parallel. In each case, the paper assesses whether the variables listed in Box 1 are likely to be *increased*, *reduced* or *unaffected* by the instrument or instrument combination, or whether the outcome is *ambiguous* and therefore depends on individual circumstances. These results are summarised in tables, which provide a useful overview of the analysis. Where possible, commentary is provided on the likely magnitude of these different effects. The paper pays particular attention to the impact of a TWC scheme on national, European and global carbon emissions.[3]

2. Economic analysis of an idealised white certificate scheme

This section provides a simplified, partial-equilibrium analysis of the impact of a TWC scheme on the markets for electricity and energy efficiency. The focus is on a national TWC scheme operating in isolation from other trading schemes and within a national electricity market that is isolated from international competition. It is assumed that the TWC scheme imposes energy efficiency obligations *solely* on the electricity sector. In practice, existing and proposed TWC schemes are not confined to electricity markets, both because they impose obligations on retailers of other energy carriers (notably gas) and because they allow electricity retailers to meet their obligations by investing in projects that affect energy carriers other than electricity. However, this simplification allows us to isolate those effects that are most relevant for studying the interactions of a TWC scheme with the EU ETS.

The analysis also assumes that the obligations to achieve energy savings fall on *retailers* of electricity. These are responsible for the purchase of wholesale electricity and the sale to end-users, but since they do not own the distribution network they have no monopoly elements.[4] Retailers are assumed to be operating in a liberalised and competitive market where electricity is supplied at marginal cost. The TWC scheme imposes obligations on retailers to achieve a certain quantity of 'electricity savings' through improvements in the efficiency of electricity use by consumers. No restriction on the type of projects or the location of consumers is assumed. Each project is assumed to involve some form of subsidy to the host consumer, to encourage them to adopt the relevant technologies.[5] These subsidies are provided by the electricity retailers, who recover the costs by increasing electricity tariffs for all consumers.

As the above description suggests, a TWC scheme is analogous to a traditional demand-side management (DSM) scheme in that it requires electricity companies to invest in projects that reduce the demand for their product. In this sense, the tradable certificates simply provide a mechanism for achieving the electricity savings target at least cost. This means that the conceptual analysis of a TWC scheme can draw upon the extensive literature on the economics of DSM schemes (Gillingham et al., 2004; Nadel and Geller, 1996). There are also some useful parallels with the operation of green certificate schemes (Bye, 2003; Jensen and Skytte, 2002a, b; Morthorst, 2001, 2003). The following discussion draws in particular upon the work of Braithwait and Caves (1994) and Huber et al. (2005).

2.1. Price and quantity effects in a national electricity market

The demand for electricity and electricity conversion equipment is derived from the demand for the services (e.g. heat, light and cooling) that these, in combination, provide. The same level of electricity service can be provided from an inefficient conversion technology with higher electricity use, or an efficient conversion technology with lower electricity use. Hence, the attribute of conversion technologies that is of interest is their energy efficiency, and this can be represented as a 'market' for energy efficiency measures ('EEM'). In practice, consumers rarely purchase 'energy efficiency' in isolation, but instead purchase products and services that have multiple attributes, including energy efficiency. Also, the energy efficiency of services such as heating is not determined solely by the attributes of conversion devices but also by the attributes of the whole system, such as the thermal insulation in a building. The notion of a market for EEM is, therefore, an abstraction, but nevertheless a useful one.

Households are assumed to purchase the combination of electricity and EEM that maximise their welfare. Firms and

[3] This paper is based on a comprehensive analysis of the interactions between white and green certificate schemes and the EU ETS, conducted on behalf of the European Commission (Harrison et al., 2005). Readers interested in exploring these issues in more detail should refer to this report—available at http://ec.europa.eu/environment/climat/pdf/ec_green_final_report051117.pdf.

[4] The model for this analysis is the current electricity market arrangements in the UK. Market arrangements are different in other Member States and may make it more appropriate to impose obligations on other parties, such as electricity distributors. This is the case, for example, with the Italian TWC scheme (Pagliano et al., 2003; Pavan, 2002).

[5] This is a considerable simplification of real-world arrangements, where retailers meet much of their energy-saving obligations through contractual arrangements with third parties, including managers of housing stock, suppliers, installers and retailers of energy efficiency equipment, and energy service companies (Klevnas et al., 2006).

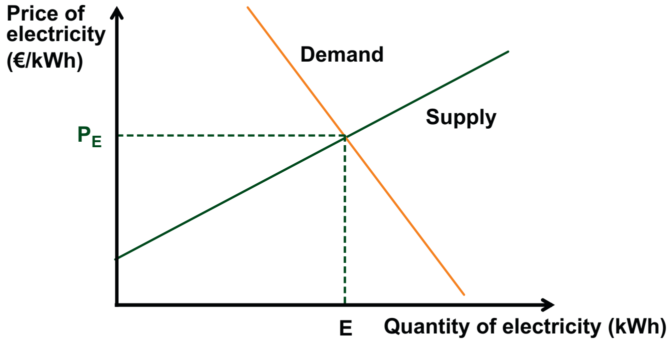

Fig. 1. Retail electricity market prior to the introduction of a TWC scheme.

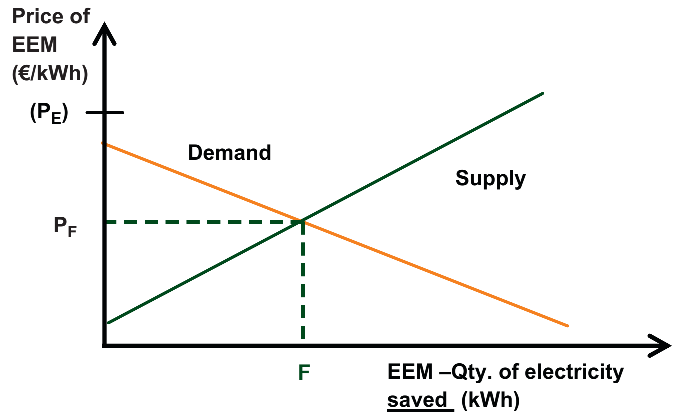

Fig. 2. Energy efficiency market prior to the introduction of a TWC scheme.

commercial organisations are assumed to purchase the combination that minimises their production costs. Market failures in both markets are initially ignored, although it is recognised that these are both extensive and important (Sorrell et al., 2004).

2.1.1. The electricity market

Fig. 1 illustrates the initial equilibrium of demand and supply in the *retail* electricity market. Prior to introduction of the TWC scheme, a quantity of electricity E is supplied at retail price P_E.

The demand curve represents consumers' marginal willingness to pay for electricity, while the supply curve represents the marginal cost of supplying electricity—which is the sum of generation, transmission, distribution and retail costs. The demand and supply curves apply to the short term, when the underlying capital stock is largely fixed. The supply curve is conditional on the existing set of generation plant, while the demand curve is conditional on the existing set of electricity—using equipment that embodies a certain level of efficiency in the use of electricity (in other words, a certain level of EEM). Both curves are theoretical constructs that represent the relationship between price and quantity that would exist in the electricity market if the prices of all other goods—including energy efficiency—were held constant.

In the short term, electricity generators will only supply electricity if the wholesale price exceeds their marginal cost. Increases and decreases in wholesale electricity prices will lead to changes in the plant mix used to meet demand. Similarly, electricity consumers will only consume electricity if the retail price exceeds their marginal valuation. Consumers will respond to increases (or decreases) in the retail electricity price by decreasing (or increasing) their consumption of electricity through measures such as turning lights off. Since electricity consumers are generally unresponsive to price changes in the short term, the demand curve could potentially be represented by a vertical line.

2.1.2. The energy efficiency market

Fig. 2 illustrates the market for those EEM that influence consumers' electricity consumption. Here, one unit of EEM represents 1 kWh/year that the measure allows the customer to save. The savings are measured against the electricity consumption required to meet a corresponding level of electricity service demand with a less efficient technology.

The demand curve represents the marginal benefit of investment in energy efficiency to consumers, or their marginal willingness to pay for EEM. This is assumed to decline with the level of EEM installed. As with electricity, the demand curve represents the relationship between price and quantity that would exist in the EEM market if the prices of all other goods—including electricity—were held constant. The supply curve represents the marginal cost of supplying EEM—where the producers in this case are the suppliers of EEM. It is assumed that the EEM market is competitive and measures are supplied at marginal cost.

Cost in this case is measured in €/kWh saved and represents the present value of capital, installation, operating and maintenance costs of the EEM for an additional kWh saved. For those investments, such as thermal insulation, which are 'pure' EEM, the cost represents the full costs of the measure. For those investments, such as refrigerators, where energy efficiency is simply one attribute of a technology, this represents the additional cost of an energy-efficient option. In the absence of the TWC scheme, consumers purchase a quantity F of EEM at a price P_F.

2.2. The effect of a white certificate scheme on the energy efficiency market

It is assumed that the TWC scheme specifies a target in terms of the total saving required in electricity consumption (Q), but (as in most existing and proposed TWC schemes) this target makes no reference to historic or counterfactual baselines for aggregate consumption by a consumer group. Instead, the target refers to the electricity saving required from investment in individual electricity-saving *projects*, such as the installation of energy-efficient light bulbs. Each individual project leads to an estimated quantity of electricity savings that is implicitly measured against a project-specific counterfactual baseline of electricity consumption. In principle, these electricity savings should be *additional* to those that would have taken place in the absence of the TWC scheme. But whether this is the case in practice will depend on how the requirement for 'additionality' is interpreted and operationalised by the regulator (Box 2).

With this formulation, a target quantity of electricity savings (Q) effectively translates into a target demand for EEM (F'). But if the regulator uses 'dynamic baselines' (see Box 2), the additional demand for EEM (Q) should be *independent* of the demand in the absence of the scheme (F). In principle, the demand for EEM in the absence of the scheme would be higher if electricity prices were higher (demand curve shifts right) and lower if electricity prices were lower (demand curve shifts left).[6] But in each case, the TWC scheme should lead to *additional* investment in EEM, above and beyond what would have taken place in the absence of the scheme. Total energy savings with the TWC scheme (F') should then exceed the energy savings without the TWC scheme (F) by an

[6] Such changes could also be stimulated by other factors, such as the introduction of minimum efficiency standards.

Box 2–Interpreting additionality

The certification of energy savings from individual energy efficiency projects involves two types of risk. First, there is the risk of certifying energy savings that are not additional, in that they would have occurred in the absence of the TWC scheme (a Type II error). Second, there is the risk of not certifying energy savings that are genuine (a Type I error). Type II errors reduce the energy savings achieved by the TWC scheme and divert subsidies away from projects that provide genuine savings, while Type I errors deny funding to worthwhile projects and increase aggregate costs. The methodology for estimating baselines and verifying additionality must achieve an appropriate balance between the two.

There are at least two interpretations of 'additionality' (Baumert, 1998). The first, *financial additionality*, refers to whether a project would have taken place in the absence of financial support from (in this case) the TWC scheme. Making this criterion operational is problematic, not least because the most cost-effective projects are the least likely to be additional.

The second interpretation, *environmental additionality*, is not a yes/no decision but relates to the quantity of energy savings that can be attributed to a particular project over a specified period of time. It represents the difference between a *baseline scenario* for energy consumption and the *measured or estimated consumption* following implementation of the energy-saving project. The key to environmental additionality is, therefore, the project-specific baseline, which may be based on historical data or forecasts, and may refer to either relative (e.g. kWh/houshold) or absolute (e.g. kWh) energy consumption.

A key issue for baseline construction is whether the baseline is fixed (*static baseline*) or whether it is updated on a regular basis to allow for changes in various factors that affect energy consumption (*dynamic baseline*). These could include weather conditions, occupancy patterns and user behaviour, which may need to be monitored at the appropriate level. More controversially, the baseline could be updated to allow for changes in those factors that could reduce or eliminate the financial additionality of the energy-saving project. For example, increases in energy prices could make it more likely that a consumer will invest in energy efficiency, or higher standards of energy efficiency may be required by government regulation. Such *ex-post* changes could increase the 'environmental integrity' of the scheme, by increasing the probability that the certified energy savings are additional. At the same time, it would introduce considerable uncertainty over the value stream from energy-saving investments and greatly increase the risk to potential investors.

Related to the baseline is the *crediting lifetime*, or the period over which certificates can be generated by a project. This may be expected to vary with between technologies and may be less than the technical lifetime of the project. Since uncertainty over energy savings may be expected to increase over time, a specified crediting lifetime may be combined with *discounting* the number or value of certificates at a fixed percentage rate (e.g. 5%/year). Risks to investors can be minimised by awarding all the credits generated from a project over its lifetime at the point of project inception—thereby giving a static baseline.

There is considerable experience with baseline construction in DSM schemes (Chomitz, 1998), project-based emissions trading schemes (Jackson, Begg et al., 2001) and the energy service industry (Goldman, Hopper et al., 2005). But since TWC schemes typically seek to encourage large numbers of small projects, the procedures for estimating energy savings may need to be relatively simple—for example, attributing a fixed quantity of energy savings to a particular type of project such as cavity wall insulation. This static baseline approach minimises Administrative costs and the risk to potential investors but at the same time increases the risk of Type II error.

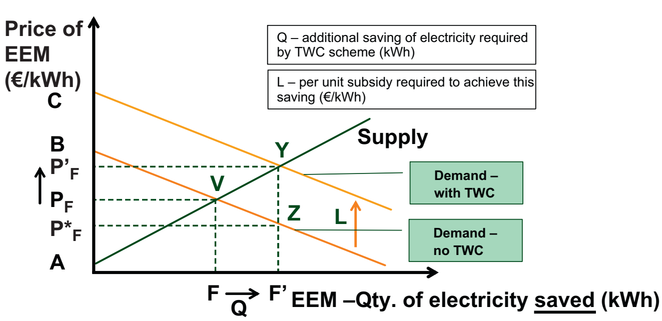

Fig. 3. Effect on the EEM market of a TWC subsidy on efficiency investment—including free riders.

amount equal to the energy-saving target (Q). The required total demand for EEM will then be $F' = F+Q'$. As shown in Fig. 3, this implies a shift of the demand curve for EEM to the right, so that more is demanded at a given electricity price. The increased demand for EEM may be achieved in one of two ways:

1. Participants in the TWC scheme (electricity retailers) may offer consumers a subsidy to encourage them to take up EEM. This subsidy may cover a portion of the cost of these measures or all of the cost, depending on the circumstances. Those energy savings that are certified as additional by the regulator would generate white certificates and would be available for compliance (or, in the case of over-compliance, for sale to other participants in the white certificate market).
2. Participants in the TWC scheme may purchase white certificates from other participants or from third parties such as ESCOs. These certificates represent energy savings that have been certified as additional by the regulator and are available for compliance. From the perspective of a third-party developer, the white certificates provide an additional revenue stream.

Competition should encourage the least cost option to be chosen. At this point, the required subsidy to the marginal consumer per unit of electricity saved (Option 1) should equal the additional revenue to third-party project developers per unit of electricity saved (Option 2). This value corresponds to the market price of white certificates (in € per kWh of electricity saved) and is represented in Fig. 3 by L.

A subsidy on investment in energy efficiency will allow consumers to purchase higher cost EEM. If the subsidy were available for *all* investments in energy efficiency by *all* consumers, it would effectively shift the demand curve for EEM upward by the amount L—as shown in Fig. 3. Consumers would then invest in additional EEM such that the additional energy saved equalled Q and the total energy saved equalled F'. The price received by EEM producers would rise from P_F to P_F'.

If the subsidy was available to *all* electricity consumers, the cost to the retailers could be high owing to the existence of 'free riders'—namely, consumers who would have purchased the relevant EEM in the absence of the subsidy. The overall cost of meeting the energy-saving target will therefore depend on the extent to which the retailers are able to exclude free riders when implementing their subsidy schemes. Importantly, for the purpose of this analysis, the ability of the retailers to eliminate *free riders* in the implementation of their subsidy schemes is considered to be

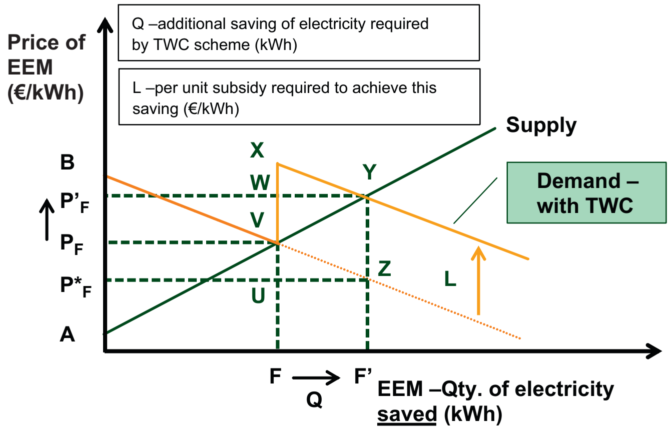

Fig. 4. Effect on the EEM market of a TWC subsidy on efficiency investment—excluding free riders.

separate from the decision by the regulator regarding the *additionality* of the resulting energy savings[7]—in part because the regulatory decisions on additionality are assumed to be made after the implementation of the subsidy schemes.[8]

If suppliers are able to exclude free riders when implementing their subsidy schemes, the subsidy (L) will only be available for additional investment in EEM beyond the baseline level (F). Following Braithwait and Caves (1994), this can be represented (rather unconventionally) by a 'kinked' demand curve, as shown in Fig. 4. For EEM below F, no subsidy is available and the demand curve is the same as in Fig. 3. For EEM above F, a subsidy of L €/kWh is available for investment in electricity efficiency and the demand curve shifts to the right.

The result in terms of EEM investment is the same as in Fig. 3: consumers invest in additional EEM such that the total kWh saved equals F'. The price received by EEM producers rises from P_F to P_F'.

The result in terms of total subsidy payments is different, however. In Fig. 3, the total subsidy payments are equal to $L \times F'$, or the area $P_F'YZP_F^*$. A large portion of this ($L \times F$) represents subsidies to 'free riders'—consumers who would have demanded a quantity F of electricity saving in the absence of the subsidy. In contrast, the total subsidy payments in Fig. 4 are only $L(F'-F)$, or the area $VXYZ$ (equivalent to area $UWYZ$). But while the retailers participating in the TWC scheme may aim to exclude free riders, this may prove difficult to achieve in practice and the precise number of free riders would be unknown.

2.3. The determinants of white certificate prices

The market price of white certificates (€/kWh of electricity saved) will be determined by the per-unit subsidy (L) required to achieve a particular energy-saving target (Q). More (less) stringent energy-saving targets should lead to higher (lower) certificate prices.

In the above formulation, the supply and demand curves for energy efficiency are assumed to be linear over the region of interest. This implies a linear relationship between the energy-saving target (Q) and the required per-unit subsidy (L)—and hence the price of white certificates. In these circumstances, the certificate price will depend on the relative slope of these curves. Specifically, certificate price will be higher if the supply of EEM is insensitive to price (supply curve is steep) and/or the demand for EEM is insensitive to price (demand curve is steep).

If dynamic baselines are used for the determination of additionality (Box 2), the certificate price required to achieve a particular energy-saving target (Q) should be independent of the marginal cost of energy efficiency investment required to meet that target (P_F'). The latter is determined by the TWC target (Q) in combination with the current demand for energy efficiency (F), which in turn depends on exogenous factors such as the current level of electricity prices. Higher (lower) demand for energy efficiency must be met with supply ($F' = F$+Q) that has higher (lower) marginal costs, but this should *not* affect the price of white certificates. Since the energy-saving target (Q) is measured relative to a dynamic baseline, the price of white certificates is a function of the difference in marginal cost between F' and F (represented by $L = P_F'-P_F$) rather than the absolute value (P_F').

To further illustrate this idea, Fig. 5 shows the effect of an increase in retail electricity prices. This makes EEM more cost-effective, which shifts the demand curve for EEM to the right. In the absence of the TWC scheme, the demand for EEM will increase from F to F_H and the quantity of energy saving (relative to F) will increase by $K = F_H-F$. If dynamic baselines are used to estimate energy savings, the price-induced energy saving (K) should *not* count towards the target (Q), since it would have occurred in the absence of the TWC scheme. The estimated energy savings from individual projects should be adjusted downwards to reflect the change in retail prices and participants in the TWC scheme will need to find additional energy savings to meet their obligations. In Fig. 5, the revised energy-saving target (Q) will now be measured from F_H rather than F, such that the required demand is equal to $F_H' = F_H$+Q. It can be seen that, assuming both dynamic baselines

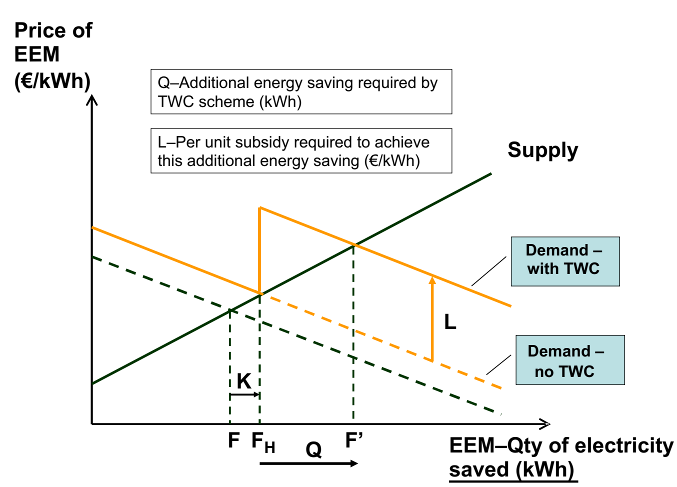

Fig. 5. Effect of TWC scheme on the market for energy efficiency when electricity prices increase and dynamic baselines are employed.

[7] Terminology in this area can be confusing. 'Additionality' is normally used in relation to project-based mechanisms for reducing greenhouse gas emissions, as established by the Kyoto protocol and relates to emission reductions that are additional to those that would occur in the absence of the relevant project. 'Free riders' is normally used in relation to DSM programmes and relates to those customers who would have installed the relevant energy efficiency measures on their own without the DSM programme.

[8] For example, suppose the supplier seeks to meet a proportion of its energy-saving target through subsidising the purchase of energy-efficient light bulbs. The cost of the subsidy scheme will depend on the proportion (Y) of households that would have purchased the light bulbs in the absence of the subsidy scheme (i.e. the proportion of free riders)—but this is unknown. Assume that the regulator makes a decision on the amount of the energy savings that may be considered 'additional' following the implementation of the subsidy scheme. Then the total allowed savings will depend on the regulator's assumptions about the energy savings from each individual light bulb (X') and the proportion of free riders (Y'). Hence, Y is relevant to the cost of the subsidy scheme to the supplier, while X' and Y' are relevant to the regulatory decision on additionality. In principle, Y' may be greater or less than Y.

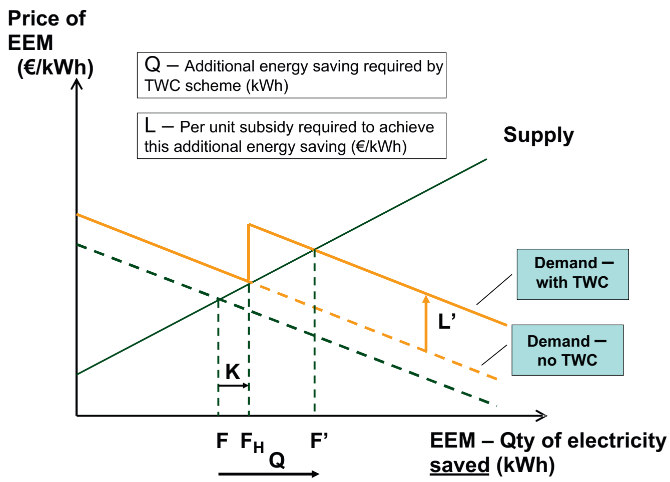

Fig. 6. Effect of TWC scheme on the market for energy efficiency when electricity prices increase and static baselines are employed.

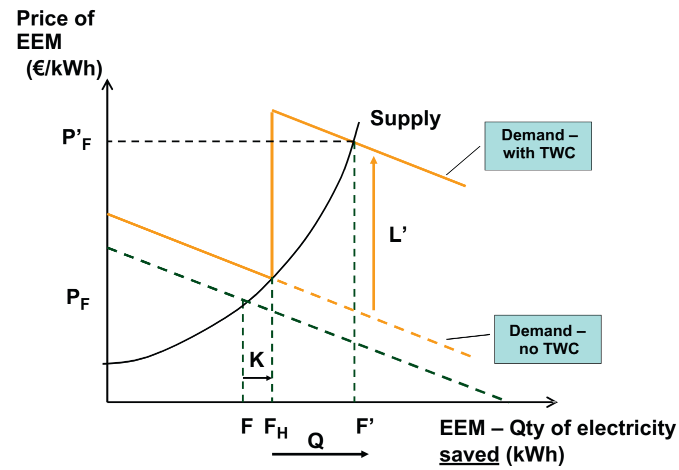

Fig. 7. Effect of TWC scheme on the market for energy efficiency when electricity prices increase, dynamic baselines are employed and the supply of EEM is unresponsive to price.

and linear demand and supply curves over the region of interest, the price of white certificates (L) is unchanged compared to a scenario of low electricity prices. Hence, in these circumstances a change in retail electricity prices and hence in the marginal cost of energy efficiency investment should have no effect on the price of white certificates.

In practice, however, it is much more likely that static baselines will be used. In these circumstances, the price-induced energy saving (K) *will* count towards the target (Q) since the estimated energy savings from individual projects will *not* be adjusted downwards to reflect *ex-post* changes in electricity prices. This possibility is illustrated in Fig. 6. As before, the increase in retail electricity prices leads to a counterfactual level of demand for energy efficiency equal to F_H. But with static baselines, the regulator does not take this into account when assessing compliance with the energy-saving target (Q) and instead measures the required level of energy saving from the previous level of demand (F), such that the required demand is equal to $F' = F+Q$. Since the energy-saving target under the TWC scheme can now be met with a smaller per-unit subsidy ($L' < L$), the price of white certificates should be reduced. As an illustration, a smaller subsidy should now be required to encourage consumers to purchase energy-efficient light bulbs. Alternatively, if the white certificate market fails to function correctly and the subsidy is unchanged (L), retailers may exceed their energy-saving target.

The conclusion that, with dynamic baselines, certificate prices are independent of the marginal cost of energy efficiency improvements may also be modified if either the supply or the demand curve for energy efficiency is non-linear over the region of interest, as shown in Fig. 7. Here the opportunities for improved energy efficiency increase only modestly for a given increase in EEM prices, leading to a steeply rising supply curve. In this case, the per-unit subsidy required for achieving the TWC target will increase as the current demand for EEM (F) increases. As a result, if dynamic baselines are employed, the price of white certificate should increase if retail electricity prices increase ($L' > L$).

In summary, the price of white certificates (L) will depend on

- the energy-saving target (Q),
- the price elasticity of EEM supply,
- the price elasticity of EEM demand,
- the current level of demand for EEM (if supply and/or demand curves are non-linear) and
- regulatory decisions on the additionality of energy savings from individual projects—particularly in relation to *ex-post* changes in electricity prices.

If (as is likely) *static* baselines are used, higher retail electricity prices should make it easier for participants to meet their energy-saving target and the price of white certificates should fall. The magnitude of the effect will depend on the elasticity of demand for energy efficiency with respect to change in electricity prices. In practice, this elasticity is likely to be small, at least in the short term, which means that increases in retail electricity prices should have a relatively small impact on white certificate prices.

The price of white certificates should remain the same whether or not retailers are able to successfully eliminate free riders when implementing their subsidy schemes. This is evident from Figs. 3 and 4, where L is the same regardless of whether free riders are subsidised. However, the number of free riders will influence the *total* cost of the scheme and hence the costs borne by consumers through increases in electricity prices.

This analysis demonstrates that, in principle, there is no necessary link between the marginal cost of energy efficiency investment (P_F') and the price of white certificates (L). The relationship depends in part on the regulators' interpretation of additionality and its ability to enforce this interpretation. If dynamic baselines are successfully implemented by the regulators, there is also no automatic feedback between electricity prices and white certificate prices (Harrison et al., 2005).[9] However, since static baselines are more likely, such a feedback may well exist in practice.

2.4. The effect of a white certificate scheme on the electricity market

The investment in additional EEM brought about by the TWC scheme means that a lower level of electricity consumption is required to achieve the same level of electricity services. A subsidy on EEM should, therefore, reduce the demand for electricity and hence reduce the price of electricity. But at the same time, investment in EEM should *increase* the demand for electricity services, since the unit price of the service has fallen—the so-called rebound effect (Khazzoom, 1980; Sorrell, 2007). The first (technological) effect leads to reduced consumption of

[9] This contrasts with green certificate schemes, where the feedback is much more direct (Harrison et al., 2005).

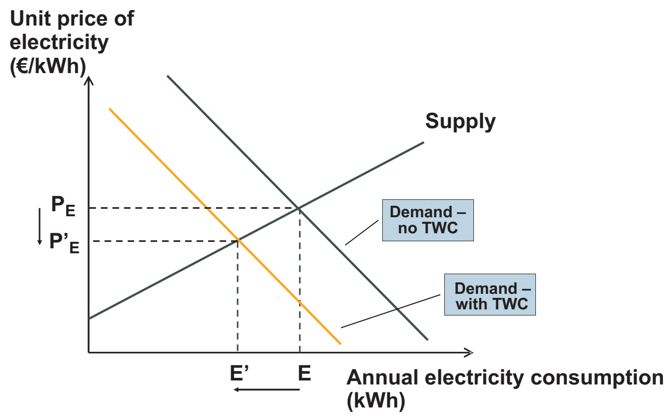

Fig. 8. Effect of TWC subsidies on the electricity market—no cost recovery.

electricity, while the second (rebound) effect leads to increased consumption of electricity. The relative importance of each effect will depend on the own-price elasticity of demand for the relevant energy service, which is likely to be low in the majority of cases (Berkhout et al., 2000; Sorrell and Dimitropoulos, 2007). Hence, it is assumed here that the rebound effect is not sufficiently large to overcome the technological effect, so the net effect is a reduction in electricity consumption.[10]

The net effect of the subsidy on the electricity market is shown in Fig. 8. Investment in EEM shifts the demand curve for electricity to the left. The new equilibrium gives a lower electricity price ($P_{E}' < P_E$) and a lower level of electricity demand ($E' < E$)—which is assumed to be the intention of the TWC scheme.

2.5. The effect of cost recovery on the electricity market

The TWC scheme needs to be paid for in some way. In addition to the cost of the per-unit subsidy ($L \times Q$), participants will incur administrative costs (AC) such as those for marketing, auditing and verification. Hence, to a first approximation the total costs (TC) are given by $TC = LQ{+}AC$. Electricity retailers incur this cost initially, although the eventual costs may be borne by electricity consumers, wholesale electricity suppliers or shareholders. The ultimate distribution of costs will depend on market conditions.

For simplicity, we assume that the cost is wholly borne by electricity consumers through a per-unit levy (l) on retail electricity prices (€/kWh). Importantly, this will increase retail electricity prices, but will not affect wholesale electricity prices or the price received by electricity generators. However, wholesale prices will be affected by any changes in the demand for electricity, including that created by the cost recovery itself. The levy is assumed to be identical for all consumers, implying that consumers pay for the total cost of the TWC scheme in proportion to their electricity consumption. This is in contrast to the benefits of the investment, which will be received by only a subset of consumers.

If consumer demand were completely unresponsive to the imposition of a levy (i.e., demand remained at E'), the required per-unit levy would be $l = TC/E'$ (€/kWh). However, if the demand

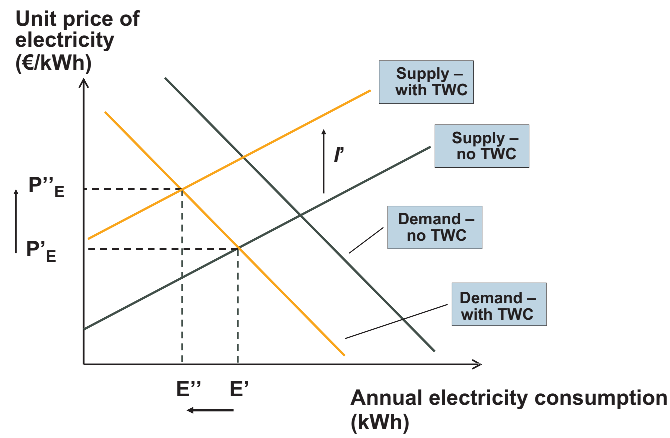

Fig. 9. Effect of TWC subsidies on the electricity market—with cost recovery.

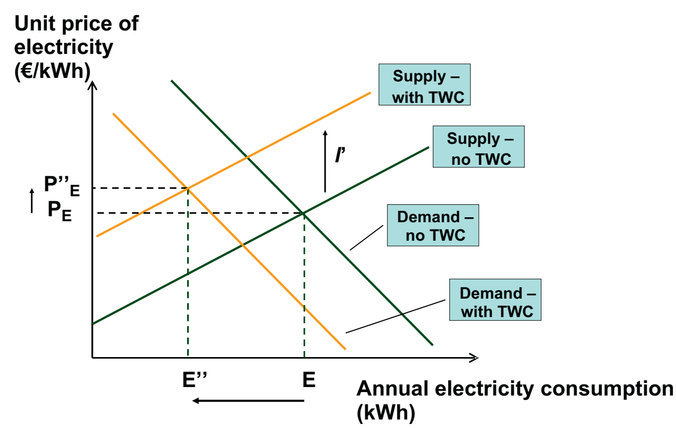

Fig. 10. Initial and final equilibrium in the retail electricity market with a TWC scheme.

curve for electricity is not wholly inelastic, a price increase of l (€/kWh) would reduce electricity demand below E'. This means that a levy of l would not recover all of the costs. If the costs were to be fully recovered, a larger price increase of l' would be required—represented by an upward shift of the supply curve (Fig. 9). Hence, following cost recovery by the electricity producers, a total of E'' kWh of electricity will be supplied at a price P_E''. Then $TC = l' \times E''$

2.6. The overall effect of a white certificate scheme

The net result of the TWC scheme can now be assessed. Prior to the introduction of the scheme, a quantity E of electricity was supplied at a price P_E (Fig. 1). Following the introduction of the TWC scheme, a quantity E'' of electricity is supplied at a price P_E'' (Fig. 10). This final equilibrium results from a combination of two factors:

1. A *reduction* in electricity demand, with a corresponding *reduction* in electricity prices following the investment in energy efficiency. This is represented by a leftward shift of the demand curve (Fig. 8).
2. An *increase* in electricity prices, with a corresponding further *reduction* in electricity demand, following cost recovery. This is represented by an upward shift of the supply curve (Fig. 9).

[10] This may not be the end of the story. Since electricity and EEM are (partial) substitutes, the reduction in electricity prices should (in principle) encourage consumers to switch from EEM consumption to electricity consumption, so the demand for EEM should fall (a leftwards shift in the EEM demand curve). However, investment in EEM tends to be *irreversible*, at least in the short term (Haas and Schipper, 1998). For example, having installed loft insulation, a consumer is unlikely to remove it following a fall in electricity prices. This suggests that, to a first approximation, any secondary effects in the EEM market can be ignored.

Table 1
Summary of price and quantity effects of a TWC scheme in an isolated national electricity market

Variable	Effect	Comments
Wholesale electricity price	Reduced	Due to lower electricity demand
Consumer electricity price	Ambiguous	Reduced by lower demand, but increased by cost recovery. Likely to increase if the supply curve is relatively flat
Electricity demand	Reduced	Due to subsidised investment in electricity efficiency (assuming the rebound effect is $<100\%$). Additional change in demand may result from consumer response to change in electricity prices following cost recovery, but sign of this is ambiguous
Non-renewable generation	Reduced	Due to lower electricity demand. Marginal plant likely to be non-renewable
Renewable generation	Unchanged	Existing renewables have low short-run marginal cost and should take preference in merit order. So unlikely to be affected by reduced demand
CO_2 emissions	Reduced	Due to lower non-renewable electricity generation. Depends on emission characteristics of the marginal plant
Investment in end-use efficiency	Increased	Increased due to obligation and availability of subsidy. May be enhanced by price response if consumer prices increase, or offset if they drop
Investment in new renewables	Reduced	Due to lower wholesale electricity prices

Table 2
Summary of distributional effects of a TWC scheme in an isolated national electricity market

Variable	Effect	Comments
Producer surplus—energy efficiency producers	Increased	Could be small, since the supply curve is likely to be relatively flat (e.g., internationally traded technologies)
Producer surplus—electricity producers	Reduced	Less if the supply curve is relatively flat
Producer surplus—overall	Ambiguous	Loss of electricity producers (national market) should outweigh gain of EEM producers (international market). Hence, likely to be reduced
Consumer surplus—beneficiaries	Increased	Direct benefits exceed indirect costs. Will increase less if supply curve is relatively flat
Consumer surplus—non-beneficiaries	Ambiguous	Likely to be reduced. Will be reduced more if supply curve is relatively flat
Consumer surplus—overall	Ambiguous	Likely to be reduced if supply curves are flat. Transfer of wealth from non-beneficiaries to beneficiaries

The initial and final equilibrium in the electricity market are compared in Fig. 10. In total, electricity demand has *reduced* from E to E'' and consumer electricity prices have *increased* from P_E to P_E''. But while a reduction in electricity demand is an unambiguous outcome of the TWC scheme,[11] the final electricity price (P_E'') may be greater or lesser than the original electricity price (P_E). It all depends on whether the reduction in prices from (1) outweighs the increase in prices from (2). This in turn depends on the relative slope of the demand and supply curves.

In practice, the electricity supply curve may be relatively flat over the region of interest. This is particularly likely if the TWC scheme covers only a subset of final consumers and/or the energy-saving targets are undemanding (Braithwait and Caves, 1994). In this case, the reduction in electricity demand following investment in energy efficiency (shift of the demand curve) would have little or no effect on electricity prices (i.e., $P_E \approx P_E'$ in Fig. 8). In contrast, cost recovery (shift of the supply curve) would still lead to an increase in energy prices (i.e., $P_E'' > P_E'$ in Fig. 9), since this is independent of the slope of the supply curve. Since there would be little or nothing to offset the cost recovery, consumer prices would increase overall.

Fig. 10 indicates the equilibrium situation in the electricity *retail* market, where E'' kWh of electricity is supplied at a price P_E''. But the situation will be different in the electricity *wholesale* market, since it is assumed that generators cannot add the levy on to their price. The wholesale price will be solely determined by electricity demand (E'').

Table 1 summarises the effect of the idealised TWC scheme on the 'price and quantity' variables listed in Box 1. The graphical analysis can also be used to estimate how the costs and benefits of the scheme are borne by producers and consumers in both the electricity and EEM markets. In the case of the latter, it is necessary to distinguish between those consumers who benefit directly from subsidised energy efficiency investments and those who do not. Full details of this analysis can be found in Harrison et al. (2005), while a summary of the results is provided in Table 2.[12] It is important to note that this does not represent a full 'welfare analysis', since neither market failures (e.g. environmental externalities) nor secondary effects in other markets (e.g. fuel markets) are taken into account. A more comprehensive analysis would require modelling of the simultaneous effects of all variables, preferably in a general equilibrium framework.

3. Economic analysis of the EU ETS

The EU ETS imposes a cap on CO_2 emissions from electric generators and major industrial sites throughout Europe and establishes a Europe-wide market for CO_2 emission allowances. The carbon price is reflected in the electricity market as an added cost to generating plant that emits CO_2.

The economic, environmental and distributional impacts of the EU ETS on an isolated national electricity market can be analysed

[11] Compared to a counterfactual scenario and assuming that the rebound effect is less than unity.

[12] The analysis is based on the standard welfare economics concepts of consumer and producer surplus (Boardman et al., 2001). Consumer surplus is a measure of consumer welfare and represents the difference between the price consumers are willing to pay and the actual price. It is given by the area below the demand curve and above the market price. Producer surplus is a measure of producer welfare and represents the difference between the price producers are willing and able to supply at and the price they actually receive. It is given by the area above the supply curve and below the market price.

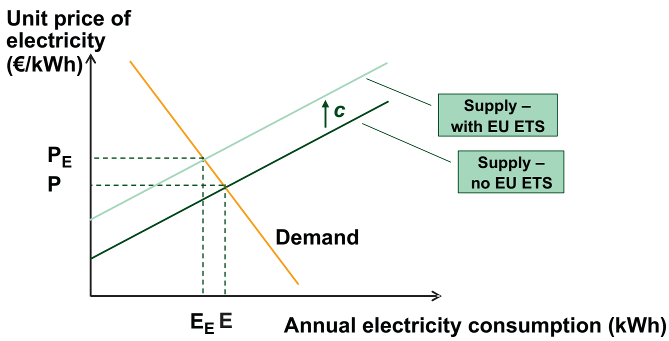

Fig. 11. Effect of the EU ETS on the wholesale electricity market.

in a manner similar to those of the TWC scheme above. Full details of this analysis can be found in Harrison et al. (2005), and only a summary of the results is provided here.[13]

The most direct effect of the EU ETS will be to reduce aggregate CO_2 emissions from participating sources to the level mandated by the cap. The introduction of a CO_2 price into the electricity market will make it more costly for generators to operate units that emit CO_2. In a liberalised, competitive and isolated generation market, these costs should increase the wholesale price of electricity by an amount corresponding to the opportunity cost of CO_2 of the marginal electricity generator in the national system. The magnitude of the price effect will depend on the CO_2 intensity of the marginal producer, which in turn will vary by time of day and time of year. Importantly, it should not depend on how the allowances are allocated. Since the electricity market is isolated from competition from outside the EU, the impact on electricity prices should be broadly the same regardless of whether the allowances are distributed for free or purchased in an auction (Harrison et al., 2005; Neuhoff et al., 2006; Sijm et al., 2006).[14]

Higher wholesale prices should translate into higher retail prices for consumers, which in turn should encourage consumers to reduce their electricity consumption—both through behavioural changes and new investment. This should reduce aggregate electricity demand compared to a counterfactual scenario in which the EU ETS was not introduced. Whether demand will decrease in absolute terms depends on the stringency of the cap and the relative cost of different abatement options.

The altered incentives for CO_2 emissions may also affect the type of generation being used to meet demand. The EU ETS will reward generators with lower CO_2 emissions, shifting the fuel mix toward lower-emitting CO_2 units. In particular, gas may replace coal in the generation mix and investment in new renewable capacity will become slightly more attractive. The impact on the output of existing renewable generators will depend on their location within the plant merit order. Since most have low short-term marginal cost and hence take preference in the merit order, small reductions in electricity demand are unlikely to affect their output.

Fig. 11 illustrates, in a stylised form, the effect of the EU ETS on the wholesale electricity market. Wholesale prices increase from P to P_E, while demand falls from E to E_E. Table 3 summarises the 'price and quantity' effects of the EU ETS, while Table 4 summarises the distributional effects.

[13] See also Reinaud (2005). Valuable reviews of the impact of Phase 1 of the EU ETS on electricity markets are provided by Sijm et al. (2006), Neuhoff et al. (2006) and Reinaud (2007).

[14] The extent to which this occurs in practice may depend on a number of factors, including the degree of market concentration (Reinaud, 2007).

4. Economic analysis of the interaction between a white certificate scheme and the EU ETS

This section explores the interactions between the idealised national TWC scheme described above and the EU ETS. It is assumed that the Member State is already participating in the EU ETS when the national TWC scheme is introduced—a scenario that is relevant to those Member States that are considering the introduction of TWC schemes and also to Member States who are increasing the stringency of targets within existing schemes.[15]

As before, the interactions are analysed in terms of the effects on the 'price and quantity' variables listed in Box 1, together with the distribution of costs and benefits. The key question is how the introduction of the TWC scheme alters the impact of the EU ETS on producers and consumers in both the electricity and EEM markets. The results are summarised in tables in a manner similar to those mentioned above.

4.1. *Effect on electricity demand and electricity prices*

The effect of an idealised TWC scheme on the *retail* electricity market was discussed in Section 2. But to investigate the effect of interactions with the EU ETS, it is important to clarify how the TWC scheme affects the *wholesale* electricity market. This is achieved with the help of Fig. 12. Prior to the introduction of the scheme, a quantity E of electricity is supplied at a retail price P. Following the introduction of the TWC scheme, a quantity E_T of electricity is supplied at a *retail* price P_T^C. In total, electricity demand has reduced from E to E_T and retail electricity prices have increased from P to P_T^C. But while a reduction in electricity demand is an unambiguous outcome of the TWC scheme, the final consumer price for electricity (P_T^C) may be greater or lesser than the original price (P), depending on the relative slope of the demand and supply curves.

As discussed above, electricity retailers are assumed to recover the costs of the TWC scheme through a per-unit levy (l) on the consumer price of electricity. Since it is assumed that consumers pay the full cost of the subsidy, this cost recovery does not affect the *wholesale* price of electricity. However, wholesale prices may fall if the cost recovery leads to an additional reduction in electricity demand. If we assume, for the purpose of illustration, that transmission, distribution and retail costs are zero, the wholesale price of electricity may be given by the cost of supplying the final demand (E_T), *excluding* the per-unit levy (l). This is represented by P_T^W in Fig. 12 ($P_T^C = P_T^W + l$). In contrast to the final consumer price (P_T^C), the final wholesale price (P_T^C) is unambiguously reduced by the introduction of the TWC scheme ($P_T^W < P$).

Fig. 13 combines the effect of the TWC scheme on the wholesale electricity market (Fig. 12) with the effect of the EU ETS (Fig. 11). Initially it is assumed that the effect of the TWC scheme is additional to that of the EU ETS and that there is no effect on allowance prices. This may be justified if the TWC scheme is introduced in only one country and affects only a small proportion of the emissions covered by the EU ETS. However, the implications of the scheme for allowance prices are discussed further below.

The combination of the two instruments leads to an equilibrium where demand E_{ET} is supplied at retail price P_{ET}^C. This represents the net effect of (a) internalising the opportunity cost of EU ETS allowances in the electricity price, (b) reductions in electricity demand as a result of subsidised energy efficiency

[15] Harrison et al. (2005) conduct a comparable analysis in which the instrument sequence is reversed.

Table 3
Summary of price and quantity effects of the EU ETS in an isolated national electricity market

Variable	Effect	Comments
Wholesale electricity price	Increased	Short-term increase due to CO_2 price impacts on the marginal generator, which normally uses fossil fuel. Magnitude depends on allowance price, CO_2 intensity of marginal technology, degree of market concentration and other factors. Long-term increase due to CO_2 price impacts on long-term marginal cost of new generation
Retail electricity price	Increased	Increases in wholesale prices should be passed through to consumer prices, unless impeded by regulatory decision-making
Electricity demand	Reduced	Due to investment and behavioural response to higher consumer electricity prices
CO_2-emitting generation	Reduced	Reduced in total by lower demand. Also, fossil plant may be displaced by non-fossil plant and high-CO_2 plants (e.g. coal) may be displaced by low-CO_2 plant (gas)
Non-CO_2-emitting generation	Unchanged	Nuclear and renewables have low short-run marginal cost and should take preference in merit order. So unlikely to be affected by reduced demand
CO_2 emissions	Reduced	Reduced by a combination of lower electricity demand and displacement of high emitting by low-emitting generation plants. Aggregate emissions set by EU ETS cap
Investment in end-use efficiency	Increased	Stronger incentive to invest from increase in retail electricity prices
Investment in new renewables	Increased	Technologies with lower CO_2 emissions (including renewables) are incentivised by higher wholesale price. But impact could be marginal for many technologies

Table 4
Summary of distributional effects of the EU ETS in an isolated national electricity market

Variable	Effect	Comments
Producer surplus—energy efficiency producers	Increased	Could be small or zero, since the supply curve is likely to be relatively flat (e.g. internationally traded technologies)
Producer surplus—high-emitting electricity producers	Reduced	Increase in costs outweighs increased revenues from higher wholesale electricity prices
Producer surplus—low-emitting electricity producers	Increased	Increase in revenues from higher wholesale electricity prices outweighs increase in costs
Producer surplus—overall	Ambiguous	Depends on the relative slope of demand and supply curves
Consumer surplus—overall	Decreased	Consumers lose from consuming less electricity and paying a higher price for what they do consume

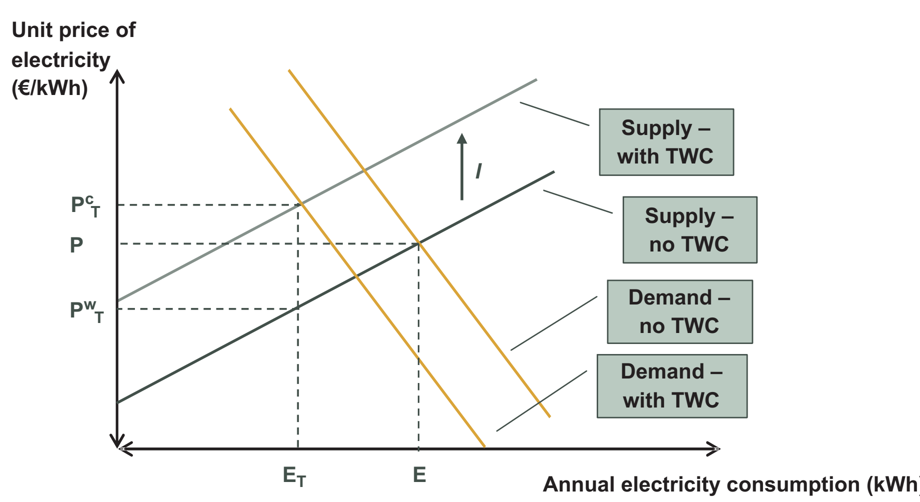

Fig. 12. Effect of a TWC scheme on the retail and wholesale electricity market.

improvements through the TWC scheme and (c) recovery of the costs of this subsidy through a levy (l) on all electricity consumers.

Compared to the EU ETS alone (E_E, P_E), the following changes are apparent:

- Electricity demand is lower than with the EU ETS alone ($E_{ET}<E_E$).
- The retail electricity price may either be higher or lower than with the EU ETS alone ($P_T^C<>P_E$). While the reduction in demand following energy efficiency investment lowers the retail price, the recovery of costs increases the retail price. If the supply curve is relatively flat, the TWC scheme is likely to increase retail prices compared to the EU ETS alone.
- The wholesale price is lower than with the EU ETS alone ($P_{ET}^W<P_E$).

Similarly, compared to the electricity market in the absence of *any* environment regulation (E, P), the following changes are apparent:

- Electricity demand is lower compared with no regulation ($E_{ET}<E$).

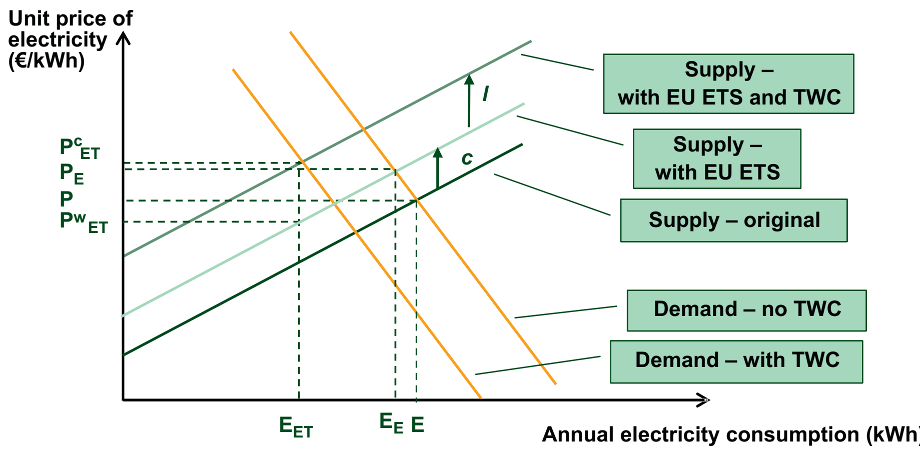

Fig. 13. Effect on the electricity market of introducing a TWC scheme alongside the EU ETS.

- The retail electricity price may either be higher or lower compared with no regulation ($P^C_{ET} <> P$). While the reduction in demand following energy efficiency investment lowers the retail price, this is offset by an increase in retail price from both cost recovery and the EU ETS. In practice, the latter two factors are likely to outweigh the first, leading to an increase in retail prices.
- The wholesale price may either be higher or lower compared with no regulation ($P^W_{ET} <> P$). In this case, the reduction in price as a consequence of demand reduction is offset by an increase in price from the EU ETS. But since cost recovery does not increase wholesale prices, these are more likely to fall than are retail prices. At the same time, if the supply curve is relatively flat, the price increase from the EU ETS is likely to dominate, leading to an increase in wholesale prices.

4.2. Effect on electricity generation and carbon emissions

The addition of the TWC scheme, therefore, leads to lower electricity demand compared with the EU ETS alone. This should reduce electricity generation from fossil fuel plants, since these are likely to be the marginal plant on the national system. There is unlikely to be a reduction in renewable electricity generation, since this generally takes preference in the merit order.

The TWC scheme may also reduce investment in new renewable generating capacity, compared to a scenario with the EU ETS alone. In the absence of other policy mechanisms, the incentive to invest in new renewable (and other) generating capacity derives primarily from the wholesale price of electricity. As indicated above, this is unambiguously reduced by the introduction of the TWC scheme.[16] However, new renewables are uncompetitive at current electricity prices and generally require dedicated support schemes. Hence, the additional effect of the TWC scheme on the incentive to invest in renewables is likely to be minimal.

Since the TWC scheme reduces electricity demand and hence electricity generation from fossil fuels, it should also lead to lower CO_2 emissions from national electricity generators, compared to a scenario with the EU ETS alone. It could, therefore, contribute towards the host country's compliance with its Kyoto obligations.[17] It is important to note, however, that

- the scheme will not lead to reductions in EU-wide or global CO_2 emissions during the EU ETS phase in which it is introduced and
- it will only contribute to EU-wide and global CO_2 reductions during subsequent EU ETS phases if it contributes to an increase in the stringency of the overall EU ETS cap.

These points deserve some clarification.

The TWC scheme will lead to reduced output from national fossil-fuelled electricity generators and hence to reduced emissions from this sector. This means that the electricity generators will either need to purchase fewer allowances to comply with their EU ETS obligations, or will be able to sell more allowances. Other EU ETS participants can be expected to purchase and use these 'freed-up' allowances to cover either increases in emissions or reduced emissions abatement. Alternatively, the generators (or purchasers) could bank any surplus allowances and use them to cover emissions in subsequent phases. In either case, the aggregate emissions from EU ETS participants as a whole will not be changed, since the number of allowances will not be changed. The TWC scheme would simply have changed the geographical or temporal pattern of emissions and would have made no contribution towards EU compliance with the Kyoto protocol. Furthermore, if EU emissions are unchanged by the EU ETS, then worldwide emissions will be unchanged as well. The contribution of the TWC scheme to global emission reductions will, therefore, be zero in the short term.

The contribution of the TWC scheme to long-term emission reductions will then depend on how the EU ETS cap is established. Since the reduction in electricity demand will reduce emissions from the generating sector, it could in principle contribute to the negotiation of more stringent emission caps for that sector in future phases of the EU ETS. By this process, the TWC scheme may contribute to additional emission reductions in the longer term compared to a counterfactual scenario in which the scheme is not introduced. Conversely, it is possible that the absence of the TWC scheme would have made no difference to the stringency of the subsequent EU ETS caps. This seems the most likely outcome following the publication of the Draft Directive for EU ETS Phase 3 in January 2008 (CEC, 2008). In this case, the TWC scheme would not have contributed any additional emission reductions—although if (as seems likely) there are failures in the market for EEM, it could have stimulated the innovation and diffusion of energy-efficient technologies, thereby affecting the cost of future emission reductions. But the important point is that the existence

[16] It is worth noting that reductions in electricity demand can make it easier to meet policy targets for renewable electricity if these are expressed in terms of the percentage of total electricity supply.

[17] This depends on who purchases and uses any 'freed-up' allowances: i.e. whether they are located within the host country, or elsewhere in the EU.

of the EU ETS cap removes the straightforward link between the TWC scheme and the resulting emission reductions. These expected emission reductions only translate into real emission reductions if they subsequently lead to a proportionate reduction in the EU ETS cap. The common assertion that a TWC scheme (or other comparable policies) will reduce emissions by X tonnes of CO_2 is therefore false.

It is important to note that this conclusion is not confined to TWC schemes but applies to all policies that affect (a) the direct emissions from EU ETS participants (e.g. a carbon tax on fuel use by the participants), (b) electricity demand (e.g. energy efficiency standards for new appliances) or (c) the carbon intensity of electricity production (e.g. support mechanisms for renewable electricity) (Sorrell et al., 2003; Sorrell and Sijm, 2003). At the same time, policies that affect emissions that are not covered by the EU ETS may contribute emission reductions independently of and in addition to the EU ETS. For example, policies that affect household fuel consumption should contribute additional emission reductions, while policies that affect household electricity consumption may not. In practice, existing and proposed TWC schemes affect both household electricity use and household fuel use.

4.3. Effect on abatement costs

The reduced emissions from national electricity generation will be paid for by electricity consumers. But if the cap is unchanged, the introduction of the TWC scheme should reduce the price of EU ETS allowances (Harrison et al., 2005). This will occur because the overall scarcity in the allowance market is 'relaxed': in effect, some abatement has already been 'paid for' through the TWC scheme. As a result, the cost of compliance for EU ETS participants will be reduced. However, in the absence of market failures, the overall cost of achieving the EU ETS cap will be *increased*. This is because, if each market operates 'perfectly', emission reductions are achieved at least cost through the EU ETS alone. The introduction of the TWC scheme will, therefore, lead to a departure from the cost-minimising optimum and increase overall abatement costs (Harrison et al., 2005). Electricity consumers who are paying for the TWC scheme will subsidise abatement by participants in the EU ETS and the scheme will raise the cost of meeting the EU ETS cap without delivering any additional emission reductions.

However, unlike the effect of the scheme on carbon emissions, the effect on abatement costs depends on the operation of the relevant market and in particular the nature and importance of various market failures. Since energy efficiency markets are generally obstructed by multiple and reinforcing market failures, the TWC scheme could potentially *reduce* the overall cost of meeting the EU ETS cap if it can overcome these failures cost effectively. The TWC scheme may also provide additional benefits, such as improving the welfare of low-income consumers. Hence, a full assessment of cost and benefits requires the assumptions behind this simple theoretical model to be relaxed.

4.4. Summary of the consequences of policy interaction

Table 5 summarises the 'price and quantity' effects of introducing the idealised TWC scheme (or tightening the target in the scheme) in a country that is already participating in the EU ETS. The columns represent

- the effect of the EU ETS alone, compared to no regulatory intervention,
- the effect of the EU ETS and TWC scheme in combination, compared to no regulatory intervention and
- the additional effect of introducing a TWC scheme (i.e., the effect of the instrument combination compared to the EU ETS alone).

As before, the graphical analysis can be used to estimate how the costs and benefits of the instrument combination are borne by producers and consumers in the electricity and energy efficiency markets. Full details of this analysis can be found in Harrison et al. (2005), while a summary of the results is provided in Table 6. Again, it should be emphasised that this is not a complete analysis of costs and benefits, since market failures and effects in secondary markets are ignored. It is hoped that when these are taken into account, the instruments lead to positive benefits for society as a whole. Nevertheless, the analysis does illustrate which groups are likely to benefit directly from the instruments and which are likely to incur additional costs. These results should still broadly apply to real-world markets.

Table 5
Summary price and quantity effects of introducing a TWC scheme in a country participating in the EU ETS

Variable	EU ETS alone	EU ETS and TWC scheme	Additional impact of introducing the TWC scheme
Electricity demand	Reduced	Reduced	Lower demand than with EU ETS alone
Wholesale electricity price	Increased	Ambiguous	Lower price than with EU ETS alone
Retail electricity price	Increased	Ambiguous, but likely to increase	Ambiguous impact. Retail price reduced by lower demand, but increased by cost recovery. Likely to increase if the supply curve is flat
National non-green generation	Reduced	Reduced	Lower generation than with EU ETS alone due to lower demand
National renewable generation	Unchanged	Unchanged	Existing renewables have low short-run marginal cost and should take preference in merit order. So unlikely to be affected by reduced demand
National CO_2 emissions	Reduced	Reduced	Ambiguous. Lower emissions from national electricity generators. But whether national emissions are lower depends on who purchases and uses the surplus EU ETS allowances
EU CO_2 emissions	Reduced	Reduced	Unaffected by TWC scheme. With EU ETS in place, TWC scheme has zero impact on EU CO_2 emissions
Investment in end-use efficiency	Increased	Increased	Increased investment due to TWC subsidies. Offset by ambiguous incentive from retail prices—but latter also likely to increase
Investment in renewable energy	Increased	Ambiguous	Lower incentive to invest due to lower wholesale electricity prices
EU ETS allowance price	–	Reduced	Lower, due to displacement of CO_2 emissions from generation. Abatement paid for by consumers through TWC scheme

Note: Columns 2 and 3 compare outcome to a situation of no regulation. Column 4 compares outcome in column 3 to that in column 2.

Table 6
Summary distributional effects of introducing a TWC scheme in a country participating in the EU ETS

Variable	EU ETS alone	EU ETS and TWC scheme	Additional impact of introducing the TWC scheme
Producer surplus			
Energy efficiency producers	Increased	Increased	Higher surplus than with EU ETS alone
High-CO_2 electricity generators	Reduced	Reduced	Lower surplus than with EU ETS alone
Low-CO_2 electricity generators	Increased	Ambiguous	Lower surplus than with EU ETS alone. But benefit from EU ETS likely to exceed loss from TWC
Electricity generators overall	Increased	Ambiguous	Lower surplus than with EU ETS alone. But benefit from EU ETS likely to exceed loss from TWC
Producers overall	Increased	Ambiguous	Ambiguous impact. But overall surplus likely to be positive
Consumer surplus			
Beneficiaries of TWC investment	Reduced	Ambiguous	Higher surplus than with EU ETS alone
Non-beneficiaries of TWC investment	Reduced	Ambiguous	Surplus more likely to be lower than with EU ETS alone
Consumers overall	Reduced	Ambiguous	Surplus likely to be lower than with EU ETS alone

Note: Columns 2 and 3 compare outcome to a situation of no regulation. Column 4 compares outcome in column 3 to that in column 2.

5. Conclusion

Compared to other market-based climate policy instruments, there has been little economic analysis of the operation of white certificate schemes. Also, there is a general tendency to analyse the impact of climate policy instruments in isolation rather than in the context of other instruments (Gunningham and Gabrosky, 1998; Sorrell et al., 2003). But if white certificate schemes are to be successfully introduced, a better understanding of both market operation and the consequences of policy interaction is required. This paper has contributed to both these aims, by developing a simple partial-equilibrium analysis of an idealised white certificate scheme and showing the consequences of introducing this alongside the EU ETS.

The analysis involves a number of simplifying assumptions and provides no substitute for the detailed investigation and economic modelling of individual schemes. The assumption of undistorted markets for electricity and energy efficiency is especially limiting, since market failures pervade both. Nevertheless, simplified models can often contribute useful insights and several of the conclusions are unlikely to be changed if more realistic assumptions are made. For example, it was argued that

- There is no necessary link between the marginal cost of energy efficiency investment and the price of white certificates.
- Unlike tradable green certificate schemes ((Jensen and Skytte, 2002b), there is no automatic feedback between electricity prices and white certificate prices. Instead, the relationship is mediated in part by regulatory decisions on additionality.
- The price of white certificates should not depend on the ability of participants to eliminate free riders when implementing subsidy schemes, although this will affect the overall costs of the scheme.
- While a reduction in electricity demand is an unambiguous outcome of a TWC scheme, the final retail price may be greater or lesser than the original electricity price depending on the relative slope of the demand and supply curves.

Most importantly, it was shown that, when operating in conjunction with the EU ETS, a TWC scheme focused solely on electricity efficiency will make no contribution to reducing EU or global carbon emissions unless and until it leads to a tightening of the EU ETS cap. Following the publication of the draft directive, this appears unlikely, at least in the period up to 2020. Hence, the common assertion that such schemes will reduce emissions by a certain amount is false. This point is frequently overlooked by policy makers and has important implications for the justification for such schemes.

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