When prices don't steer – mimicking ambitious carbon pricing with energy performance standards

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Abstract
Pricing carbon is often considered to be the cornerstone of any climate policy and, at least in economic theory, it is the only policy intervention required to reach an optimal level of mitigation. In practice, various market and behavioural failures, as well as political barriers, necessitate a policy mix that also encompasses policies to induce energy efficiency and stimulate the up-take of renewable energy sources. Minimum energy performance standards (MEPS) are one group of instruments to drive energy efficiency. However, MEPS are viewed very differently by different actors; some see them as complementary to carbon pricing, while others view them as market distortion. Recent studies indicate that MEPS for appliances and vehicles are currently the best performing climate policy instruments. There is a need for more research about how MEPS and carbon pricing policies interact and how they can best be combined for an effective climate policy mix.

In this paper, we examine the advantages and potential of using MEPS to drive more ambitious climate policy. We first model the market price of appliances in a UK market and how life cycle costs (LCC) shift when the social cost of carbon (SCC) is factored in. We then examine how the inclusion of the SCC affects the point at which least life cycle costs (LLCC) for an appliance class are reached. We consider carbon prices ranging from the current carbon market price to high-end estimates of SCC, and then estimate the corresponding MEPS in each scenario. Finally, we discuss the implications for mixed policy design when climate change externalities are addressed primarily through MEPS, as well as the merits of such a policy approach.

Introduction
The 2015 Paris Agreement reiterated the need for effective, progressive and urgent action in response to climate change, particularly noting the need to shift consumption and production patterns and lifestyles in developed countries (United Nations 2015). To meet the targets of the agreement, it is argued that decarbonization by mid-century is needed to maintain a likely chance of staying within 2 °C of warming until 2100 or a medium chance of 1.5 °C (Rogelj et al. 2016). The success of decarbonizing the power sector depends both on the deployment of renewable energy technologies and demand reductions triggered by improvements in energy efficiency (IEA 2016b, 329); in the case of the latter, more energy-efficient appliances can play a key role (Dietz et al. 2009). In fact, Sachs claims that minimum energy performance standards (MEPS) for vehicles and appliances appear to be the best performing US climate polices (Sachs 2012), and recent evaluations of the European Union's (EU) MEPS indicate that the same may apply to Europe (Kemna and Wierda 2015).

This paper focuses on the roles of carbon pricing and minimum energy performance standards (MEPS) to drive the energy efficiency of appliances in a climate policy context. Below, we argue that policy interventions targeting the appliance market are needed due to various political barriers, market failures and behavioural anomalies, which implies that a) the full social costs of carbon will not be paid by market actors, and b) even if the market price for carbon would equal the full social costs, we cannot expect that consumers will make 'rational' decisions when purchasing new appliances. Further, we argue that some of the challenges currently observed in carbon pricing could be addressed by considering the full social costs of carbon when setting MEPS. In this way, we advocate for an increasing role for more ambitious MEPS to drive energy efficiency for climate policy, and argue that MEPS could be set so they 'mimic' the behaviour of rational buyers, i.e. buyers that would need to consider the full costs of carbon when they purchase appliances and have access to perfect information. Further to this hypothesis, we identify the least life cycle costs (LLCC) across different energy efficiency classes with and without SCC. The LLCC including SCC can be used to inform the setting of ambitious MEPS as part of a climate policy mix. The advantages and disadvantages of such an approach are discussed.

FAILURES AND BEHAVIOURAL ANOMALIES ON THE MARKET FOR ENERGY EFFICIENT APPLIANCES

Market failures in the market for energy efficient appliances provide a strong rationale for policy intervention. In their seminal work, Hausman and Joskow (1982) identified four market failures: energy prices below social marginal cost, underestimation of future energy prices, consumer discount rates (DR) above social DR, and the principal agent problem. Houde and Spurlock (2016) revisited these failures in the U.S. context and find that carbon damages still remain systematically unaccounted for in energy prices. They find mixed evidence of consumer estimation of energy prices and heterogeneity in consumer discount rates (with only a fraction responding to energy costs), but they find there is still evidence of information and incentive asymmetry between landlords and tenants. Moreover, they identify two additional supply side market failures, namely market power (due to a concentrated appliance market with oligopolistic structures) and innovation market failures (underinvestment of firms in innovation due to positive knowledge externalities).

Beyond these market failures, various (systematic) behavioural anomalies have been observed (Gillingham and Palmer 2014). Despite 'correct' carbon price signals and full information, consumers have shown to be loss averse, affected by choice framing, social norms, and they pay limited attention to non-salient information. This can result in inelastic demand for energy efficient appliances; and higher electricity prices may not be enough to influence purchase behaviour (Vandenbergh 2009). In contrast, a fully (economically) rational consumer would fully take into consideration changes in electricity prices when making a purchase decision.

In this study we focus on the internalization of climate externalities of energy consumption, assuming economic rationality of consumer responses to changes in life cycle costs (LCC).

CARBON PRICING

Putting a price on carbon through taxes and emission trading schemes (ETS) has been argued as a first-choice policy to deliver cost effective abatement and innovation incentives at low administrative cost by internalising climate externalities (Aldy and Stavins 2012). This has subsequently become a key component of many national policies towards meeting Kyoto commitments and reducing GHG emissions.

In theory, an efficient carbon price takes into consideration estimates of damages from climate change in the form of a social cost of carbon (SCC) and marginal emission abatement costs (MAC). As long as the MAC do not exceed the SCC, further abatement efforts should be undertaken, as they are beneficial from a societal perspective (Aldy and Stavins 2012). However, estimating the costs and benefits of climate change mitigation involves many uncertainties and assumptions (Arent et al. 2014; Nordhaus 2007; Schelling 1992; Stern 2007). Estimates for the SCC vary from one digit values (in USD) per ton CO_2 (Tol 2005) to several hundred (Moore and Diaz 2015) and even over a thousand USD per ton (Ackerman and Stanton 2012), depending on what assumptions are made about discount rates, what damages are considered, how the probability of catastrophic damage is captured, etc. USD 43 is the central US Government estimate for the social cost of one ton of carbon in 2020, assuming a social discount rate of 3 % (Revesz et al. 2014). Prior to 2009 the UK government used an SCC based on the Stern Report equivalent to USD 83.[1] While much research needs to be done on the SCC (Burke et al. 2016), current evidence suggests that at low societal discount rates (as applied in the climate context), the range from USD 20 to 150 per ton of CO_2 covers most of the current estimates.

So far, theory has proved different from reality regarding both the coverage and ambition of carbon pricing policies. Currently, carbon pricing instruments cover less than 15 % of global emissions (20–25 % if China implements its ETS as planned in 2017); and the prices implemented in existing policies in 2016 are very modest, showing a range from USD 1/ton up to USD 26/ton with only a very few outliers going above 50 up to USD 131/ton (the Swedish carbon tax being the highest figure) (World Bank, Ecofys, and Vivid Economics 2016). The low ambition in setting carbon coverage, caps and prices are indicative of political challenges (Sterner and Köhlin 2015).

The difference between the actual modest carbon prices and the increasingly higher estimates of SCC also reflects the discrepancy between social benefits and the individual willingness to pay (WTP) for CO_2 emissions. Most studies of WTP for CO_2 emission reductions focus on specific contexts, e.g. flying (Brouwer, Brander, and Van Beukering 2008) or car purchases (Achtnicht 2012). They show that while stated average maximum WTP can be high, revealed WTP is much lower, even as low as EUR 0 per ton CO_2 for median WTP results and EUR 6 to 12 for mean WTP (Diederich and Goeschl 2013; Löschel, Sturm, and Vogt 2013). While there are no studies about WTP for CO_2 emissions reductions via energy efficient appliances specifically, a significant positive WTP for energy efficiency attributes of appliances has been revealed (Galarraga, González-Eguino, and Markandya 2011; Ward et al. 2011).

MINIMUM ENERGY PERFORMANCE STANDARDS (MEPS)

The rationale behind minimum energy performance standards (MEPS) is to direct technological change, force manufacturers into innovation and consumers into the adoption of more

1. However the UK now uses a carbon price based on mitigation costs rather than SCC (based on estimated EU Allowance (EUA) prices so in 2016 approximately USD 7.50).

Table 1. Current minimum energy performance standards.

Product Group (domestic appliances)	*MEPS*	*Energy label categories*
Refrigerators	EEI < 42 (A+)	A+++ EEI < 22; A++ EEI < 33; A+ EEI < 42
Dishwashers (full size)	EEI < 63 (A+)	A+++ EEI < 50; A++ EEI < 56; A+ EEI < 63
Tumble Dryers (condenser)	EEI < 76 (B)	A+++ EEI < 24; A++ EEI < 32; A+ EEI < 42; A EEI < 65; B EEI < 76
Televisions	EEI ≤ 0,80 (D)	A++ EEI < 0,16; A+ EEI < 0,23; A EEI < 0,30; B EEI < 0,42; C EEI < 0,60; D EEI < 0,80

Sources: (Harrison and Scholand 2014; Topten International Group 2017).

energy efficient technology. A strong rationale for MEPS has been that they deliver both energy savings and cost savings for consumers (Siderius 2014). It has been argued that energy efficiency of products is not only a low hanging fruit, but in fact "fruit that is lying on the ground"(Chu 2009). Product efficiency standards guarantee improvements in energy efficiency and force the worst-performing products off the market. Energy savings from MEPS are also arguably more predictable[2], quantified and verified than the effect of carbon pricing policies. Another benefit of MEPS is that they force all manufacturers to adhere to the standards to access the market for sale of products, thus avoiding carbon leakage that is a concern in jurisdictions with carbon pricing and often used as an argument for exemptions and mechanisms that moderate the carbon price. In general, it appears as if EU industries have become more and more positive towards MEPS (Dalhammar 2016).

Another advantage to an ambitious MEPS approach is that MEPS limit the space for product differentiation with respect to the product feature 'energy efficiency'. As a consequence, firms can no longer keep the energy efficiency artificially low for customers with a low WTP for energy efficiency and charge inflated premiums for energy efficient products to customers with high WTP for this product quality, as was found to be the case, particularly for markets with concentrated power and low competition (Houde and Spurlock 2016, 76).

Despite the potential of energy efficiency policies, some studies have also identified a gap between the potential of these policies and what has been actually realised. Some of the explanations for this gap have been attributed to the market failures and behavioural anomalies mentioned above, but others relate to the setting of the MEPS. For example, Siderius (2013) and Dale et al. (2009) demonstrate that product prices can be overestimated and thus lead to less stringent MEPS based on LCC calculations. Where there is a weak relationship between energy efficiency and prices, Siderius argues for selection of MEPS guided by the variation in efficiency in products on the market, outlining three possible approaches (Siderius 2014): first, a minimum level that cuts off 20 % of the market; second, an average level cutting off 50 % of the market; and third, a maximum level cutting off 80 % of the market.

In theory, the first approach is similar to the EU Ecodesign MEPS already in place; and the third approach is most similar to the Japanese top runner approach, in which the standard is set by the top performers in the market.[3] In reality, EU standards may even be more stringent than Japanese standards and the standards as such are not the only factors that matter; for instance labelling may have a stronger impact in some product categories (Reeves et al. 2015).

In the EU MEPS exist for a wide variety of product categories. Here we focus on refrigerators, dishwashers, tumble dryers, and televisions as indicative cases.

CAN MEPS INTERNALIZE THE CLIMATE EXTERNALITIES?

While the focus of carbon pricing schemes is on internalizing the climate externality into energy prices, MEPS are primarily aimed at reducing energy use and saving money (a LLCC approach). There are strong indications that MEPS are better than carbon pricing instruments at tackling several of the market failures mentioned above, e.g. by forcing producers to innovate and landlords to purchase more energy efficient appliances. In contrast, it is still somewhat unclear to which degree MEPS can be used to internalize the climate externality.

We are not aware of any attempts so far to base the cut-off level for MEPS on SCC estimates. In this paper we consider the approach of setting MEPS through LCC with a social cost of carbon for four appliance groups (see Table 1). While we focus our analysis on the UK, we test the sensitivity of our results with respect to key factors that may differ between the UK and other countries. A brief methods section is followed by the presentation of our main results and their discussion. Policy implications are then outlined and discussed.

Research design and methods

THEORY

Under the Ecodesign Directive (Directive 2009/125/EC)[4], the analytical determination of MEPS is generally made by determining which efficiency requirement leads to a MEPS that is the LCC minimum for end-users (Article 15). In Annex II, the Directive reads: "Concerning energy consumption in use, the level of energy efficiency or consumption must be set aiming at the life cycle cost minimum to end-users for representative

2. Arguable as we acknowledge uncertainties regarding overlap with other policies, actual consumer behaviour, and rebound effects which can influence the actual versus potential energy savings from MEPS.

3. In the Top Runner programme target achievement is based on sales weighted average efficiency of shipments for each supplier, compared to traditional MEPS where all products from all suppliers must exceed the minimum efficiency level specified. For a more in-depth comparison see (P. J. S. Siderius and Nakagami 2013).

4. Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products.

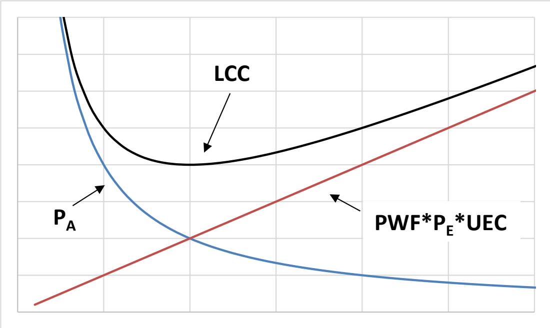

Figure 1. Schematic illustration of LCC equation and determination of LCC minimum.

product models, taking into account the consequences on other environmental aspects."

In modelling LCC and estimating LLCC, we can use the approach of LCC optimization outlined in Van Buskirk et al. (2014).[5] In that study, LCC is defined as:

$$LCC = P_A + PWF * P_E * UEC \qquad (S1)$$

Where P_A is the total average appliance price for one efficiency class, *PWF* is the present worth factor, P_E is the price of electricity, and *UEC* is the annual unit energy use in the respective efficiency class.[6] When price increases with decreasing annual unit energy use, and when there is a limit to the minimum energy use, then for very low UEC price increases without bound, and we typically have an LCC vs. UEC relationship as illustrated in Figure 1.

As illustrated in the figure, when the purchase price of an appliance increases without bound as energy use decreases towards zero, and as energy operating costs increase without bound for very low efficiencies, the minimum LCC, which is the sum of purchase price and the present value of operating costs, can be found somewhere in-between. This minimum in the LCC function theoretically determines the optimum value for MEPS.

If we focus our attention on the LCC function near the minimum value, then the LCC vs. UEC function can be approximated at a quadratic function near the minimum LCC value:

$$LCC(UEC) = LCC_{min} + C * (UEC - UEC_{min})^2 \qquad (S2)$$

Where LCC_{min} is the LCC value at the minima, and UEC_{min} is the energy use corresponding to the minimum LCC value, and C is a constant that describes the curvature of the LCC vs. UEC curve near the LCC minimum. When including the SCC the price of electricity is increased by the product of the SCC and the emission factor (EF) and the revised equation (S1) for the LCC including the SCC is:

$$LCC_{SCC} = P_A + PWF * (P_E + EF * SCC) * UEC \qquad (S3)$$

5. LCC optimization method is only briefly presented here, for a full explanation please refer to supplementary data ("Supporting Information") which can be accessed online in Van Buskirk, Kantner, Gerke, & Chu, (2014).

6. P_A and *UEC* are corrected for the product features 'capacity' (refrigerators, dishwashers and tumble dryers) and 'screen-size' (televisions). See (Van Buskirk et al. 2014) for how this correction was carried out.

Note that because of the change in the price of electricity, the energy use for the minimum LCC has now shifted to a lower value. Note that near the old LCC minimum, we can now write LCC as a function of SCC and UEC in the following way:

$$LCC_{SCC}(UEC) = LCC_{min} + C * (UEC - UEC_{min})^2$$
$$+ PWF * EF * SCC * UEC \qquad (S4)$$

We can now calculate the minimum LCC as described by equation S4 by taking the derivative of the right hand side respect to UEC setting it equal to zero and solving for the minimum UEC as a function of SCC and other parameters. When we do this, we get the following equation that describes the shift in UEC for a MEPS policy that is set based on LLCC with SCC included:

$$UEC_{SCC\_min} = UEC_{min} - \frac{PWF * (EF * SCC)}{2 * C} \qquad (S5)$$

This equation describes that near the old LCC minima, the shift in optimum unit energy consumption due to consideration of SCC is proportional to the value of SCC, the emissions factor, the PWF and the shift is inversely proportional to the curvature of the LCC vs. UEC curve (i.e. C) near the LCC minima.

In one of the analyses that we provide below, we use product price, efficiency and annual energy use data collected from internet marketplaces to statistically estimate the minimum LCC, the value of UEC at the LCC minimum, and the curvature of the LCC vs. UEC function near the LCC minimum for different products in the UK market. We then use equation (S5) to estimate the shift in energy use implied by an LLCC MEPS policy that considers SCC.

Equation (S5) above answers the question: *for a given SCC, what is the corresponding shift in UEC?* Alternatively we can ask the reverse question: *for a shift in efficiency level (i.e. shift in UEC) what is the corresponding carbon price (CP) that can make a switch from a lower to a higher efficiency class economically beneficial (i.e. the LCC is lower)?* For that we replace the SCC in (S3) with CP and equalize (S3) for pairs of efficiency classes. Solving for CP results in:

$$CP = \frac{\frac{P_{A++} - P_{A+}}{PWF} + (UEC_{++} - UEC_{+}) * P_E}{(UEC_{+} - UEC_{++}) * EF} \qquad (S6)$$

Where ++ indicates the more efficient appliance class and + the less efficient appliance class in the pair. In order to test the robustness of the resulting carbon price values, we included a sensitivity analysis. This included a variation in electricity price (from GBP 0.10 to 0.20/kWh) and a variation in emission factor (from 200 gCO_2/kWh to 700 gCO_2/kWh). Note that the approach presented in (S6) makes the conservative assumption of fully rational consumers, i.e. consumers that buy appliances based on (feature-adjusted) LLCC. In reality the demand for energy-efficient appliances is never that elastic and a higher electricity (and carbon) price would be needed to achieve the shifts between efficiency classes. Moreover, the sensitivity analysis assumes, for simplicity, an inelastic electricity demand.

Table 2. Population and distribution of product models in dataset and % sales in EU.

	n =		*A+++*	*A++*	*A+*	*A*	*B*	*C*
Refrigerators	978	Number of models	37	317	624	0	0	0
		% sales in EU 2014	4 %	21 %	72 %	2 %	0 %	0 %
Dishwashers	358	Number of models	54	89	184	31	0	0
		% sales in EU 2013	3 %	23 %	35 %	38 %	0 %	0%
Tumble Dryers	148	Number of models	4	49	13	0	63	19
		% sales in EU 2014	2 %	22 %	16 %	2%	34 %	23 %
Televisions	232	Number of models	0	11	103	99	19	0
		% sales in EU 2013	0 %	1 %	23 %	45 %	13 %	3 %

Sources: (Michel, Attali, and Bush 2013; Michel, Attali, and Bush 2015; VHK et al. 2014).

DATA

The appliance data that we use in the model (incl. sales price, electricity use, product features, efficiency rating) have been taken from online marketplaces for energy efficient appliances[7] and reflect the market offering in the UK in 2016.

The UK domestic electricity price used for this study is USD 0.17/kWh including taxes (GBP 0.14/kWh)[8], which was the average price for a medium consumer in the first half of 2016 (Department for Business, Energy & Industrial Strategy 2016). See Table 2[9, 10, 11].

The carbon intensity of electricity generation in the UK was 413 g CO_2/ kWh in 2014 (IEA 2016a). This is the average emission factor over a full year period. The marginal emissions factor was likely higher, but it typically did not exceed 700 g CO_2/ kWh in the UK in the past (LCP and enappsys 2014). While for the UK, the marginal emissions factor is likely lower today (due to the phase-out of coal), it might well be higher in other countries where the share of coal in electricity generation is higher. The emissions factor for bituminous coal is about 900 g CO_2/ kWh (IEA 2016a).

The SCC estimate used for this study is USD 150 (GBP 123). While being at the high end of estimates, this SCC value should be seen as conservative in the context of this study, since we argue in favour of MEPS as climate policy instrument in comparison to carbon pricing at social costs. Hence, we confront MEPS with a very ambitious carbon pricing policy and see how they compare.

Results

Figure 2 shows average price and LCC curves for four different appliances and their respective efficiency classes on the UK market in 2016. The general appliance price trend observed (black lines) is clear (with the exception of televisions): the lower the annual energy use of an appliance the higher its price.

In contrast, LCC trends (dark grey lines) are less clear. For refrigerators and dishwashers the least efficient model class has also the least life cycle costs (LLCC). For tumble dryers and televisions models in the least efficient class have the highest LCC.

If the SCC is accounted for in the LCC (light grey lines), the cost-ranking of efficiency classes is little affected. Only for refrigerators the LLCC moves from A+ to A+++; and for tumble dryers the average model in class A++ has now LCC that are almost as low as the average model in class A+, which has the LLCC. While the inclusion of SCC does not alter the ranking of LCCs very much, it clearly increases the level of LCC.

The space between the LCC curves (dark grey) and the LCC curves with SCC (light grey) is where LCC curves would be located for lower SCC estimates between USD 0 and 150 per ton of CO_2.

CHANGE IN SCC CORRESPONDING TO CHANGE IN MEPS LEVEL

In Table 3, we compare shifts between efficiency classes (as they might occur if more stringent MEPS are implemented) to the carbon prices that would be needed to incentivise the same shifts. Note that, due to market failures and behavioural anomalies, these cost incentives do not imply that all consumers would actually change their behaviour. In other words, the LCC-elasticity of the demand for energy efficiency in appliances is not complete.

The carbon prices displayed in Table 3 reveal a clear polarization. First, for several appliances carbon prices would have to be much higher than they are today in order to incentivize a shift between efficiency classes. In most of these cases they must exceed even the high SCC estimate of USD 150. On the other hand, there are appliances for which no carbon price is needed and the LCC should already be incentive enough to purchase a model from the more efficient appliance class. This is the case for televisions, where the current MEPS clearly does not incentivise an optimised market in regard to energy efficiency.

CHANGE IN UEC CORRESPONDING TO ADDITION OF SCC

In addition to the results regarding the SCC corresponding to a change in MEPS level described above, we provide for dishwashers and tumble dryers refined estimates of the shift in optimum UEC due to consideration of an SCC of USD 150 using formula (S5).

The above figures illustrate the statistical estimation of the curvature LCC minimum for dishwashers and tumble dryers. For these estimates, market data were used to estimate a reference line that provided market average UEC vs. appliance capacity

7. Enervee market, https://enervee.com/ in the U.S. and http://www.johnlewis.com/ in the UK.

8. The exchange rate used in this study is 1.223.

9. Dishwashers: Class A includes slim models. In Figure 2 we graph only models with 12 place settings as 82 % of models on the market were 12 place settings in the EU 2009 (European Commission 2010), The category with a capacity of 12 place settings includes 57 models in the Enervee dataset.

10. Tumble dryers: Class C includes slim models. In Figure 2 we graph only models with 8kg capacity (the median size) with 60 models in that category

11. Televisions: 16 % of sales were of unknown energy class.

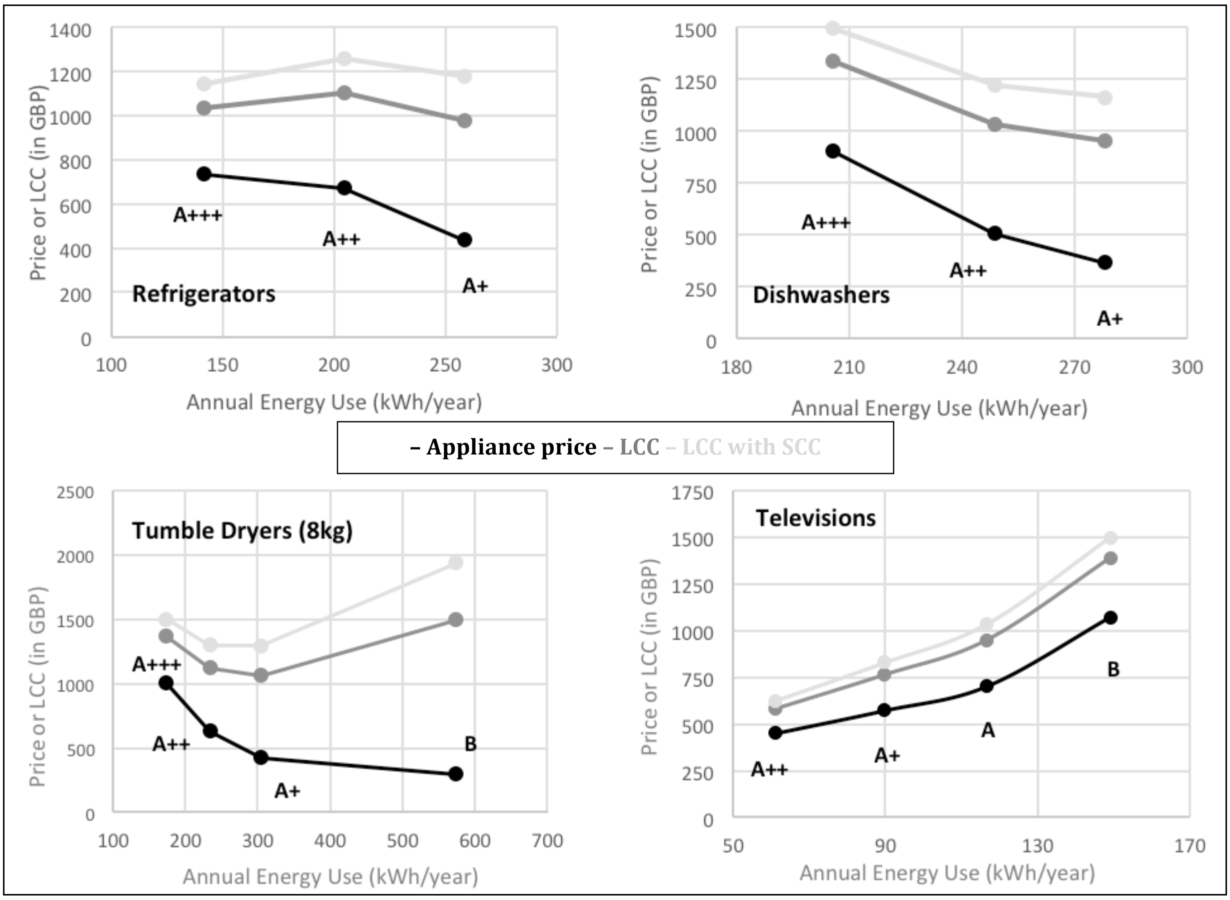

Figure 2. LCC curves for appliances in the UK, with and without SCC.

Table 3. Minimum carbon price levels (in GBP/ton) required to set the same incentive as MEPS.

Appliance	*Shift from*	*Minimum carbon price needed to trigger the shift (in GBP/ ton)* EF=413; P_E=0.14	EF=413; P_E=0.10	EF=413; P_E=0.20	EF=700; P_E=0.14	EF=200; P_E=0.14
Refrigerators	A+ to A++	372	468	226	219	767
	A+ to A+++	77	174	0	46	159
Televisions	A to A+/A++/A+++	0	0	0	0	0
	A+ to A++/A+++	0	0	0	0	0
	A++ to A+++	0	0	0	0	0
Tumble dryers (condenser, 8kg)	B to A+/A++/A+++	0	45 (to A+++)	0	0	0
	A+ to A++	136	233	0	81	281
	A+ to A+++	382	479	237	226	789
Dish washers (12 place settings)	A+ to A++	429	526	284	253	885
	A+ to A+++	862	959	717	509	1780

EF = emissions factor (in gCO_2/kWh); PE = price of electricity (in GBP/kWh).

(i.e. the number of place settings for dishwashers, and the kg of clothes drying capacity for tumble dryers). The LCC was then examined relative to this market average energy use, and was fit to a quadratic function of energy use relative to the reference. The PWF used in these LCC calculations was set to 15. This quadratic function fit provides an estimate of the LCC minimum and the curvature of the minimum. For dishwashers the estimated curvature is 0.098 UK Pounds per $(kWh/yr)^2$ while for tumble dryers the curvature of the LCC minimum was estimated as 0.0097 UK Pounds per $(kWh/yr)^2$. Using the value of SCC of USD 150/ton and the emission factor for the UK, these curvature values correspond to a shift in optimum UEC of 38.9 kWh/year for tumble dryers and 3.9 kWh/year for dishwashers. This means that in the MEPS context, a relatively small shift in MEPS can account for SCC in the LCC optimization of the MEPS level.

Discussion

There is a clear indication from the products examined that progressive MEPS (i.e. moving up one or more energy classes) would easily internalise the climate externality. Furthermore, we showed that moving up a full energy class is not necessary to

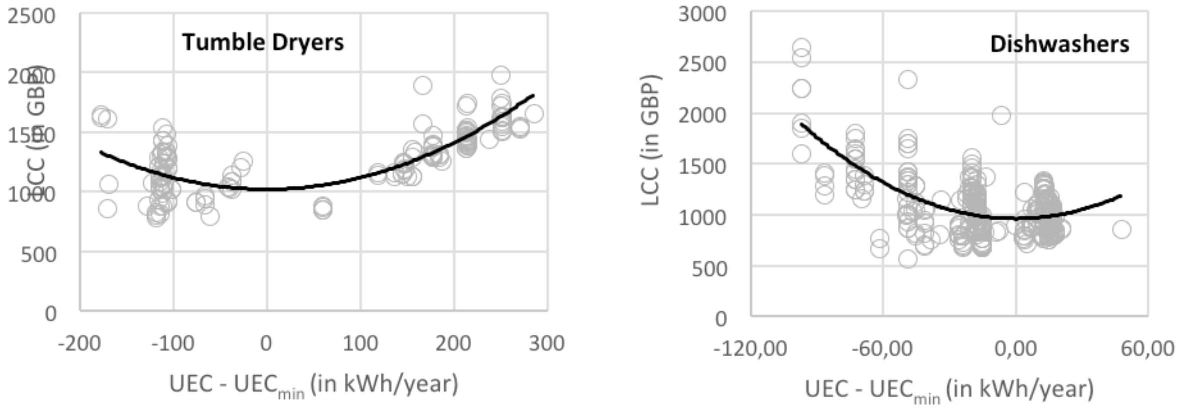

Figure 3. Curvature of LCC minimum estimated from market data for tumble dryers and dishwashers.

achieve this, but it could be accomplished at a modest increase in stringency – even when assuming that the SCC is relatively high (i.e. 150 USD/ton). For televisions, rational consumers should already be incentivised by electricity prices (that include a modest carbon price) to purchase the LLCC models, and thereby abate emissions. This implies, for policy makers, that MEPS can lead to energy efficiency improvement that would be hard, if not impossible, to incentivise with carbon pricing policies. MEPS can, in some cases, help to ensure that non-economically rational consumers actually choose LLCC appliances. In order to cause, through carbon-energy pricing alone, the kind of purchasing and usage behaviour that a particular MEPS would achieve, the carbon price would have to be even higher than indicated by the values in Table 3 and, therewith, in a range that is likely beyond what is political feasible based on current pricing trends.

IMPLICATIONS FOR CONSUMERS

In the absence of socially optimal MEPS, it is interesting to investigate whether consumers actually consider LCC (with or without SCC) in their purchase decisions. In order for a carbon price incentive to work, it is a necessary pre-condition that the LCC for an efficient appliance (including the carbon price) is lower than for a less efficient appliance. This would, at the same time, be sufficient for economically rational consumers with full information. However, consumers systematically deviate from the rational choice ideal.

This, however, poses the question to what degree energy prices influence investments in energy efficient appliances. The short and sobering answer is 'Not much!' A recent study from the US found no evidence that electricity price increases made consumers more likely to buy more energy efficient (Energy Star labelled) air-conditioners, clothes washers, dish washers and refrigerators (Jacobsen 2015). Similarly, a simulation of the UK refrigerator market found that energy savings from a 10 % electricity price increase will be much lower if the assumption of rational choice is abandoned and it is assumed that consumer only partially perceive energy costs (Cohen, Glachant, and Söderberg 2014).

Our study supports these findings with evidence of several instances in which the LCCs of the more efficient appliance classes are lower – even without adding the SCC. This is particularly the case for televisions, for tumble dryers class B and for refrigerators class A+. Consumers still buy the less efficient appliances with higher LCCs (see also discussion below and Table 2) and producers are still able to offer these models (see Table 2). This seemingly irrational consumer behaviour cannot even be explained by the assumption that the features of appliances differ across efficiency classes. First, appliance prices and energy use data in our analysis are adjusted for key product features (e.g. fridge capacity or screen-size). Second, other analysis has found that products tended to improve in quality with the progression of new MEPS (Taylor, Spurlock, and Yang 2015).

IMPLICATIONS FOR MEPS POLICIES

Our modelling indicates that current MEPS are partially outdated. It seems that for some product categories in the Ecodesign Directive, the MEPS is chasing the technology development on the market, confirming observations made in earlier MEPS research (Siderius 2013). LCC curves show policy makers where MEPS should be set already now, while the market data shows them how consumers react to existing MEPS. The novel approach to include SCC in the LCC indicates to politicians how MEPS can be used for ambitious climate policy, and that further tightening of MEPS is in best societal interest.

The result in the market of moving each product group up one energy class with more ambitious MEPS, would be roughly equivalent to cutting off 50 % of the market for tumble dryers and dishwashers and over 70 % of the refrigerator market; while for the televisions market that we examined in our dataset, moving up energy classes would exclude very few models (see Table 2). Moving up one energy class can be viewed as akin to the medium ambition MEPS presented earlier, while two or more energy classes would be more akin to a top runner approach, cutting off significantly larger portion of the market, but still technically feasible.

Including SCC can help drive climate policy through MEPS; but once the climate externalities have been internalized, increasing the ambition of MEPS may need to rely on other rationales. As suggested by Siderius (2013), using learning curves and a more top runner oriented approach is an option to continuously push innovation. Studies by Van Buskirk et al. (2014) and Taylor, Spurlock, and Yang (2015) indicate that MEPS can lead to a win-win-win situation, as regulated product groups not only become more energy efficient, but they also find product prices drop quicker than for non-regulated product groups; and MEPS appear to improve other product qualities such as repair costs. In this situation, the only losers will be the enterprises that lag behind, e.g. because they have not invested enough in product development or have capital invested in producing inefficient products.

IMPLICATIONS FOR CLIMATE POLICY

We have shown that for some product groups, energy savings from these products can be achieved through more ambitious MEPS that internalise a high carbon price (as least higher than any carbon price currently implemented by any carbon pricing policy currently in operation) that better reflects research estimating high social costs of carbon. Designing MEPS based on carbon price equivalents at SCC level also seems to improve political feasibility. Generally, the political feasibility of enforcing MEPS seems to be much higher than the potential for enforcing pricing policies that reflect the true cost of carbon; this is evidenced by the large and increasing number of MEPS for an increasing number of products, in an increasing number of jurisdictions (Reeves et al. 2015). In comparison, pricing policies are rather limited in scope and most importantly ambition.

Since the potential cost of mitigation (higher appliance cost in some cases) is bundled with a benefit of cheaper use and distributed amongst consumers, implementing a climate policy with ambitious MEPS can be more politically feasible due to higher consumer acceptance, than through carbon pricing. We should, however, mention that there has also been a backlash against some MEPS both in the EU and US, which seems to coincide with the regulation of products that are more visible for private consumers such as lighting products and small household appliances (Sachs 2012). The anti-regulatory backlash in the EU has been especially noteworthy in the UK media (Barford and Dalhammar 2015).

Ambitious MEPS are frequently criticised to be redundant if carbon prices increase to better reflect social cost of carbon. However, this can be addressed through the design of the carbon pricing policies to better reflect a policy mix. ETS caps can be planned with MEPS in mind and reduced by the amount of estimated savings from MEPS. Subsequent adjustments will be more feasible with the market stability reserve of the EU ETS which will start operating in 2019 (European Commission 2016). Such mechanisms could enable the EU ETS to respond more flexibly to the performance of other policies like MEPS. It is even less problematic to have a policy mix of MEPS and carbon taxes (as opposed to ETS), where only the price of the carbon tax needs to be decided (Sterner and Köhlin 2015). Hood (2013) argues that energy efficiency policies can work alongside carbon prices and lower the economy-wide carbon price necessary to meet the emissions target by ensuring negative-cost energy efficiency is not left untapped.

Conclusion

In order to maintain a chance of meeting the two degree target, low-carbon energy technology, and energy efficiency measures in particular, have to be further developed and implemented as soon as possible. Modest carbon prices can be seen in this context as a short-term tool to clear the market of low-cost, well-proven abatement options, but the generally low carbon prices neither provide the incentives for consumers to buy more energy efficient appliances nor provide incentives for long-term industry investment in innovation.

In this paper we show how a rather modest tightening of existing MEPS is enough to mimic a situation in which a high carbon price, representing the SCC, is internalized in the electricity price. Moreover, more ambitious MEPS would require very high carbon prices to push the market to the equivalent LCC optimum. This finding is robust with respect to the key variables of electricity price and emissions factor, so that it has high validity beyond the specific case of the UK. Our findings support further advantages of MEPS over carbon pricing, namely addressing behavioural market failures to provide certainty that consumers actually move to more efficient appliances. It should be noted again that our model gives a snapshot of the market and does not consider dynamic effects like elasticity and learning curves, which could be areas for further research.

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