The employment double dividend of environmental tax reforms: Exploring the role of agent behaviour and social interaction

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It has been long debated whether environmental tax reform (ETR), i.e. a revenue-neutral shift of the tax burden from labour to carbon emissions, can have a double dividend, in terms of climate and economic goals. So far this question has been addressed in public finance and environmental economics using models with rational and representative agents. Here we examine the relevance of deviating from these standard behavioural assumptions. Our motivation is that research from other fields indicates that impacts of both environmental and income taxation on households are sensitive to behavioural biases, such as habits, imitation or status seeking. A related feature is that consumers and firms are heterogeneous with respect to many characteristics, some of which are crucial for the distributional effects of a tax reform. We combine insights from social psychology and behavioural, evolutionary and labour economics to identify behavioural cases in which the impacts of an ETR is likely to differ significantly from those in the traditional framework. Our findings show that households' time use patterns and the distinction between extensive and intensive labour supply are relevant and deserve more attention.

Keywords: bounded rationality; carbon tax; climate policy; heterogeneity.

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1. Introduction

With anthropogenic climate change likely exceeding the goals set by the international community in Paris 2015, the need for comprehensive climate policies and their appropriate assessment is more urgent than ever. A revenue-neutral tax shift away from labour and towards carbon dioxide (CO_2) emissions, i.e. an environmental tax reform (ETR), is widely considered as such a policy. So far the analysis of ETRs has largely taken place within the domain of public finance and environmental economics relying much on computable general equilibrium (CGE) and macro-econometric models. These tend to focus on representative or average and rational behaviours of consumers and firms.

Here we discuss how considering different types of behaviour, social interactions and heterogeneity of firms and households results in a richer understanding of the mechanisms underlying, and outcomes of, environmental tax reforms. Bounded rationality and non-market social interactions explain how information and innovations diffuse. This is relevant as an ETR is supposed to trigger low-carbon innovations and transitions. Recent studies on ETRs are increasingly paying attention to heterogeneity (e.g., Aubert and Chiroleu-Assouline, 2019; Fullerton and Monti, 2013; Jacobs and de Mooij, 2015; Jacobs and van der Ploeg, 2019; Rausch and Schwarz, 2016). This allows, among others, to more accurately account for distributional impacts of the policy. However, heterogeneity is often limited to only one dimension, or where studies go into more detail, there is a disconnect with the macro level.

This study offers a critical review of modelling practices to evaluate the impacts of environmental tax reforms. We examine whether and how a heterogeneous population of boundedly-rational and socially-interacting firms and households can affect the mechanisms of environmental tax reforms, and thus outcomes in terms of relevant

economic and environmental indicators. To this end, we synthesise the results from the traditional literature in public finance with insights from behavioural and evolutionary economics, adding observations from labour economics and studies on time use. In the last decade, behavioural economics has come to be seen as particularly important in the context of environmental and energy policies (Allcott and Mullainathan, 2010; Gsottbauer and van den Bergh, 2011; Shogren and Taylor, 2008). Evolutionary economics is relevant as it can offer insights about how the combination of multiple, heterogeneous agent populations affects climate policies. We offer an explorative study aimed at assessing important model elements or assumptions that deserve investigation. The result can serve as an input to subsequent quantitative model and policy studies focusing on a particular element or assumption in more detail.

In this study we focus on the so called 'employment double dividend' (EDD), denoting a reduction in both environmental pressure (notably CO_2 emissions) and unemployment, given the limited space we have available. The EDD is highly dependent on decision making and thus particularly interesting from a behavioural perspective. It harmonises two goals that are often presented as being conflicting, namely emissions reduction (an environmental goal) and employment (an economic goal).

We will evaluate outcomes under distinct sets of behavioural assumptions with respect to these two dividends. Our analysis follows a three-step procedure. First, we identify the main mechanisms through which an ETR is commonly assumed to culminate in an employment double dividend in existing economic models. Second, we critically review central modelling assumptions. Third, we examine double-dividend outcomes for a number of cases combining relevant behaviours, heterogeneity and social interactions of agents, making use of the mechanisms identified in step two to illustrate how policy-makers can benefit from increased realism of economic models.

Following this approach, we find that complementarity between household consumption of leisure and commodities is not necessarily conducive to an employment dividend. The opposite may hold true when one distinguishes between extensive and intensive labour supply, i.e. the number of employed people and the hours worked per employee, respectively. The reason is that increased labour supply through employed individuals can undermine the creation of new jobs. On the firm side, emissions reduction is achieved through costly abatement. If companies are not able to establish product or process innovation, they may face extinction. Notably, equity impacts are influenced by heterogeneity of skills and consumption choices. In addition, time use is relevant, especially for the labour-leisure trade-off, but has been neglected in traditional studies of ETR.

The remainder of the paper is organised as follows. Section 2 offers an introduction to the double-dividend notion and a roadmap to this study. Section 3 sketches the mechanisms of environmental tax reforms and how they relate to an EDD (Section 3.1). Next, in Section 3.2 it offers a critical discussion of several key assumptions in the light of different streams of literature and summarises the resulting additional mechanisms we think should receive attention in modelling and policy analysis. Section 4 presents the results of a qualitative assessment of different behavioural cases. Section 5 discusses the main insights. Section 6 concludes.

2. Context and approach

2.1. The double-dividend notion

Research on environmental tax reforms centres on the double dividend (DD) hypothesis, the notion that one might reap two types of benefits from the policy: one of environmental and the other of economic nature. This combines the concept of Pigouvian taxation, aimed at internalising (environmental) externalities, with the need for distortive taxation in

second-best economies[1]. While existingstudies tend to represent the first dividend through greenhouse gas or CO_2 emissions reduction, the economic dividend has been approached in various forms. Most authors view it either as enhanced efficiency of the tax system (Bovenberg and de Mooij, 1994) or increased employment (see e.g. Bovenberg and van der Ploeg, 1998; Bovenberg and van der Ploeg, 1998; Koskela and Schöb, 1999; Nielsen et al., 1995). We will concentrate our analysis on the latter, also known as the employment double dividend (EDD). While carbon taxes are first and foremost instruments of climate policy, the revenues they are able to generate have triggered much debate about if their use can achieve a second, i.e. economic or welfare, dividend.

A persistent terminological contribution of Goulder (1995) is the distinction between a weak and strong DD. Both take environmental improvement through a tax shift as given. The strong DD notion implies economic improvements compared to a situation with no tax reform. This means an environmental tax could be based on pure efficiency grounds, regardless of its environmental benefits. The weak DD means that there are economic benefits of recycling the pollution tax revenues through cuts in distortionary taxation as compared to returning them to households in a lump-sum fashion, but that there are not necessarily economic improvements compared to the absence of a pollution tax. This hypothesis is supported analytically by Bovenberg and de Mooij (1994). Empirically, Bovenberg and Goulder (1996) confirm this result using a numerical model of the United States' economy. Based on a literature review, Ekins and Speck (2011, p.37) summarise that empirical models typically find a weak double dividend.

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[1] For a more general discussion of Pigouvian taxation in second-best economies see for instance Bovenberg and Goulder (2001).

Theory and empirics of the double dividend

Most studies show improvement in environmental quality due to pollution taxes. See Bosquet (2000) for an overview of empirical modelling results, or Andersen and Ekins (2009) for an overview of real world cases of ETR in Europe. A recent meta-analysis of ETR simulations using CGE models also concludes that there is consensus about ETRs leading to environmental improvement, while the second dividend remains ambiguous (Freire-González, 2018). Some authors have suggested that environmental benefits may be disappointing under certain conditions (Bosello et al., 2001, p.34 or Bayindir-Upmann and Raith, 2003).

The bulk of the literature in public economics focuses on the existence of the more disputed strong double dividend. It is difficult to draw clear conclusions from analytical models, because as soon as they are extended, for instance with out-of-equilibrium labour markets, there are no longer generally accepted results for a potential strong double dividend. Recycling tax revenues through tax cuts can result in an efficiency dividend only if an initially sub-optimal tax system moves closer to an optimum. Expectedly, many scholars have identified pre-existing distortions, particularly in the labour market, as a crucial condition for the existence of a strong DD (e.g. Bovenberg and Goulder, 1996). The meta-analysis by Freire-González (2018) shows the ambiguity of the results: out of 69 simulations from 40 different studies using CGE models, 55% find evidence for the existence of a strong double dividend and 45% do not. An older study by Patuelli et al. (2005) performs a meta-analysis of 186 simulations (61 studies) including both CGE and macro-econometric models. Their statistical analysis reveals that the type of revenue-recycling and the type of model used both significantly influence the impact of an ETR on gross domestic product and employment.

2.2. Conceptual Approach

The outcomes of every model depend crucially on its underlying assumptions. The modeller's ideas about the functioning of a policy shape the structure of the model (see Figure 1). We perform a synthetic, critical literature review, followed by a qualitative analysis to develop hypotheses about how different behavioural assumptions may affect the outcome of environmental tax reforms. As a first step, we undertake a literature review focused on analytical and numerical models of environmental tax reforms. We highlight key mechanisms used in these models we encountered when reviewing literature from public and environmental economics ("Literature review A"). Each of their assumptions implies certain mechanisms in the model ("Model structure") and affects the model outcomes, as shown in our conceptual framework (Figure 1).

In a second step, we add insights from other fields, such as behavioural or evolutionary economics ("Literature review B"). We attempt to synthesise the results from our two literature reviews and point out the relevance of interdisciplinary insights. Accounting for the results from Literature review B can affect some of the widely used assumptions for modelling ETRs as well as the mechanisms (Section 3.2).

Finally, we hypothesise about the potential impacts of altering these assumptions on the expected outcome of the policy using sets of distinct behavioural cases (Section 4). As the literature review follows an explorative approach, the topics are selected in a subjective manner and we do not claim to be comprehensive. [Figure 1 near here]

3. Synthetic literature review

3.1. Basic mechanisms of environmental tax reforms

In most analytical ETR models, firms are assumed to decide about the combination of input factors to maximise their profit. The upper half of Figure 2 represents the labour demand side with the effects of the policy on carbon emissions and labour demand. A

carbon tax raises the unit cost of carbon emissions (1)[2], mainly through a higher price on production inputs with a high carbon content, such as fossil fuels. The tax cuts enabled through revenue recycling ensure that the unit cost of labour falls (2). Indeed, labour costs may theoretically rise, for instance, due to strong labour unions. For simplicity, we assume the case where tax recycling is strong enough to overcome these opposing effects on labour costs so that the net labour cost falls. In order to lower its costs and maximise profits, the representative firm will try to replace carbon emissions with labour (3 and 4). This is the driving force for innovation that incentivises firms to adjust their production function. [Figure 2 near here]

If the benefits of reduced labour costs are split between employers and employees, for instance by recycling revenues through both income and payroll tax cuts, not only will the cost of labour then fall, but also households' after-tax nominal wage rate will increase (6). The latter is expected to promote labour supply because higher nominal wages increase the opportunity cost of leisure (7). The labour-leisure decision is complex, because the relative prices of clean commodities, dirty commodities and leisure all change simultaneously. Carbon-intensive goods become more expensive compared to labour-intensive goods. The exact impacts on the supply and demand of labour, and consumption of clean, i.e. low-carbon, and dirty, i.e. high-carbon, goods cannot be determined *ex ante*. These depend on the production technology and ability to innovate on the firm side and on preferences and habits on the household side (arrows 3, 4, 5, 7 and 8).

Table 1 summarises the main mechanisms found in the literature on ETRs in public economics. Direct effects correspond to price changes triggered by the tax reform.

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[2] The numbers in parentheses in this subsection all refer to arrows in Figure 1, e.g. (1) refers to arrow 1.

Indirect effects include impacts on household labour-leisure decisions and the firm input-factor decisions. In Table 1, as for the remainder of the paper, we assume a general rise in the consumer price index as indicated by empirical studies (Freire-González, 2018)[3]. This can be justified based on the current reliance on carbon emissions of virtually all consumption. [Table 1 near here]

3.2.Critical assessment of model assumptions

Homothetic preferences

ETR analyses traditionally assume that household preferences are homothetic, implying that a change in income does not affect the share of expenditure for different types of goods (see e.g. Bovenberg and de Mooij, 1997 ; Parry and Bento, 2000, Babiker et al., 2003). Under these preference assumptions uniform commodity taxes are optimal and lump-sum recycling is most desirable on efficiency grounds (i.e. when ignoring the environmental externality). The model of Babiker et al. (2003) shows that tax cuts can reduce welfare compared to lump-sum recycling of carbon tax revenues. Parry and Bento (2000) employ a static model with homothetic preferences between two pollutive consumption goods, one of which is deductible from the income tax. An income tax reduction in this case leads to higher net wages and a shift from tax-favoured to non-favoured goods. We would expect an analogous effect if the labour tax cuts induced some kind of shift between dirty and clean consumption goods. This welfare gain (termed "strong revenue-recycling effect") changes, when the homothetic preference assumption is loosened (Parry and Bento, 2000, p.22).

[3] It should be pointed out that the evidence is limited: only five simulations in Freire-González (2018) include a consumer price index.

Homothetic utility functions are a convenient assumption for the tractability of models, but questionable when confronted with empirical evidence. Indeed, the carbon intensity of consumption tends to decrease with rising income. While rich households on average generate higher total emissions per capita, low income households need to assign a larger share of their expenditure to emission-intensive consumption such as energy use for heating or cooking (Büchs and Schnepf, 2013; Chitnis et al., 2014; Jones and Kammen, 2011; Weber and Matthews, 2008).

Data for the United States used by Sager (2019), for instance, shows that the expenditure share for energy services[4] is higher for low income households than for high income households. According to an analysis of survey data from the United Kingdom (UK), CO_2 emissions are regressive in income for home energy and indirect emissions[5], whereas transport emissions seem to be more 'homothetic' in the sense that they increase almost proportionally with income (Büchs and Schnepf, 2013).

Some recent models of ETR policies incorporate a subsistence level of polluting consumption by assuming Stone-Geary preferences. Aubert and Chiroleu-Assouline (2019) consider a model with heterogeneous workers and imperfect labour markets. Only under specific assumptions, including a low subsistence level of polluting consumption, the initially regressive reform can be rendered Pareto-improving through a non-linear income tax. A study by Jacobs and van der Ploeg (2019) shows that improvements in social welfare are possible without deteriorating inequalities, namely if the government uses lump-sum transfers besides labour taxes. Finally, Klenert and Mattauch (2016)

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[4] Energy services include air travel, electricity, gasoline, heating fuel and natural gas.

[5] Indirect emissions are those not directly emitted by the household, but embodied in consumption of food, recreation or personal care, for instance.

investigate different revenue recycling options, finding that only lump-sum recycling of tax revenues will lead to a progressive result, while all other recycling options render the reform regressive.

Weak separability

Another common, yet difficult assumption is weak separability between leisure and commodity consumption (Babiker et al., 2003; Bovenberg, 1999; Parry and Bento, 2000). It means that households allocate constant fixed expenditure shares to leisure and commodity consumption. This implies that the labour supply decision and consumption choices are independent, i.e. the amount of labour supply does not affect the types of goods and services consumed. A notable exception is Parry (1995), who analyses the optimal pollution tax when leisure and consumption are separable. He concludes that a DD may materialise only if leisure and the polluting consumption good are sufficiently weak substitutes, while most other early models of environmental tax reform find a double dividend under the assumptions of complementarity between leisure and polluting consumption paired with weak separability. A study by West and Williams III (2007) estimates the cross-price elasticity between gasoline and leisure using United States household expenditure data, finding these goods to be complements. Using a demand system without homotheticity and separability, they show that the optimal gasoline tax rate should be more than one-and-a-half times the rate one would find using a separable utility function. Parry and Bento (2000) speculate that in their ETR model relaxing the assumption of weak separability would lead to additional welfare gains through positive feedback on labour supply (p.23).

Such feedback effects are highly relevant. While increased income through higher labour supply allows for more budget to be spent on consumption, it also reduces the time budget for leisure. How people spend, and what they consume during their free time,

influences the carbon intensity of their consumption. Hence, it is important to account for how commodity consumption of a household responds to changes in time use, for instance when they enter employment. Individuals may substitute time-intensive with time-saving consumption when working hours increase. Goods and services which require processing – be it physical or mental – are likely to be replaced with alternatives that require less time, but are often more carbon-intensive. Examples are replacement of reading with recreational activities that require special equipment or travel such as outdoor sports[6], substitution of raw food ingredients with processed foods, or shifting to faster transportation modes.

The most recent time use survey for Germany, for instance, confirms that eating and drinking outside the house as well as entertainment and culture activities are predominantly performed by employed households, while unemployed individuals are likely to spend more time on food preparation and other activities that take place in their own home, as well as on the job search. Compared to an employed person, an unemployed person on average spends more than twice as much time on preparing meals at home and on household work. Jobless households also undertake more low-emission activities like walking and sleeping (Statistisches Bundesamt, 2015). In addition, this data shows that the unemployed invest more time in home-based cultural activities, such as reading, artistic activities or games, whereas employed people have a higher time expenditure for cultural events outside the home. This includes visits to the cinema, theatre or amusement

[6] Some studies of time use show that time spent on reading is declining, while household spend more time on sports and outdoor activities (see e.g. Jalas and Juntunen, 2015) . The material and emission intensity of these activities is highlighted for instance by Aall et al. (2011) in a study for Norway.

parks (Statistisches Bundesamt, 2016). In a time use study for France, De Lauretis et al. (2017) show that high-income households attribute less time to sleep, the least carbon-intensive category. The hypothesis that employed households engage in more carbon-intensive activities is supported also by results of Gough et al. (2011), who find that working households in the UK have higher emissions than unemployed households when other factors, including income, are controlled for. Not only unemployment, but also part-time work may be correlated with low- or high-carbon activity patterns.

It has been recognised that the degree of substitutability between leisure and commodity consumption affects the likelihood of a double dividend to occur. Two examples illustrate this. First, assume that for *Household A* free time and holiday consumption are complements (negative cross-price elasticity). In this case, a rise in holiday prices reduces the demand for both leisure and holidays, so wage and price changes work in the same direction. The reason is that a price rise for holidays makes leisure time more expensive relative to working time, which promotes labour supply.

The overall effect on labour supply is less clear, if leisure and commodity consumption are substitutes. To illustrate, assume *Household B* has to commute to work by car, so the cross-price elasticity of leisure and the car is positive. A carbon tax in this case raises the price of car use and hence the cost associated with working. While a higher wage promotes labour supply, the increase in commuting costs works in the opposite direction.

The representative household

The typical analytical model for ETR analysis assumes a representative agent with upward sloping labour supply (e.g. Bovenberg, 1999; Bovenberg and de Mooij, 1994). In reality the goal of the policy is to stimulate employment at the *extensive* margin, i.e. to create more jobs and reduce unemployment rates, rather than to encourage employed

people to work more hours and thus curb *intensive* labour supply. This distinction is naturally neglected when a representative household is used, although empirical studies show that the wage elasticity of labour supply varies widely between groups of households. According to Fleetwood (2014), the shape and existence of labour supply and demand curves are highly uncertain. The wage elasticity of labour supply for instance is often found to be negative and labour supply curves can be backward-bending instead of upward-sloping. Women typically have relatively higher wage elasticities than men and their intensive and extensive labour supply reactions to wages differ. This is highly relevant for an ETR, because employees who respond to a policy by increasing their working hours may inhibit the creation of new jobs and thus undermine a second dividend.

Recently, Jacobs and de Mooij (2015) suggested that the weak double dividend only holds for models assuming a representative household. The reason is that in these models, no redistribution is necessary or desirable and hence income taxes are distortionary. When households are heterogeneous in skills, however, the distorting effect of labour taxes is balanced out by distributional gains under optimal taxation. In this case the marginal cost of public funds equals one and cutting distortionary taxes does not imply welfare gains. Deviations in the optimal environmental tax level compared to the Pigouvian rate may still occur, but they will depend on the complementarity between labour and consumption or environmental quality.

Skill heterogeneity is rather established in public economics, and is a key reason for the second-best theory of optimal taxation[7]. The abilities of low- and high-skilled households are commonly approximated through income, warranting the labels low- and high-income households, respectively. This distinction has been used sparsely in ETR studies in the past, but is gaining momentum lately. The need for including skill heterogeneity is also important with respect to potential discrimination on the labour market.

A second type of heterogeneity we want to consider is pro-environmental preferences. We assume that they contribute to a lower carbon-intensity of consumption, ceteris paribus. As utility is not only derived from leisure and commodity consumption, but also from preserving the natural environment, households exhibiting pro-environmental preferences have a higher willingness to pay for 'green' goods. Hence, an ETR would likely result in different price responses from households with distinct environmental preferences. While we assume for the sake of our analysis that the carbon tax increases awareness about pollution and hence may produce a stronger demand reaction among agents with pro-environmental preferences (*crowding-in*), the monetary incentive itself might cause a *crowding-out effect*, i.e. erode initial intrinsic motivation. Both forms of crowding effects have been shown to be empirically relevant (Frey and Jegen, 2001), with the net effect being uncertain in general. However, this does not affect our general point, which is that demand reactions vary across individuals.

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[7] See Lipsey and Lancaster (1956) for the basic idea of the theory of second-best and Diamond and Mirrlees (1971a, 1971b) for a first comprehensive application of it to optimal income taxation.

For practical purposes we limit ourselves to these two types of heterogeneity, while noting that other interesting types of household variation exist and have already received some attention. The meaning of spatial heterogeneity between urban and rural populations for tax incidence of the French energy tax reform of 2018, for instance, is addressed using a formal model by Douenne (2020). This study shows that the incidence of energy taxes can depend strongly on the ownership and thus use of capital goods with particular energy-use features, such as cars or homes.

The atomistic household

Consumption choices are not made in a vacuum, but determined by socio-cultural context, that is, influenced by others with possibly different information, resources or preferences. An important example of other-regarding preferences, i.e. preferences influenced by peer behaviour, is status seeking. Discussed already in 1899 by Thorstein Veblen, it is now widely accepted as an important driver of consumption. According to Frank (1985), under status-seeking, consumption and income taxes alleviate existing distortions caused by the under-consumption of non-positional goods, i.e. goods that depend relatively little on how they 'compare with things owned by others' (Frank, 1985, p.101), to the advantage of positional goods, for which comparison with others is important. In various studies, Norman Ireland shows that a tax on positional – or conspicuous – consumption itself, as well as income taxation can lead to Pareto improvements, which leads him to conclude that over-consumption leads to over-supply of labour (Ireland, 1994, 1998, 2001).

If positional consumption is carbon-intensive compared to non-positional consumption, employment and consumption should be too high and an employment double dividend accordingly more difficult to achieve. The result will also depend on the source of the budget for positional goods: increased labour supply affects both dividends,

whereas shifting expenditure between goods will affect mostly the environmental dividend. In a study on the interrelationship of mobility and status, Gössling and Nilsson (2010) argue that institutions like "frequent flyer" programs encourage this polluting activity by interlinking flying with social status. If status was instead conveyed through low-carbon commodities or behaviours, it would facilitate the consumption transition that ETR aims to initiate. Examples include college education, reading particular types of literature or consuming ecologically sustainable food (see e.g., Currid-Halkett, 2017 for an overview of these new subtle status symbols in the United States).

A number of additional behaviours have been studied in the context of social interaction, including the adoption of energy-efficient technologies based on peer-behaviour (Bollinger and Gillingham, 2012) or attitudes towards climate policies based on political affiliation (Dietz et al., 2007; Tobler et al., 2012). Although we focus on status seeking, our point is to illustrate the general relevance of social, non-market interaction for agent decisions and hence ETR outcomes.

The representative firm

Just as households are heterogeneous, so are firms. The effect of an environmental tax reform will likely differ across different sectors and trigger different strategic reactions. We thus want to introduce two possibly relevant types of heterogeneity on the firm side. As discussed in Section 2 an ETR changes the relative and absolute prices of carbon and labour. We account for differences in the ratio of labour to carbon firms use to produce one unit of output. This distinction is relevant if the reactions are non-linear based on this key feature that determines the policy's impact on a company. In an empirical study for Sweden, Brännlund et al. (2014) find that the impact of a carbon tax on environmental performance is almost twice as large for firms in energy-intensive sectors compared to non-energy-intensive companies. Bumpus (2015) carries out interviews with high-level

strategic decision makers of energy-intensive firms in British Columbia which reveal that firms with low carbon-intensity see the tax as a compliance cost burden rather than an innovation opportunity. In addition, a high share of firms in energy-intensive and industrial sectors is extremely environmentally pro-active in climate change mitigation compared to other firms. This last point is the conclusion of a study among 552 companies in Europe and North America (Backman et al., 2017). Not surprisingly, the studies above indicate that emission-intensity seems to determine different reactions of firms to an ETR, justifying this type of heterogeneity.

The second type of firm heterogeneity that will be considered in our analysis is firm size. Empirical evidence points to firm size as a crucial determinant for strategic choices such as innovation, both in response to climate policies, but also other changes in a firm's environment. The results of the aforementioned study also show that large firms are more pro-active than small firms, although this difference is much more significant for Europe than for North America (ibid.). Another study by Audia and Greve (2006) investigates the effects of low performance on strategies and risk taking behaviour of small and large firms in the Japanese shipbuilding industry. Their conceptual framework is the shifting-focus model of risk taking which assumes that managers pay attention to more than one reference point. Only small firms switch to less risky strategies when they perform below their aspiration levels in this study. Large firms do not adjust the riskiness in their decision making. The authors explain this by the higher proximity between small firms' survival points and their aspiration levels which makes them more vulnerable to extinction. Together this evidence gives rise to the question whether the impacts on and responses of firms of different size to an ETR will vary. Additionally, firm size is likely correlated with some other key characteristics for strategy choice, such as the age of the company, its market power and political influence and its access to financial capital. The

main difference we will assume in our analysis is that small firms may be forced to exit the market more easily than their larger competitors. Another type of heterogeneity that could be relevant for future research is trade-intensity, as Yamazaki (2017) shows in an ex-post empirical evaluation of the environmental tax reform in British Columbia, Canada.

A neglected factor that connects firms and households is skill requirements, because demand for high and low-skilled labour can develop distinctly, depending on firms' strategic reaction to a tax reform. In a meta-analysis of labour demand, covering 151 studies containing 1334 estimates, Lichter et al. (2015) find that the wage elasticity of labour demand is higher for low-skilled workers than for the average worker. It is unclear whether an ETR will lead to a proportional increase in labour demand for high- and low-skilled households. When difference in skills is addressed, it is usually connected to revenue recycling. For instance, Bosello and Carraro (2001) simulate an ETR using a labour market that is disaggregated in terms of skills. They find that recycling revenues to all workers results in a higher employment boost than limiting the transfers to low-skilled workers. The study by Aubert and Chiroleu-Assouline (2019) mentioned earlier introduces the possibility of unemployment among low-skilled workers into a model of ETR through a search and matching approach. Low-skilled labour supply is inelastic, while high skilled labour is supplied endogenously. Hence low-skilled workers can be employed or unemployed (*extensive margin*), while high-skilled workers choose the amount of hours they supply (*intensive margin*). In this case, a progressive labour tax can increase disincentives to work, but could simultaneously increase employment among low-skilled workers. Accounting for these effects highlights trade-offs between efficiency and equity. Assuming merely a general increase in labour demand discards the

fact that low-and high-skilled individuals tend to have different options and that companies will discriminate between skills depending on the strategy they apply.

One strategy of companies is to save energy by replacing machines or energy inputs directly with human labour. In that case they likely hire low-skilled labour. This may slow down or reverse recent trends in automation in assembly of cars, machines or packaging processes, for instance, but is unlikely to be adopted in all sectors. Another strategy of firms is to hire high-skilled workers who adopt or develop innovations which reduce carbon intensity. In addition, a producer can switch to an entirely new product or service, which may or may not change the skill structure among its employees. A car manufacturer for example might switch from automobiles with a combustion engine to electric vehicles because of a tax-induced shift in demand. This restructuring is unlikely to change the skill levels needed in the production process. Firms in different sectors are likely to make different choices among these options under the influence of an ETR and thus the impacts on the labour market are less clear than previously anticipated. One study showing the ambiguity of input elasticities is Fiorito and van den Bergh (2016). Studying volumes and prices of production inputs in the manufacturing sector of seven industrialised countries[8], they find mostly negative cross-price elasticities between labour and energy inputs, indicating complementarity. For Germany, the United Kingdom and the United States however, the corresponding cross-price elasticities are positive, indicating potential to substitute away from carbon emissions.

The atomistic firm

[8] These countries are France, Germany, Italy, Japan, Spain the United Kingdom and the United States.

Environmental tax reforms are usually analysed in a typical neoclassical setting with an isolated representative and profit-maximising firm. Cyert and March (1963)'s book *A Behavioral Theory of the Firm* lay the foundation for boundedly rational firm behaviour for various disciplines. Evolutionary economics focuses on the role of populations of agents interacting over social networks. This allows for a more disaggregate approach and an emphasis on change processes, which provides important advantages when studying the dynamic pattern of ETR impacts resulting in a major transition away from a high-carbon economy.

Satisficing

We abandon the doctrine of profit-maximisation and replace it with aspiration levels reached through the application of routines. Routines are one of the core concepts of evolutionary economics, defined as repeated sequences of (inter-)action, based on Nelson and Winter (1982). Forming the social analogy to genes in biological evolution, routines carry information, can mutate or be adjusted and hence are central to all processes of transition, selection and innovation of firms. Routines make firms inert, but at the same time they create a stable environment for decision making. We will assume that a firm only tries to adjust its routines, if it performs below its aspiration level. The formation of aspiration levels can be considered as a type of satisficing behaviour. Based on the theory of structural inertia we will assume that routine use makes large firms more inert than smaller firms. Regarding the ETR we can assume that routines slow down the transition process compared to profit-maximising firms. The use of aspiration levels means that only firms which are negatively affected by the tax reform, i.e. perform below their aspiration levels, will react to the policy with structural changes. For small firms routines imply an extra pressure for preventing extinction, because any delay in reaction to the policy can threaten their existence and lead to market exit.

Innovation through social Interaction

On the firm side social interaction between different companies is especially important with respect to the search and innovation process. Basically there are two types of interaction: imitation of competitors and cooperation. According to (Rycroft, 2007), the dominant assertion is that network-based partnerships are at the core of faster innovation. That is because these collaborations can deal better with the variety and uncertainty of a globalised economy. While this hypothesis is not uncontested, for our analysis we will assume that interaction between firms increases the speed of innovation diffusion and thus the potential of a double dividend to occur. Furthermore, social interaction should particularly improve the survival rates of small firms in a changing environment as they can lower their search costs.

On the perception of taxes

The idea that tax-induced price changes generate distinct demand responses when compared with equivalent market price fluctuations has been termed *tax salience* (Rivers and Schaufele 2015, p.24). While distinct reactions to taxes and other price changes are not necessarily relevant for analytical models, different demand elasticities are highly relevant for numerical analyses of environmental tax reforms. Rivers and Schaufele (2015) study the effects of the ETR in British Columbia and find that under a tax rate of \$25/tCO_2e the demand reduction induced by the local carbon tax is four times as strong as suggested by price elasticities. A study by Brännlund et al. (2014) observes a similar 'signalling' effect of carbon taxes in the context of the Swedish ETR. Analysing micro-level firm data, they discover that the tax reduces the carbon intensity of production significantly more than an equivalent change in fuel prices. The effects of carbon taxes compared to other price changes are illustrated in Figure 3. [Figure 3 near here]

Traditional models do not account for salience or signalling effects, but tax changes are expected to have the same effect as equivalent price changes. Two early studies of tax salience performed by Chetty et al. (2009) and Finkelstein (2009) focus on households in the United States. Whereas Chetty et al. show that higher salience of taxes amplifies the demand reaction, Finkelstein's results indicate that lower tax salience reduces the demand elasticity.

In an empirical investigation of the demand reaction to gasoline taxes, Li et al. (2014) use household- and state-level data from the United States. Compared to tax-inclusive gasoline prices a gasoline tax induces a stronger demand reaction for fuel consumption as well as vehicle choice. A recent study by Andersson (2019) estimates the effect of the Swedish carbon tax on emissions using a quasi-experimental approach with a synthetic control of comparable OECD countries. It finds a carbon tax elasticity of fuel consumption three times larger than the price elasticity. While the drivers of these results cannot easily be determined, all the previous studies indicate that some form of tax salience or signalling effect seems to apply to both households and firms.

The impacts of changing assumptions on model mechanisms

We have laid out the main mechanisms through which an employment double dividend is expected to be realised in Section 3.1 and discussed a number of key assumptions in Section 3.2. While potential impacts of different assumptions about agent behaviour on the double dividend will be analysed in Section 4, implications for the channels through which the policy works, i.e. for the model structure, are summarised in Table 2. The left columns are identical with Table 1 whereas the column on the far right adds more subtle insights about mechanisms we identified in Section 3.2. [Table 2 near here]

Questioning homothetic preferences implies that one needs to expect different demand reactions by high and low income households following an ETR (i). How households use their free time when their employment situation changes is a crucial determinant of the carbon intensity of their consumption and hence the effectiveness of the tax reform (ii). The distinction between labour supply at the intensive and extensive margin, respectively, introduces an additional threat to the employment dividend (iii). Workers who increase their hours of labour may prohibit the creation of new jobs. Last but not least, the strategic choice of firms in reaction to an ETR will determine whether demand for high- or low-skilled labour increases (iv). We will now turn to developing concrete behavioural cases with distinct assumptions about households.

4. Analysis of distinct behavioural cases

In this section we will apply the insights presented in Section 3 to the mechanisms of environmental tax reforms in the form of eight different behavioural cases. Outcomes will be evaluated in terms of the likelihood of an employment double dividend, i.e. CO_2 emission reduction and an increased employment rate. We will evaluate each agent along the mechanisms identified in Tables 1 and 2. As the price change for carbon- and labour-intensive goods is expected to work in opposite directions, it is unclear what exactly will happen to the overall commodity price index (CPI). To simplify the analysis, we will restrict it to the case where the price index rises because almost all commodities will get more expensive, i.e. a rise in CPI. We perform a qualitative analysis of household reactions to ETR first and after that analyse the different firm cases. Due to uncertainty about the magnitude of the effects, we abstain from combining the two.

4.1. The household decision

We consider four different household cases:

(1) HH-RR – one rational representative household (like traditional models: baseline)
(2) HH-RH – rational, but heterogeneous households (differing in skills and pro-environmental preferences)
(3) HH-BRH – boundedly rational (prone to salience effects) and heterogeneous households
(4) HH-SH – Socially interacting (through status-seeking) and heterogeneous households

Household heterogeneity here always refers to the variety in skills and pro-environmental preferences discussed before. Rationality is a disputed concept. Here we refer to a rational household as an atomistic utility maximiser with complete information and perfect foresight. Table 3 presents the potential for a double dividend to occur across the four cases. The detailed steps of the analysis can be found in the appendix.

To construct our baseline HH-RR case similar to traditional ETR analyses, we only use the channels in Table 1. An increase in nominal wage rates is expected to lead to an increase in labour supply and thus promote the second dividend. If commodity consumption and leisure are complements, a rise in commodity prices will strengthen both dividends, because price and wage rise promote labour supply and reduce commodity consumption. If leisure and commodities are substitutable, on the other hand, higher commodity prices still imply lower consumption, but also lower labour supply, thus strengthening the first dividend but weakening the second. The relative potential for a double dividend is represented in the upper left cell of Table 3. The dividends should not be interpreted as dividends received by a certain type of household, but rather display how different types of households contribute to an overall double dividend. [Table 3 near here]

Column 2 displays the HH-RH case where households are rational, but heterogeneous

in skills and preferences. The potential for a DD varies widely between the high- and low-skilled groups. There are three main reasons for this pattern. First, the tax reform may stimulate intensive labour supply and thus inhibit the creation of new jobs. Second and in connection to the criticism brought forward by Bayindir-Upmann and Raith (2003), higher employment almost certainly will translate into higher consumption, especially for low income groups. Third, the consumption of low-income households has been shown to be more carbon-intensive as they spend a larger share of their income on food, housing and energy (see Section 3.1). This is why we see negative impacts for the environment in these cells of Table 3. For high-skilled households the chances are better for both dividends because the substitutability between their commodity consumption and leisure actually leads to a decrease in intensive labour supply, thus promoting the EDD, rather than preventing it. Additionally, the higher distance to subsistence levels and decreasing marginal returns to consumption open up space for consumption reduction.

For the behavioural case with tax salience (HH-BRH, column 3) we see a similar pattern as for the second case, but overall the likelihood of a DD seems larger. This result roots in the amplified demand reduction in response to a tax, compared to a price change. One might argue that this is only a short-term effect and in the long term the remaining income will be spent. What we have assumed here is that real income falls and households rather reduce their demand for commodities instead of increasing their labour supply to sustain their former consumption level. In this case there will not be any remaining income even in the long run.

The last household case HH-SH assumes socially interacting heterogeneous agents and is displayed in the last column of Table 3. Here we see strong deviations from the former results. A crucial difference in the analysis is that we assume all households, including high-skilled individuals with pro-environmental preferences, to increase their

labour supply at both margins. This is based on the analyses of Ireland (1998, 1994 and 2001), and the assumption that status-seeking leads to over-supply of labour. One could criticise that status-seeking does not increase labour supply, but rather shifts resources from non-positional to positional goods (see e.g. Frank, 1985). From an environmental perspective however, status-seeking is problematic because it creates externalities. The essential question is how status is conveyed. We assume that the mainstream status symbols are very carbon-intensive, which is responsible for the negative results with respect to environmental benefits. The weak chances for an EDD stem from the strong increase in intensive labour supply. Pro-environmental preferences can make a difference in this case as they may promote the environmental dividend through low-carbon status symbols which are currently rather a niche than the norm in Western societies.

In general we see that the DD potential is higher for high-skilled groups, in particular those with green preferences. More thought should be put into the distinction between commodities as leisure complements versus substitutes. This difference mainly stems from the time required to consume certain goods and thus there is a strong link between the labour decision and the consumption decision as mentioned earlier. Due to the distinction between intensive and extensive labour supply, our analysis further suggests a reversed pattern of influence of leisure complements on the EDD than is normally suggested. Since household heterogeneity and different behaviours can have a tremendous effect on the DD outcome, a more detailed analysis of ETR best devote attention to these.

4.2. The firm decision

Regarding the firm side, we also distinguish between four cases:

(1) F-RR – one rational, i.e. profit-maximising, representative firm (baseline)

(2) F-RH – profit-maximising heterogeneous (in size and labour-to-carbon ratio) firms

(3) F-BRH –heterogeneous firms satisficing with aspiration levels and routines

(4) F-SH – socially interacting heterogeneous firms

In the F-RR case the ETR will lead to an increase in carbon efficiency which is positive for emission reduction, i.e. the environmental dividend. So is the second mechanism on the firm side: increased cost of carbon and lower labour cost lead to replacement of carbon with labour. This shift is expected not only to improve the environment, but also to have a positive impact on employment by raising labour demand (++/+). This baseline case is again based on the mechanisms from Table 1 and the result are shown in the upper left cell in Table 4.

Similar to the household analysis, cases 2 to 4 are evaluated using Table 2, i.e. we use one additional mechanism[9]: market exit or extinction of firms. Overall the results suggest that the outlook is more positive for the environmental dividend than for employment. There is not much variation across the different cases within the types of firms, and the environmental benefits from energy-intensive industries are always at least as high as from the labour-intensive sectors. The latter result is not surprising. As energy-intensive firms bear the largest share of the costs of the tax reform, they supposedly react strongest. In addition, they probably have the largest abatement potential. [Table 4 near here]

[9] Table 2 also includes different strategies for hiring low versus high-skilled labour. We only pay limited attention to these demand variations here, because we have no reliable information of strategy structures with respect to this point.

Behavioural Case 2, F-RH, considers heterogeneity of profit-maximising firms in terms of size and carbon-intensity. We disregard the possibility of renewable energy use here, because this strategy will not have any impact on labour demand, and also refer to energy-intensity. The results show similar emission reductions among all energy-intensive companies. For large firms these reductions are the result of efficient abatement due to economies of scale and innovation, whereas small energy-intensive firms are exposed to frequent extinction resulting in emission reduction. This comes at the cost of losing jobs among smaller companies and thus lowers the potential for the second dividend.

Case 3 introduces decision making based on aspiration levels and routines (satisficing). The results are shown in the third column of Table 3. In this case the transition process slows down for all types of companies, because routine-based decision making introduces inertia. The greatest difference compared to case 2 pertains to small labour-intensive firms. The reason is that they are likely to exceed their original aspiration levels after an ETR and thus will not introduce any changes at all – based on the idea that firms react mostly when they underperform. While automation tends to cause job losses in small labour-intensive companies, such as in the service industry, labour cost reductions due to an ETR could help to protect jobs in these sectors. That is why we added the (+). The negative impact on employment for small energy-intensive firms stems from the increased extinction risk they are exposed to when they use routines compared to a traditional profit-maximiser.

Social innovation which allows for cooperation among firms and imitation of competitors coins the fourth behavioural case, displayed in the last column. Our assumption is that these conditions will facilitate a faster innovation process and hence a more rapid transition away from carbon emissions. Extinction rates of small firms in

energy-intensive industries are lowered, because they can copy successful competitors or economise on their resource use through cooperation. This has a positive impact on the second dividend. Even small labour-intensive firms may contribute to environmental improvements in this case because they can imitate emission reducing techniques from their larger competitors without investing a lot in R&D. A downside may be a lower demand for high-skilled labour in the R&D process.

In sum, we take away three main insights from the firm analysis. Although we expect similar emission reductions within the distinct types of firms across our cases, the mechanisms to arrive there differ. For some of the companies, abatement comes about through market exit rather than innovation. This holds particularly when comparing small carbon-intensive firms with and without social innovation. Second, the different cases mainly affect the speed of transition, a factor that is neglected in traditional analyses. Third, as our examples of replacement of human labour through automation or lower research personnel demand in the case social innovation show, the different cases may affect different types of jobs in a separate manner. It is thus likely that they will affect the distributional outcome of an ETR. These factors should be included in the policy analysis in order to get a comprehensive picture, including equity impacts.

5. Discussion

Results of behavioural cases

The qualitative analysis of four behavioural cases was performed for households and firms, respectively. Even if some of the results for the double dividend potential are similar to the baseline rational representative agent case (RR), the underlying mechanisms of an ETR and its side effects are much more differentiated than is usually considered. The distinction between extensive and intensive labour supply reversed our understanding of the impact of the substitutability between commodity consumption and

leisure on employment. If leisure and consumption are complements, an ETR may increase the supply of labour at the intensive margin, which will inhibit, rather than support the creation of new jobs (employment dividend). Tax salience has a positive effect on emission reduction and on employment creation among the high-skilled labour force, whereas status-seeking may pose a serious threat to both dividends if positional consumption causes over-supply of labour.

The analysis of firms shows higher potential for the environmental dividend in all cases compared to the baseline, and particularly in emission-intensive sectors. Adding the possibility of market exit threatens the second dividend for small firms. Emission reduction may be realised through extinction at the cost of losing jobs, rather than through innovation. We expect routine-based decision making and social innovation to affect the speed of the transition of the economy. Routines are likely to slow down the transition to a low-carbon economy while non-market interactions can accelerate it. Allowing firms to cooperate and imitate successful competitors probably decreases the risk of extinction for small firms as well. Finally, the shift from labour to carbon can happen through direct replacement of carbon through human energy or through innovation in carbon productivity as a result of R&D. The latter channel is most likely the more important one and will require high-skilled labour. Although an ETR may have the potential to temporarily slow down current digitalisation and automation trends, the outcome in terms of labour demand is likely to be skewed between high and low-skilled households. These different impacts for different segments of the population need to be considered in policy evaluations.

The assessment was based on a combination of a critical literature review and additional own argumentations that integrated insights from different fields. It should be seen as a starting point for behavioural modelling approaches to studying the

environmental and socio-economic impacts of ETRs. Given the broad scope, we had to be selective and focus on important cases, rather than offer an exhaustive treatment of potential behavioural assumptions and implications. Because of the qualitative nature of our analysis, we further had to neglect the interaction of behavioural cases, especially between firms and households. To more systematically address this, specific formal models are required, which can benefit from our explorative insights. Agent-based modelling is one technique to overcome restrictive assumptions of traditional models and to comprehensively incorporate relevant boundedly-rational and socially-interactive behaviours as well as heterogeneity in the context of ETR. These models have seen considerable application to climate policy (Castro et al., 2020), but not been systematically used to answer questions about a DD of an ETR. In future work we intend to elaborate some of the ideas exposed here along these lines.

Limitations

Only the basic channels of one type of dividend – the employment double dividend – were considered, while it should be noted that other definitions of the economic dividend and other channels exist and have been studied. Examples include additional production factors (e.g. Bovenberg and van der Ploeg, 1998), informal labour markets (e.g. Goulder, 2013, Bento et al., 2018) or health benefits (e.g. Williams, 2002). Our analysis concentrates on the impacts on labour and commodity markets. Based on empirical studies, we assumed a general rise in the consumer price index. We also assumed that benefits of the tax reform are split between employers and employees and we considered only labour and carbon as input factors to production. Altering these central assumption will likely affect our results. Finally, as we do not employ a model we cannot draw any conclusion about optimal tax policy. The point we want to make is that some of the typical assumptions should be re-evaluated with respect to empirical evidence and future models

should be built with the necessary flexibility in mind.

6. Conclusions

The aim of this study was to examine whether and how particular deviations in behaviour from rational representative agents affect the mechanisms set in motion by an environmental tax reform (ETR). To that end, a literature review was performed to identify the effects of the policy on labour and commodity markets. Adding insights from literatures on time use, labour studies and behavioural and evolutionary economics has provided insights about extending existing models of ETR with other relevant mechanisms (Table 2).

One important result is that complementarity between leisure and commodity consumption does not have to be favourable for an employment dividend. Considering the distinction between extensive and intensive labour supply, the opposite can be true if increased labour supply through employed individuals undermines the creation of new jobs. Allowing for the possibility of firm bankruptcy can further threaten the employment dividend. Heterogeneity in skills and consumption choices affects the equity impacts of an ETR through tax incidence and potential shifts in labour demand. With respect to the labour-leisure trade-off, more attention should be paid to the use of time as a resource, in addition to income.

Although we did not focus on the magnitude of the various behaviours on the outcome of an ETR, our analysis has revealed the importance of deviations from assumptions of traditional models. Not only do they have the potential to affect the outcome in terms of the double dividend – as already shown by recent ETR studies – but they actually require us to consider additional mechanisms through which the tax reform unfolds and re-think the way we model the environmental and socio-economic impacts of an ETR.

Appendix – Detailed analysis of behavioural cases

Table A1. Potential of an ETR to create a double dividend under various behavioural cases

			ETR POLICY		ANALYSIS				DD	ANALYSIS				DD	ANALYSIS				DD
HOUSEHOLD						Case 1: HH-RR – Representative and rational													
	Insights from the literature in public economics (Section 3.1) →		w	↑	1	Labour supply (L_S)	↑	(-)/+	+/++										
			p	↑	2	Complements (C_C)	↓	+/+											
			p	↑	3	Substitutes (C_S)	↓	0/0											
	Results from Section 4.1					Case 2: HH-RH – Heterogeneity					Case 3: HH-BRH – Tax salience					Case 4: HH-SH – Status seeking			
	Low skills (Upward-sloping labour supply, C and V are complements)	No environmental preferences	w	↑	4	Extensive L_s	↑	-/+	---/0	16	Extensive L_s	↑	-/+	0/0	28	Extensive L_s	↑	-/+	---/-
					5	Intensive L_s	↑	-/-		17	Intensive L_s	↑	0/-		29	Intensive L_s	↑	-/-	
			p	↑	6	Demand for C_C	↓	-/0		18	Demand for C_C	↓	+/0		30	Demand for C_C	=	-/-	
		environmental preferences	w	↑	7	Extensive L_s	↑	-/+	--/0	19	Extensive L_s	↑	-/+	-/+	31	Extensive L_s	↑	-/+	-/-
					8	Intensive L_s	↑	-/-		20	Intensive L_s	↑	-/-		32	Intensive L_s	↑	-/-	
			p	↑	9	Demand for C_C	↓	0/0		21	Demand for C_C	↓	+/+		33	Demand for C_C	=	-/-	
	High skills (Backward-bending labour supply, C and V are substitutes)	No environmental preferences	w	↑	10	Extensive L_s	↑	-/+	0/+++	22	Extensive L_s	↑	-/+	+/++++	34	Extensive L_s	↑	-/+	--/-
					11	Intensive L_s	=	0/+		23	Intensive L_s	=	0/+		35	Intensive L_s	↑	-/-	
			p	↑	12	Demand for C_S	↓	+/+		24	Demand for C_S	↓	++/++		36	Demand for C_S	=	0/-	
		environmental preferences	w	↑	13	Extensive L_s	↑	0/+	++/+++	25	Extensive L_s	↑	0/+	++/++++	37	Extensive L_s	↑	0/+	+++/++
					14	Intensive L_s	↓	0/+		26	Intensive L_s	↓	0/+		38	Intensive L_s	↑	+/-	
			p	↑	15	Demand for C_S	↓	++/+		27	Demand for C_S	↓	++/++		39	Demand for C_S	↓	++/++	
FIRM						Case 1: F-RR – Representative and rational													
	Insights from the literature in public economics (Section 3.1) →		MC_C	↑	1	Carbon efficiency	↑	+/0	++/+										

			MC_L	↓	2	Substitution	↑	+/+												
Results from Section 4.2					**Case 2: F-RH – Heterogeneity**					**Case 3: F-BRH – Satisficing**					**Case 4: F-SH – Social innovation**					
Energy-intensive (Low L/C ratio)	small	MC_C	↑	3	Carbon efficiency	↑	+/0	+++/0	17	Carbon efficiency	↑	+/0	++++/-	1	Carbon efficiency	↑	++/0	+++/+		
		MC_C	↑	4	Extinction	↑	+/-		18	Extinction	↑	++/--		2	Extinction	=	0/0			
		MC_C	↑	5	Substitution	↑	+/+		19	Substitution	↑	+/+		3	Substitution	↑	+/+			
		MC_L	↓	6	Substitution				20	Substitution				4	Substitution					
	large	MC_C	↑	7	Carbon efficiency	↑	+/0	+++/+	21	Carbon efficiency	↑	+/0	++/+	5	Carbon efficiency	↑	+/0	+++/+		
		MC_C	↑	8	Substitution	↑	++/+		22	Substitution	↑	+/+		6	Substitution	↑	++/+			
		MC_L	↓	9	Substitution				23	Substitution				7	Substitution					
Non energy-intensive (High L/C ratio)	small	MC_C	↑	10	Carbon efficiency	↑	+/0	++/+	24	Carbon efficiency	=	0/0	0/(+)	8	Carbon efficiency	↑	+/0	++/+		
		MC_C	↑	11	Extinction	=	0/0		25	Extinction	=	0/0		9	Extinction	=	0/0			
		MC_C	↑	12	Substitution	↑	+/+		26	Substitution	=	0/(+)		10	Substitution	↑	+/+			
		MC_L	↓	13	Substitution				27	Substitution				11	Substitution					
	large	MC_C	↑	14	Carbon efficiency	↑	+/0	++/+	28	Carbon efficiency	↑	+/0	++/+	12	Carbon efficiency	↑	+/0	++/+		
		MC_C	↑	15	Substitution	↑	+/+		29	Substitution	↑	+/+		13	Substitution	↑	+/+			
		MC_L	↓	16	Substitution				30	Substitution				14	Substitution					

Note: For more detailed explanation of each case, see the text below.

Households

Behavioural case 1: HH-RRA – Representative and rational

1. A higher wage increases labour supply [/+], which is good for the second dividend but potentially threatens the first [(-)/].
2. Commodity demand goes down after prices rise. This promotes the first dividend [+/]. If leisure and commodity consumption are complements it promotes the second dividend as well [/+].
3. If they are substitutes there is a trade-off between leisure and consumption reduction. The effects on the first and the second dividend are unclear [0/0].

Behavioural case 2: HH-RHA – Heterogeneity

Low-skilled HHs

4. A higher wage rate promotes extensive labour supply and thus the second dividend [/+]. We assume that increased labour supply and lower complement consumption will lead to a shift towards substitute commodities. Since commodities that are substitutable for leisure are assumed to be time-saving, they likely have a higher carbon intensity [-/].
5. A higher wage also promotes intensive labour supply for low income households as they are close to subsistence consumption. This is bad for the second dividend because it prevents the creation of new jobs [/-]. For consumption and the first dividend the argument from above holds [-/].
6. The commodity price rise induces a demand reduction. We assume that low income households with no environmental preferences replace these commodities with time-saving and high-carbon alternatives, thus leading to an overall negative impact on the environment. The impact of increased labour supply is unclear [-/0]. At the extensive margin it promotes the second dividend, at the intensive margin it prevents it.
7. A higher wage rate promotes extensive labour supply and thus the second dividend [/+] (like in 4.). Although these households have pro-environmental preferences we assume them to attach more weight to work-related high energy consumption due to their low income and absolute level of consumption [-/].
8. Intensive labour supply rises too, following the higher wage rate [/-] (like in 5.) and we assume a similar increase in substitute consumption [-/].
9. The consumption of complements falls after the price rise, but we assume that it is to some extent replaced by low-carbon substitutes (such as services) rather than high-carbon substitutes, based on HHs pro-environmental preferences. The impact is not expected to be strong though [0/]. Again, the impact of increased labour supply is unclear [/0].

High-skilled HHs

10. A higher wage rate promotes extensive labour supply for high-skilled workers as well and with it higher consumption of high carbon-leisure substitutes, such as private vehicles for commuting. This means a negative impact on environmental quality and a positive employment impact [-/+].
11. Intensive labour demand is assumed to stay the same for high income HHs without environmental preferences, because they are further away from subsistence consumption and experience decreasing returns to additional income. This gives room for the second dividend as there is no competition between employed and unemployed people to fulfil labour demand. We assume that consumption patterns stay the same [0/+].

12. The price increase for commodities depresses demand. As high income households are assumed to substitute commodities and leisure, the labour supply falls as well, again promoting the second dividend rather than weakening it [+/+].
13. Extensive labour supply increases, but HHs with pro-environmental preferences are assumed to use their income for less carbon intensive consumption [0/+].
14. Intensive labour supply falls following a wage increase. HHs with pro-environmental preferences derive additional utility from preserving the natural environment and thus attach a lower weight to utility from income. This reduction is an additional stimulation for the second dividend by creating more labour demand, we assume they only reduce intensive labour supply so far as to sustain their old consumption habits [0/+].
15. The increased commodity price lowers the demand for substitute commodities, which likely improves the environment [+/]. This reduction will bring about an increased demand for leisure, e.g. to have the time to consume rather time-intensive but low-carbon goods, and thus a reduction in labour supply. As, however this reduction can be expected to come from already employed people, it would free up jobs for the unemployed and thus be – again contrary to the traditional argument – promoting the second dividend, rather than inhibiting it [/+].

Behavioural case 3: HH-BRHA – Tax salience

Low-skilled households

16. No change compared to case 2. The reason is that low income households are already very attentive to prices even without tax salience.
17. No change compared to case 2. See above.
18. The commodity price increase reduces commodity consumption, which is complementary to leisure and hence promotes labour supply. This favours the second dividend if it is at the extensive margin but threatens it when at the intensive margin. Thus the overall effect remains unclear [/0]. Due to the over-reaction to the tax we assume an overall reduction in carbon-intensive consumption, leading to a positive effect on the environment [+/].
19. No change compared to case 2.
20. No change compared to case 2.
21. Again, the price rise in leisure complements lowers intensive labour supply, thus promoting the second dividend. Due to tax salience, we assume that commodities are not replaced by other consumption [+/+].

High-skilled households

22. No change compared to case 2.
23. No change compared to case 2.
24. The price rise induces a demand reduction of leisure substitutes, leading to lower (intensive) labour supply. We assume the demand reduction to be stronger under tax salience [++/++].
25. No change compared to case 2.
26. No change compared to case 2.
27. Again, based on the literature we assume that the demand reduction will be stronger than without tax salience, improving the probability of both dividends compared to the second (and first) case [++/++].

Behavioural case 4: HH-SHA – Status seeking

Low-skilled households

28. No change compared to case 2.
29. Intensive labour supply increases following a higher wage rate, preventing the second dividend. As individuals are seeking status, they use their additional income to consume mainstream positional goods, which are typically high-carbon goods substitutable to leisure, such as cars, bigger houses, carbon-intensive holidays, etc. [-/-].
30. The price increase lowers consumption of complements, but they are likely to be replaced by time-saving high carbon consumption, made necessary and financed through increased labour supply [-/-].
31. No change compared to case 2.
32. Intensive labour supply increases after a rise of the wage rate, inhibiting the second dividend. Although the pro-environmental preferences make households use additional income for supposedly 'green' status goods it still increases their overall material consumption [-/-]. That is because they cannot afford the free time necessary to truly consume green, as that is time-intensive.
33. The price change leads to a lower consumption of leisure complements, supporting (intensive) labour supply. In the status-seeking case, where low-skilled green households try to imitate high-skilled green households, they will try hard to consume low carbon leisure substitutes to position themselves. This yields environmental improvements but still inhibits the creation of new jobs through increased intensive labour supply [+/-].

High-skilled households

34. No change compared to case 2.
35. When agents are status seeking even when their income is high the wage rate will lead to increased labour supply at the intensive margin to sustain or expand consumption. This works against both dividends [-/-].
36. The price rise induces a demand reduction for commodities. As they are mostly leisure substitutes, this fosters an increase in labour supply. When positional consumption matters we assume that consumption levels will at least stay the same and be financed through increased labour supply if necessary [0/-].
37. No change compared to case 2.
38. Some status seeking agents may be expected to increase their intensive labour supply even when they have a high income and environmental preferences. This can weaken the second dividend. However, any additional income is expected to be used for lowering carbon consumption, which is the status symbol of the 'green elite', e.g. local and seasonal products, and thus be beneficial for the environment [+/-].
39. The demand for time-saving leisure substitutes will go down following a price increase favouring more time-intensive consumption and hence lower intensive labour supply. For rich households with pro-environmental preferences this could be a return to truly green time-intensive status symbols [++/++].

Firms

Behavioural case 1: F-RRA – Representative and rational

1. A higher marginal cost of carbon emissions incentivises firms to improve their carbon efficiency. This improves the environment but has not necessarily an impact on labour [+/0].

2. The lower cost of labour together with the higher cost of carbon incentivises a shift from labour to carbon which supports both dividends [+/+].

Behavioural case 2: F-RHA – Heterogeneity

All firms

3-16. The policy induces the same changes across all firms: the higher price of carbon leads to efficiency improvements, and together with the lower unit cost of labour induces a factor shift. This always leads to positive effects for the environment and employment. A new channel exists that is particularly relevant for small firms: extinction (or market exit). The higher cost of carbon will put pressure especially on small energy-intensive firms who operate close to their survival point. This increased extinction risk threatens the employment dividend. We assume that the environmental impact of large energy-intensive firms is stronger than that of small competitors or labour- intensive firms.

Behavioural case 3: F-BRHA – Satisficing

Energy-intensive

17. No change compared to case 2.
18. Extinction rates of small firms are higher under routine use and aspiration levels, because transitions happen slower and managers choose from selection of all existing options only.
19. Higher cost of carbon induces factor shift, but slower.
20. Lower cost of labour induces factor shift, but slower.
21. No change compared to case 2, but process expected to be slower.
22. No change compared to case 2, but process expected to be slower.
23. No change compared to case 2, but process expected to be slower.

Non-energy-intensive

24. Small labour-intensive firms who require little energy will potentially perform above their aspiration levels and will thus not adjust (except maybe in the very long run). No effect on employment or emissions [0/0].
25. The probability of extinction for small labour-intensive firms does not change. Their costs probably get lower, but so do those of their competitors. No impact on either of the dividends.
26. Substitution of carbon through use of labour is probably limited in these industries. However, current trends in robotics may be slowed down, leading to a temporary protection of jobs. This favours the second dividend. The impacts for the first dividend are probably negligible [0/(+)]. The robotic argument steps a bit outside our analysis and is thus put in parentheses.
27. See 10.
28. No change compared to case 2, but process expected to be slower.
29. No change compared to case 2, but process expected to be slower.
30. No change compared to case 2, but process expected to be slower.

Behavioural case 4: F-SHA – Social innovation

Energy-intensive

1. Higher cost of carbon leads to efficiency increases. Under social innovation the speed of transition is higher than in case 2 [++/0].
2. The extinction rates of small firms are probably not increasing significantly if they can cooperate and/or imitate successful competitors. Thus there will be no big extinction impact on either of the dividends [0/0].
3. Substitution will also happen faster than in the atomistic case 2. The impact on labour may be stronger because of the transition speed, or weaker because of less labour requirements due to cooperation. Thus we are not changing it compared to case 2 [++/+].
4. See 3.
5. Efficiency improvements motivated by a higher unit cost of carbon are assumed to happen faster.
6. Substitution of carbon with labour is assumed to happen faster.
7. See 6.

Non-energy-intensive

8. If small labour-intensive firms are able to observe and learn from their competitors, efficiency improvements seem more likely in this sector. This promotes environmental benefits [+/0]. The result is the same as in the case 2, where firms maximise profit, but the reason is different. Here the firms evolve through learning to arrive at a similar result.
9. The extinction rate for small labour-intensive companies should not become higher, as in case 2 because they can imitate the best practice of others, hence improving the chances for an EDD.
10. No change compared to case 2. But again, result driven by non-market cooperation instead of profit maximisation.
11. See 10.
12. Result as in case 2. Firms come close to profit-maximisation over time through social learning and copying their competitors' behaviours.
13. Substitution is also happening, because in large companies – even if they are labour-intensive – monitoring of routines and practices will lead to a factor shift. However, total emission reduction is probably small, but research in efficiency improvements creates jobs, which promotes the second dividend.
14. See 13.

References

Aall, C., Klepp, I.G., Engeset, A.B., Skuland, S.E., Støa, E., 2011. Leisure and sustainable development in Norway: part of the solution and the problem. Leis. Stud. 30, 453–476.

Andersen, M.S., Ekins, P., 2009. Carbon-energy taxation: lessons from Europe. Oxford University Press.

Audia, P.G., Greve, H.R., 2006. Less likely to fail: Low performance, firm size, and factory expansion in the shipbuilding industry. Manage. Sci. 52, 83–94.

Babiker, M.H., Metcalf, G.E., Reilly, J., 2003. Tax distortions and global climate policy. J. Environ. Econ. Manage. 46, 269–287.

Backman, C.A., Verbeke, A., Schulz, R.A., 2017. The drivers of corporate climate change strategies and public policy: a new resource-based view perspective. Bus. Soc. 56, 545–575.

Bayindir-Upmann, T., Raith, M.G., 2003. Should high-tax countries pursue revenue-neutral ecological tax reforms? Eur. Econ. Rev. 47, 41–60. https://doi.org/10.1016/S0014-2921(01)00193-3

Bollinger, B., Gillingham, K., 2012. Peer effects in the diffusion of solar photovoltaic panels. Mark. Sci. 31, 900–912.

Bosello, F., Carraro, C., 2001. Recycling energy taxes: impacts on a disaggregated labour market. Energy Econ. 23, 569–594.

Bosquet, B., 2000. Environmental tax reform: does it work? A survey of the empirical

evidence. Ecol. Econ. 34, 19–32.

Bovenberg, A.L., 1999. Green Tax Reforms and the Double Dividend: An Updated Reader's Guide. Int. Tax Public Financ. 6, 421–443. https://doi.org/10.1023/A:1008715920337

Bovenberg, A.L., de Mooij, R.A., 1994. Environmental Levies and Distortionary Taxation. Am. Econ. Rev. 84, 1085–1089.

Bovenberg, A.L., De Mooij, R.A., 1997. Environmental tax reform and endogenous growth. J. Public Econ. 63, 207–237.

Bovenberg, A.L., Goulder, L.H., 2001. Environmental taxation and regulation, in: Auerbach, A., Feldstein, M. (Eds.), Handbook of Public Economics. Amsterdam, pp. 1471–1545.

Bovenberg, A.L., Goulder, L.H., 1996. Optimal environmental taxation in the presence of other taxes: general-equilibrium analyses. Am. Econ. Rev. 86, 985–1000.

Bovenberg, A.L., van der Ploeg, F., 1998. Tax Reform, Structual Unemployment and the Environment. Scand. J. Econ. 100, 593–610.

Bovenberg, A.L., Van Der Ploeg, F., 1998. Consequences of environmental tax reform for unemployment and welfare. Environ. Resour. Econ. 12, 137–150. https://doi.org/10.1023/A:1016040327622

Brännlund, R., Lundgren, T., Marklund, P.-O., 2014. Carbon intensity in production and the effects of climate policy—evidence from Swedish industry. Energy Policy 67, 844–857.

Büchs, M., Schnepf, S. V, 2013. Who emits most? Associations between socio-economic factors and UK households' home energy, transport, indirect and total CO2 emissions. Ecol. Econ. 90, 114–123.

Bumpus, A.G., 2015. Firm responses to a carbon price: corporate decision making under British Columbia's carbon tax. Clim. policy 15, 475–493.

Castro, J., Drews, S., Exadaktylos, F., Foramitti, J., Klein, F., Konc, T., Savin, I., van den Bergh, J., 2020. A review of agent-based modeling of climate-energy policy. Wiley Interdiscip. Rev. Clim. Chang. e647.

Chetty, R., Looney, A., Kroft, K., 2009. Salience and taxation: Theory and evidence. Am. Econ. Rev. 99, 1145–1177.

Chitnis, M., Sorrell, S., Druckman, A., Firth, S.K., Jackson, T., 2014. Who rebounds most? Estimating direct and indirect rebound effects for different UK socioeconomic groups. Ecol. Econ. 106, 12–32.

Currid-Halkett, E., 2017. The sum of small things: A theory of the aspirational class. Princeton University Press.

Cyert, R.M., March, J.G., 1963. A behavioral theory of the firm. Englewood Cliffs, NJ 2, 169–187.

De Lauretis, S., Ghersi, F., Cayla, J.-M., 2017. Energy consumption and activity patterns: an analysis extended to total time and energy use for French households. Appl. Energy 206, 634–648.

De Mooij, R.A., Bovenberg, A.L., 1998. Environmental Taxes, International Capital Mobility and Inefficient Tax Systems: Tax Burden vs. Tax Shifting. Int. Tax Public

Financ. 5, 7–39. https://doi.org/10.1023/A:1008606824395

Diamond, P.A., Mirrlees, J.A., 1971a. Optimal taxation and public production I: Production efficiency. Am. Econ. Rev. 61, 8–27.

Diamond, P.A., Mirrlees, J.A., 1971b. Optimal taxation and public production II: Tax rules. Am. Econ. Rev. 61, 261–278.

Dietz, T., Dan, A., Shwom, R., 2007. Support for climate change policy: Social psychological and social structural influences. Rural Sociol. 72, 185–214.

Douenne, T., 2020. The vertical and horizontal distributive effects of energy taxes: A case study of a french policy. Energy J. 41.

Ekins, P., Speck, S., 2011. Environmental tax reform (ETR): a policy for green growth. Oxford University Press.

Finkelstein, A., 2009. E-ztax: Tax salience and tax rates. Q. J. Econ. 124, 969–1010.

Fiorito, G., van den Bergh, J.C.J.M., 2016. Capital-energy substitution in manufacturing for seven OECD countries: learning about potential effects of climate policy and peak oil. Energy Effic. 9, 49–65.

Fleetwood, S., 2014. Do labour supply and demand curves exist? Cambridge J. Econ. 38, 1087–1113.

Frank, R.H., 1985. The demand for unobservable and other nonpositional goods. Am. Econ. Rev. 75, 101–116.

Freire-González, J., 2018. Environmental taxation and the double dividend hypothesis in CGE modelling literature: A critical review. J. Policy Model. 40, 194–223.

https://doi.org/10.1016/j.jpolmod.2017.11.002

Frey, B.S., Jegen, R., 2001. Motivation crowding theory. J. Econ. Surv. 15, 589–611.

Gössling, S., Nilsson, J.H., 2010. Frequent flyer programmes and the reproduction of aeromobility. Environ. Plan. A 42, 241–252.

Gough, I., Abdallah, S., Johnson, V., Ryan-Collins, J., Smith, C., 2011. The distribution of total greenhouse gas emissions by households in the UK, and some implications for social policy.

Goulder, L.H., 2013. Climate change policy's interactions with the tax system. Energy Econ. 40, S3–S11.

Goulder, L.H., 1995a. Environmental taxation and the double dividend: A reader's guide. Int. Tax Public Financ. 2, 157–183. https://doi.org/10.1007/BF00877495

Goulder, L.H., 1995b. Effects of carbon taxes in an economy with prior tax distortions: An intertemporal general equilibrium analysis. J. Environ. Econ. Manage. https://doi.org/10.1006/jeem.1995.1047

Ireland, Norman J, 2001. Optimal income tax in the presence of status effects. J. Public Econ. 81, 193–212.

Ireland, N. J., 2001. Optimal income tax in the presence of status effects. J. Public Econ. 81, 193–212. https://doi.org/10.1016/S0047-2727(00)00108-0

Ireland, N.J., 1998. Status-seeking, income taxation and efficiency. J. Public Econ. 70, 99–113.

Ireland, N.J., 1994. On limiting the market for status signals. J. Public Econ. 53, 91–

110.

Jacobs, B., de Mooij, R.A., 2015. Pigou meets Mirrlees: On the irrelevance of tax distortions for the second-best Pigouvian tax. J. Environ. Econ. Manage. 71, 90–108. https://doi.org/10.1016/j.jeem.2015.01.003

Jacobs, B., van der Ploeg, F., 2019. Redistribution and pollution taxes with non-linear Engel curves. J. Environ. Econ. Manage. 95, 198–226.

Jalas, M., Juntunen, J.K., 2015. Energy intensive lifestyles: Time use, the activity patterns of consumers, and related energy demands in Finland. Ecol. Econ. 113, 51–59.

Jones, C.M., Kammen, D.M., 2011. Quantifying carbon footprint reduction opportunities for US households and communities. Environ. Sci. Technol. 45, 4088–4095.

Koskela, E., Schöb, R., 1999. Alleviating unemployment: The case for green tax reforms. Eur. Econ. Rev. 43, 1723–1746. https://doi.org/10.1016/S0014-2921(98)00043-9

Li, S., Linn, J., Muehlegger, E., 2014. Gasoline taxes and consumer behavior. Am. Econ. J. Econ. Policy 6, 302–342.

Lichter, A., Peichl, A., Siegloch, S., 2015. The own-wage elasticity of labor demand: A meta-regression analysis. Eur. Econ. Rev. 80, 94–119.

Lipsey, R.G., Lancaster, K., 1956. The general theory of second best. Rev. Econ. Stud. 24, 11–32.

Nelson, Richard R, W.S.G., 1982. An Evolutionary Theory of Economic Change. Belknap Press/Harvard University Press, Cambridge.

Nielsen, S.B., Pedersen, L.H., Sørensen, P.B., 1995. Environmental policy, pollution, unemployment, and endogenous growth. Int. Tax Public Financ. 2, 185–205.

Parry, I.W.H., 1995. Pollution taxes and revenue recycling. J. Environ. Econ. Manage. https://doi.org/10.1006/jeem.1995.1061

Parry, I.W.H., Bento, A.M., 2000. Tax deductions, environmental policy, and the "double dividend" hypothesis. J. Environ. Econ. Manage. 39, 67–96. https://doi.org/10.1006/jeem.1999.1093

Patuelli, R., Nijkamp, P., Pels, E., 2005. Environmental tax reform and the double dividend: A meta-analytical performance assessment. Ecol. Econ. 55, 564–583. https://doi.org/10.1016/j.ecolecon.2004.12.021

Rivers, N., Schaufele, B., 2015. Salience of carbon taxes in the gasoline market. J. Environ. Econ. Manage. 74, 23–36.

Rycroft, R.W., 2007. Does cooperation absorb complexity? Innovation networks and the speed and spread of complex technological innovation. Technol. Forecast. Soc. Change 74, 565–578.

Sager, L., 2019. Income inequality and carbon consumption: Evidence from Environmental Engel curves. Energy Econ. 84, 104507.

Statistisches Bundesamt, 2016. Zeitverwendung für Kultur und kulturelle Aktivitäten in Deutschland. Sonderauswertung der Zeitverwendungserhebung. Stat. Bundesamt, Wiesbad.

Statistisches Bundesamt, 2015. Zeitverwendungserhebung, Aktivitäten in Stunden und Minuten für ausgewählte Personengruppen 2012/2013. Stat. Bundesamt, Wiesbad.

Tobler, C., Visschers, V.H.M., Siegrist, M., 2012. Addressing climate change: Determinants of consumers' willingness to act and to support policy measures. J. Environ. Psychol. 32, 197–207.

Weber, C.L., Matthews, H.S., 2008. Quantifying the global and distributional aspects of American household carbon footprint. Ecol. Econ. 66, 379–391.

West, S.E., Williams III, R.C., 2007. Optimal taxation and cross-price effects on labor supply: estimates of the optimal gas tax. J. Public Econ. 91, 593–617.

Williams, R.C., 2002. Environmental tax interactions when pollution affects health or productivity. J. Environ. Econ. Manage. 44, 261–270. https://doi.org/10.1006/jeem.2001.1237

Yamazaki, A., 2017. Jobs and climate policy: Evidence from British Columbia's revenue-neutral carbon tax. J. Environ. Econ. Manage. 83, 197–216. https://doi.org/10.1016/j.jeem.2017.03.003

Table 1. Main mechanisms of ETR including effects on households and firms

Agent	Direct effects	Indirect effects
Household	Nominal wage rate increases (6)	Labour supply increases (7)
	Low-carbon goods relatively cheaper than high-carbon goods (1)	Lower total commodity consumption (8)
		Shift from high-carbon to low-carbon goods (8)
		Increase labour supply (7)
Firm	Unit cost of carbon increases (1)	Reduce carbon emissions (3)
	Unit cost of labour decreases (2)	Labour demand increases (4)
	Labour relatively cheaper than carbon (1,2)	Substitute carbon with labour (3,4)

Note: The numbers in the table relate the effects to the arrows of the mechanisms in Figure 1. Column two shows primary price effects and column three the associated changes in demand and supply. Commodities in our analysis are assumed to be either labour- or carbon-intensive (we sometimes refer to the former as 'low-carbon')

Table 2. Effects of key assumptions on mechanisms of an ETR

Agent	Traditional mechanisms of ETR		Additional mechanisms of ETR
	Direct effects	Indirect effects	New indirect effects
Household	Nominal wage rate increases	Labour supply increases	Extensive labour supply increases (iii)
			Intensive labour supply may rise or fall (iii)
	Low-carbon goods relatively cheaper than high carbon goods	Lower total commodity consumption	Only possible for high income households (subsistence limit) (i)
		Shift from high carbon to low carbon goods	Will require more time: lower intensive labour supply (ii) (iii)
		Increase labour supply	Increase in intensive labour supply (iii)
Firm	Unit cost of carbon increases	Reduce carbon emissions	Increase carbon efficiency at the margin (e.g. optimisation of internal processes or shift to renewable energy sources).
	Unit cost of labour decreases	Labour demand increases	Hire more workers proportionally
	Labour relatively cheaper than carbon	Substitute carbon with labour	Direct emission replacement through low-skilled labour (iv)
			Indirect emission replacement by high-skilled labour (iv)

Note: Extension of Table 1 by the right column based on our literature review. New mechanisms become relevant when (i) moving away from homothetic preferences, (ii) dropping weak separability between leisure and consumption, (iii) distinguishing extensive and intensive labour supply, and (iv) allowing for distinct demand for low- and high-skilled labour.

Table 3. Double dividend potential of an ETR for different cases

		HH-RR Fully rational	**HH-RH** Heterogeneity	**HH-BRH** Tax salience	**HH-SH** Status seeking
Representative household		+/++			
Low skills	No environmental preferences		---/0	0/0	---/-
	environmental preferences		--/0	-/+	-/-
High skills	No environmental preferences		0/+++	+/++++	--/-
	environmental preferences		++/+++	++/++++	+++/++

Note: The four columns show the results of the four household cases. Values left of the '/' symbol refer to the environmental dividend, those on the right to the employment dividend. '+' indicates better chances for a dividend to occur, '-' lower chances, and '0' an unclear effect. The signs are the result of the various mechanisms from Tables 1 and 2, working in the same or opposing directions and thus more signs mean a higher likelihood of an effect.

Table 4. Double dividend potential of an ETR for different firm cases

		F-RR Profit-maximiser	**F-RH** Heterogeneity	**F-BRH** Satisficing	**F-SH** Social innovation
Representative firm		++/+			
Energy-intensive	small		+++/0	++++/-	+++/+
	large		+++/+	++/+	+++/+
Non-energy-intensive	Small		++/+	0/(+)	++/+
	large		++/+	++/+	++/+

Note: The four columns show the results of the four firm cases. Values left of the '/' symbol refer to the environmental dividend, those on the right to the employment dividend. '+' indicates better chances for a dividend to occur, '-' lower chances and '0' that the direction is unclear. Each mechanism (from Tables 1 or 2) is the source of a sign, working in the same or opposite direction, so more signs indicate a higher likelihood of an effect.

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