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Social Implications of Green Growth Policies from the Perspective of Energy Sector Reform and its Impact on Households

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by

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- Abstract -

This paper reviews the literature on distributional effects of energy and carbon taxation with focus on microsimulation models. Most studies find that direct energy and carbon taxation tends to be regressive. Regressive effects occur mostly with respect to taxation of electricity or space heating. Taxation of transportation fuels show less regressive, neutral, or even progressive effects. Adequate revenue recycling often allows for neutralisation or full elimination of regressive effects so that energy and carbon tax reforms can be progressive. Some studies find evidence for the existence of a double dividend. There seems to be an efficiency-equity trade-off in revenue recycling, i.e. whether to foster growth or to assist low-income households. While a large number of studies on advanced economies are available, there clearly is a gap with regard to evidence for developing countries. Another gap relates to the lack of documentation on the challenges of incorporating macroeconomic models and long-term modelling perspectives in microsimulation. Both aspects can be of great importance with respect to the design of green growth policies. Thoughtful incorporation of social considerations, including aspects of poverty in modelling approaches could enhance the existing instruments of ex-ante policy assessments since poverty is a tangible concept which is well-known, understandable, and openly observable for citizens and policy makers.

Keywords: Distributional Effects; Environmental Tax Reform; Green Growth; Energy Poverty; Microsimulation

JEL-Classification: H23; H31; Q54

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1. Introduction

The success of environmental policies depends on what they deliver and how much they cost, but also on how the costs and benefits are distributed in society. In order to find both immediate support for passing reforms and long-term support for lasting change, environmental policies must be designed so that benefits and costs are distributed in a fair and transparent manner. This is even more important where environmental policies have the potential to directly affect the price of necessities, such as space heating, water heating or electricity.

In order to ensure sustainability in the social and physical sphere, green growth strategies, environmental policies, and energy policies need to take into account potential social drawbacks. Potential distributional consequences require careful attention in the design of meaningful and workable green growth strategies. This will help to ensure long term support for the policy and help to avoid inequitable outcomes. Information and thoughtful analyses, also on the interaction of environmental policies, energy policies, and social policies, is the key to a better understanding of such policy linkages as required for adequate policy design. In order to ensure that policies are balanced between social and environmental concerns from the start, such analyses should be carried out in early stages of policy planning and parallel to policy implementation and possible reform.

The intent of this paper is: (a) to review existing knowledge and empirical insights on distributional consequences of environmental and energy policies on households; (b) to take stock of work completed to date; (c) to identify key policy challenges; and (d) to identify research gaps where further work is required. Studies from both developed and developing countries are considered as there are important differences in economic structures, including the existing tax and social security schemes. Given that poverty and deprivation are significant issues in developing countries, they also require careful consideration. The literature review focusses on evidence from real-world household data and economic models with behavioural components and endogenous substitution of goods. The review considers mainly model-based impact assessments – understood as formal ex-ante evaluations of the potential impacts of policies before their adoption. These types of models are ideal for the analysis of the distributional effects of green growth polices as they are able to capture distributional effects in detail and can simulate counterfactual policy scenarios before policies are introduced.

This paper's central message is that green growth policies will have important distributional consequences in most cases. Richer and poorer households are often affected in a different way and to a different extent. But mitigation of distributional effects is possible if adequate policy actions are taken. This relates to the actual design of the energy and environmental policies, but also social policies.

The paper is organised as follow, it will:

- Provide an overview of economic tools for the analysis of distributional effects;
- Review the main findings from the literature on the distributional consequences of green growth policies to provide a concise source of information for policy makers and researchers;
- Give an overview of methodological issues how to assess distributional effects;
- Provide a discussion on the importance of household behaviour and the interaction of behavioural aspects with green growth policies;
- Review existing linkages between poverty and energy consumption;
- And outline knowledge-gaps and lessons-learned to inform a future work agenda.

2. Addressing Distributional Effects: A Challenge for Green Growth Policy Design

The introduction of tailor made, country-specific policies is the core of any meaningful green growth strategy. There is of course no one-size-fits-all policy recommendation. Advanced, emerging and developing economies will face different policy challenges and opportunities in greening growth, as will countries with different economic and political circumstances and natural resources endowments. There are, on the other hand, common considerations that need to be applied in all settings. And in every case, when considering policy reforms, the analysis of macroeconomic and environmental impacts are insufficient. Policy reform requires examining winners and losers. And the analysis should be completed by a deeper look at distributional consequences and the possibilities to design compensatory measures to alleviate potentially negative outcomes on inequality and poverty.

One important obstacle to the implementation of green growth policies is the fear of negative social consequences resulting from distributional impacts. If proper analysis is carried out from the beginning of policy development, and if potential distributional effects are considered throughout the process of planning and implementation, these concerns can be effectively mitigated. Convincing and thoughtful analysis of possible distributional effects can further help to justify green growth strategies in the process of political negotiations and parliamentary approval.

Environmental or green tax reforms can be highly beneficial in many cases. There are two simple reasons for this conclusion. Firstly, green tax reforms will increase the cost of polluting activities which leads to a decrease of those activities and an according improvement of environmental quality. It is further possible to decrease fossil fuel dependency or non-renewable resource consumption. Secondly, green tax reforms allow for a revenue neutral reduction of other taxes, such as labour taxes, which can result in positive welfare effects. This concept is known as “double dividend”.[1,2]

Environmental taxes can have important distributional consequences. However, a central feature of green tax reforms is that they raise revenues through the taxation of polluting activities. Generated revenues can be used to stabilise the national budget, decrease other taxes, or hand back the revenues to households via other transfer schemes. The recycling of revenues from the green tax also offers the possibility to mitigate distributional effects generated by the green tax.

Direct taxation of unwanted economic activities (e.g. greenhouse gas emissions, other types of pollution, or non-renewable resource consumption) is known to be very efficient in many aspects. Since consumption patterns and substitution possibilities often differ between households along the income distribution, e.g. in the case of energy, direct taxation will likely cause different *relative cost-burdens* for poorer and wealthier households.

Since redistribution takes place to some extent via the tax and social security schemes in many countries, post-tax and benefits incomes and consumption budgets are of great interest for the examination of distributional effects. This implies that the interaction of green growth policies and existing tax and social security schemes is of relevance for policy design.

Distributional impacts of taxation across the income distribution are often measured as tax burden *relative to* disposable income or the consumption budget of households following the principle of “equal sacrifices”.[3] This implies that households with low income take over smaller burdens relative to wealthier households. Burdens of taxation are said to be progressive if wealthier households take over larger relative burdens compared to poorer households; are said to be neutral if relative burdens are distributed equally across the income distributions; and regressive if poorer households take over higher burdens relative to wealthier ones.

For a number of OECD countries, recent OECD work shows that taxation of transportation fuels tend to have progressive impacts, taxation of space heating is rather neutral, and taxation of electricity tends to produce regressive impacts.[4] Distributional impacts of carbon taxation has gained interest in recent years in the field of economics as well as other social sciences.[5] The OECD also published a report in 2006 with a broad view on the distributional effects of environmental taxation including methodological issues or aspects of the distribution of environmental quality.[6] A report on household behaviour in relation to environmental policies was presented by the OECD in 2008.[7]

It is widely accepted that regressive distributional effects should be avoided in order not to overburden the least well off in society. Income taxation in most developed countries is designed in a progressive way in order to satisfy the principle of equal sacrifices.[8] Distributional effects of energy related taxation should receive increased attention since energy services, such as space heating, water heating, or electricity, can be regarded as basic goods in developed countries and emerging economies. They contribute not only to well-being but ensure healthy living conditions and participation in society. Options for the substitution of such goods are often limited, particularly for lower income households. However, as the use of fossil fuel energy sources results in negative environmental consequences, the transition of energy systems towards sustainable energy sources is advisable.

Consequently, regressive effects should be avoided in the implementation of green growth strategies (i.e. overburdening poorer households as compared to richer ones). Historically, the poorest 30% of incomes received special attention related to issues of energy poverty and energy affordability.[9] Alternatively, those who are at the risk of income poverty should also be considered. Deprivation with respect to energy consumption should be avoided in any event. Adequate indicators of energy affordability can be of great use for ex-ante policy design and ex-post policy assessment and reform since they allow for the identification of households that are most vulnerable to changes in energy prices.[10,11]

Different types of distributional effects are affecting private households as a consequence of environmental regulation. This includes:

- Changes in prices for goods;
- Changes in the return of factors like labour (i.e. income from labour), capital, and resources;
- Temporary effects in the transition process such as changes in the quantity and quality of jobs in different sectors of the economy; and
- Changes in the prices of land or house values.[12,13]

More than 120 studies have been reviewed in order to provide an overview of the existing research on distributional effects of green growth policies and energy sector reform, and to identify knowledge gaps. A concise summary of the most important aspects is presented below.

3. The Economic Toolbox for the Analysis of Distributional Effects

The toolbox for the analysis of distributional effects consists of several types of models which differ in terms of their economic focus:

- Microsimulation (MS) models allow for a fact-driven analysis of household behaviour including labour market participation and consumption decisions. These models are typically built upon rich sets of real-world household data and have a much higher resolution on the household level as compared to other model types.[14] The advantage of microsimulation models is that they allow for a very detailed analysis of distributional effects at the household level.

- Computable general equilibrium (CGE) models allow for a detailed analysis of policy impacts through the whole economy, including aspects of international trade, by taking feedback effects from different economic sectors and production factors into account. The advantage of CGE models is that they allow for an analysis of global effects of policy reform, such as effects on industries or trade patterns.
- Input-Output (IO) models are similar to CGE models and are based on the industrial structure of the economy for a given year. However, they are often less flexible in describing the behaviour of firms and households. They can however be useful to evaluate indirect economic effects of price changes in the economy and are combined with MS models in some studies.

Different from the modelling approaches which take a forward looking or counterfactual perspective, empirical studies (ES) use economic data to evaluate consequences of past reforms. Although this survey predominantly focusses on modelling results, empirical studies are considered if the results are relevant and can be compared to other economic models. ES provide detailed information on past reforms and can help to understand general economic or distributional effects of future policy actions. They can inform about effects on households, businesses, trade patterns etc, dependent on their focus. Since economic models are contingent on the theoretical framework, ES are highly useful to contrast the predictions of economic models with past experiences.

4. Main Findings from the Literature Review

4.1. The Case of Developed Countries

As environmental concerns gained momentum in the 1990s, environmentally motivated "green taxes" were established in some developed countries by the year 2000. This was the case for Denmark, Finland, France, Germany, the Netherlands, Norway, Spain, Sweden, Switzerland, the UK, the USA, and Japan.[15] Ex-post studies focussing on the economics of environmental taxation noted the importance of distributional effects with respect to the political feasibility of reforms. It was found that direct energy taxes or carbon taxes are mostly regressive and that revenue recycling measures can mitigate these impacts making them more progressive.[16] Differences are observed for direct taxation of transportation fuels *versus* electricity and heat. Taxation of transportation fuels seem to have less severe distributional effects compared to the taxation of electricity and heat.[15] However, the results differ between countries.[15,16] By the year 2000, the available information on detailed distributional effects remained limited,[17] but the expansion and advancement of the economic toolbox for the analysis of such effects was already under way.

The distributional effects of taxation of the carbon content of fossil energy is examined for the cases of Australia[18], Cyprus[19], the Czech Republic[20], Denmark[21], Estonia[22], the EU as a whole[23,24], Germany[25,26], Ireland[27], New Zealand[28], Norway[29], Spain[14,30,31], Sweden[32], the United Kingdom[33,34], and the United States[35–37]. Most of the studies use MS techniques, while some apply IO or CGE models (see Table 1 for details). There is clear evidence that carbon taxes will result in regressive effects. This is that poorer households will take over larger burdens of carbon taxation in cases when no revenue recycling measures are implemented. However, with the inclusion of revenue recycling measures, regressive effects can be eliminated. Revenue recycling in order to eliminate distributional effects is modelled differently in the studies, dependent on country specific aspects. Revenue recycling measures such as lump-sum transfers, increased benefit payments, or decreased tax rates of other taxes for poorer households are typically used in order to help eliminate negative distributional effects.

In order to find the most effective ways of revenue recycling, it is important to account for country specific aspects, such as the existing social security scheme, general economic circumstances, as well as the existing tax and benefit schemes. This is one reason why an analysis of distributional effects of green growth policies should be carried out *simultaneously* to policy planning and implementation. There is further evidence that broad taxation of greenhouse gas emissions is preferential to the taxation of CO_2 emissions alone.[38,39] This is because multiple taxation of greenhouse gases is considered to increase cost-effectiveness of policies. However, there might be obstacles with respect to practical feasibility of multiple greenhouse gas taxation and detailed results will differ between countries dependent on the structure of the economy.

The studies mentioned above focus on carbon taxation in general. This may include situations in which the prices for electricity and space heating are affected along with prices of other goods. This type of situation is different to the situation when only fossil transportation fuels are taxed. In this case, distributional effects have been shown to be less severe. However, evidence on the issue is mixed.

A study on several EU countries[40] and a study on the case of France[41] indicate that distributional effects of transportation fuels are less severe and can easily be eliminated by revenue recycling. For the case of Italy,[42] it is found that taxation of transportation fuels could be progressive even without revenue recycling. However, for the case of Belgium,[43,44] evidence suggests that the taxation of transportation fuels can have regressive impacts dependent on the chosen revenue recycling scheme. A crucial issue here is if taxes are redistributed in favour of households or businesses.

The incidence of taxation of transportation fuels is also dependent on the wealth of a country (and therefore patterns of car usage) as well as the initial tax burden and existing general patterns of taxation. One example is the case of Serbia. The lower income country has a smaller share of the population with access to cars, and cars are a more luxury good. Therefore, taxation of transportation fuels tends to lead to additional tax burdens for wealthier households and has a moderate average effect on low income households.[40] This again shows that country and case specific analyses of potential distributional effects of green growth policies are required.

Other studies examine specific policies, such as the long-term impact of an emissions trading scheme in Australia[45], the existing broad set of environmental taxes in Denmark[21], the consequences of the EU energy package for Finland[46], or renewable energy subsidies in Germany[47–51]. Similarly as in the case of carbon taxation, regressive distributional effects are reported in the studies and revenue recycling is found to be able to mitigate these effects. An important caveat is related to the use of subsidies for the promotion of green technologies. As reported for the case of renewable energy promotion in Germany, the distributional effects on the poor are considerable. Renewable subsidies in Germany are financed by a surcharge which is directly passed through to consumers. The surcharge has similar effects as direct energy taxation and therefore causes regressive effects. Since no revenues are generated by subsidies, options for the mitigation of such impacts may be more limited. Addressing the social impacts of green growth strategies may be more complex where subsidies form a core part of policy design, as compared to carbon taxation.

4.2. The Case of Emerging Economies and Developing Countries

Distributional effects of green growth policies can have very severe consequences in developing countries where poverty, deprivation and energy access are real issues. As a result, thoughtful and reliable ex-ante studies of likely distributional effects are required. The context in which distributional effects arise can be different in developing countries and emerging economies compared to developed countries. Firstly, the potentially weak capacity of governments to implement new tax schemes or to redistribute revenues from green tax reforms could be a challenge. Secondly, economies in developing countries are often highly trade exposed and are specialised in export of a small number of goods. Agricultural products or natural resources can be of great importance. Thus, changes in world factor prices or land-rents can be of particular importance with respect to distributional consequences of green tax reform and other environmentally motivated policies. The latter aspect seems to be underexposed in the existing literature and should receive increased attention in the future.

Consequently, models need to take such country-specific effects into account so that distributional consequences of green growth strategies can be addressed adequately. If global factor prices, behaviour, and disposable income or expenditure budgets of households are of importance, then combined CGE and MS studies are in order. An additional challenge in the analysis of distributional effects in developing countries is limited availability or accuracy of data. Boccanfuso et al. (2011) presented a survey on distributional effect of climate change policies in developing countries which highlighted these considerations.[52] They mention existing studies from Pakistan, Chile, Indonesia, Senegal, South Africa, Costa-Rica, and the Philippines. In addition, studies on Mexico and China have also been completed.

While potential distributional effects of carbon taxation are similar to the case of developed countries, some important differences exist. Some studies have shown that carbon taxes could be introduced to China in a neutral fashion if revenue recycling measures are implemented.[53–55] Considered options for recycling are lump-sum transfers on an equal per capita basis, reduced electricity prices for poorer households, and reduced indirect taxes. While differences in urban and rural areas play a minor role in the case of developed countries, they are of great importance in the case of China. Carbon taxation would likely affect urban households the most, while distributional effects in rural areas would likely be moderate. Adequate revenue recycling schemes would need to effectively address these issues.

Studies on carbon taxation in Indonesia[56], Mexico[57], the Philippines[58], and South Africa[59,60] also find that distributional effect are to be expected, but can be mitigated. However, workable revenue recycling strategies might be different as compared to developed nations because of the different economic conditions in developing countries. A reduction of labour taxes in the case of the Philippines was suggested as an option for effective mitigation of unwanted distributional effects. For the case of South Africa, even a third dividend of environmental taxation in the form of poverty reduction is discussed. In some cases, revenue recycling could be used towards the reduction of poverty and the generation of positive social effects. Furthermore, the distributional impact of environmental taxation is discussed to be potentially harmful if necessities, such as food, are affected by price increases. The aspect of availability and affordability of basic goods (other than energy) should therefore receive special attention in the case of developing nations.

Important differences are also found for the case of taxation of liquid fuels. If fuels used for space heating are taxed, this will usually result in considerable negative distributional effects.[61,62] Similar to the case of developed countries, taxation of fuels used for transportation show less negative distributional effects. A study from Costa-Rica found that distributional effects of transportation fuels might even differ dependent on which fuel is taxed.[63] Taxation of gasoline is shown to be progressive while taxation of diesel has negative distributional effects. The reason is that poor households rely more on public transport which usually is fuelled by diesel. Subsidies for transportation fuels are shown to be of little use for the mitigation of distributional effects in developing countries.[64]

Subsidies play a relatively prominent role in developing countries and economies in transition. There clearly is a lack of knowledge about the distributional effects of transportation fuel subsidies in general. Existing evidence suggests that they are a very poor instrument to mitigate distributional effects. Wealthier households tend to profit to a strong extent from fuel subsidies, while subsidies fail to assist the poor, i.e. in developing countries.[64] Thus subsidies cannot be considered an adequate measure to mitigate negative distributional effects of exogenously rising transportation fuel prices.

Overall, country and case specific analyses of potential distributional effects are advisable if workable green growth policies are to be developed and implemented. However, the perspective on distributional effects is different for developed countries. Because of the importance of the agricultural sector, rural and urban areas will likely show different effects. Specific needs of poorer households (including affordability or availability of food, clean water, shelter etc) should receive special consideration.

Evidence on developing countries appears to be more incomplete as compared to developed countries. Data availability and the capacity to build adequate models seem to be the key issues. Many models further neglect specific aspects of developing economies, such as regulated branches of the economy without competitive pricing or the existence and importance of informal markets. Production of biofuels in relation to rents in the agricultural sector and food supply can be a challenge. Subsidies to utilities tend to be initially regressive and models likely tend to overestimate the regressivity of subsidy reductions. Substitution of fossil energy sources by firewood could further have negative effects with respect to deforestation and biodiversity.[52]

5. Comparing Methodological Approaches

This section compares approaches and illustrates advantages and disadvantages of the various methods, including potential shortcomings with respect to data availability.

While CGE has a strong macroeconomic focus when looking at complex, price driven interventions, MS is able to produce much more detailed results with respect to household behaviour. But prices for goods, capital rents, land prices, wages and incomes as well as terms of trade might change significantly due to the policy intervention. Moreover, macroeconomic factors can be of particular importance for small or trade exposed economies and developing countries where conditions on the world market often have strong effects on the local economy.[52] And indirect policy effects through multi-market interactions, market spill-overs, and feedback effects etc. often dramatically change the overall impact of a policy initiative.

Consequently, a combination of both types of models, CGE and MS model (MS-CGE), can be beneficial. In this case, the CGE model captures economy-wide and growth effects of tax changes, while the MS model allows for an assessment of the poverty and inequality impact of tax changes. Changes in wages, employment, and product prices are taken from the CGE model. Consumption levels are then calculated in the MS model and together with aggregated labour supply given back to the CGE model.[65] However, MS-CGE models have received moderate academic interest in the past and there are a limited number of studies available.[30] One reason might be data availability: MS models require large micro-data sets with observed economic and socio-demographic characteristics.

Household databases which include detailed information, e.g., on income, housing and other demographic, social and economic characteristics of the individuals and households are, however, scarce. Micro-data sets might not be available in adequate quality, i.e. for many low- and middle-income countries.

Since microsimulation usually builds on a large set of detailed real-world data, the approach is ideal for an assessment of distributional issues. There is, however, no clear definition of what microsimulation actually is, and existing studies differ with respect to many details in the modelling approaches.

Three elements are central for microsimulation models: (1) a micro-dataset; (2) details on the policy to be simulated; and (3) a theoretical model of the behavioural response of households.[14] Behavioural aspects are mostly related to consumption decisions and labour supply. Both aspects are highly relevant with respect to energy taxation. Since there are social security schemes in many countries, transfers and benefits, or more general, the interaction of energy market reforms with existing social security schemes, should receive increased attention. The consumption budget of households as a proxy for lifetime income is usually a good measure of what households are able to spend.[40] If time matters, e.g. if the simulation should inform about long-term effects of energy taxation, additional aspects, such as fertility decisions, inter-temporal consumption, retirement, schooling and other aspects might matter.

Since energy taxation may change the structure of the economy, e.g. towards green growth, changes in factor prices, such as prices for labour and capital, are relevant.[66] Microsimulation models are usually unsuited to capture those macroeconomic effects.[65] Examples for such an approach can be found in the literature but linkages of MS and CGE are not standard.[25,30,36,44,45] Also a critical assessment of recycling scenarios in many applications is advisable. Many beneficial results in model analyses can be attributed to revenue recycling schemes which allow for the reduction of some existing market distortion (e.g. in the labour market). Why are policies not implemented anyway? And is the implementation feasible to start with? This suggests looking carefully at the primary impacts of energy and climate policies.

Combined MS-CGE models can be particularly useful if long-term distributional effects are of interest.[45] Developing countries often rely on the export of a small number of goods and are vulnerable to changes in global prices. In this case, linked MS-CGE models can provide important information not only regarding detailed domestic effects but also with respect to changes in prices on a global scale.[52] As the agricultural sector can be of great importance in developing countries, additional model components might be required. However, building and combining MS-CGE models to assess long-term distributional effects can be challenging.

All of the surveyed studies neglect aspects of domestic energy efficiency, poverty, and energy related deprivation. There is a growing body of literature on energy poverty that goes beyond the perspective of the work on fuel poverty in the United Kingdom. However, literature on the distribitional impacts of tax reforms and literature on poverty research seem to have no overlap. This is because the discussion on energy poverty in developed countries is a rather new in most advanced economies. Thus, deprivation with respect to energy consumption currently receives growing academic interest, also among economists and modellers. Preventing the negative effects of impacts of increased energy prices, such as health impacts or social exclusion, is of critical importance for feasibility and long-term acceptability of green growth strategies.

Poverty defined as relative deprivation with threshold-character[67,68] actually has much in common with the analysis of the incidence of energy taxation. Income and wealth and the social bases of self-respect, or the lack of it, are more or less openly observable for everybody. This allows for interpersonal comparisons without relying on such unworkable concepts as people's utility or capabilities.[69] Regressive effects of energy taxes may contribute to an increase in poverty and deprivation over time if lower income households are adversely affected by a tax reform. Vice versa, environmental tax reforms offer the chance to decrease poverty to some extent if benefits are distributed in favour of the poor.

Thus, adequate policy design requires detailed information on the distributional effects along the income distribution as well as information on the incidence and intensity of poverty. It seems straightforward to include indicators of poverty in the assessment of distributional effects of green growth policies. Indicators of income poverty, material deprivation, or in particular energy related deprivation could simply enter assessments of distributional effects, such as it is the case for many other socio-demographic criteria. The inclusion of such indicators will inform not only about the distributional consequences in general but also about the vulnerability of specific groups in society with respect to energy consumption. It will also help to identify those who are most vulnerable, and will ultimately help to reveal the driving forces creating these situations.

In order to strengthen understanding and to make the analysis of distributional effect of carbon and energy taxation workable for policy planning and design, some aspects should receive increased attention in the future. In summary, the analysis of distributional effects and potential poverty issues should take the following aspects into account:

- The analysis of distributional effects of policies should be carried out ex-ante and during the process of policy planning and implementation. This allows for the identification of possible negative distributional effects before policy implementation and the design of effective measures to mitigate such effects.
- Rigorous assessment of price and non-price related behaviour of households is needed. Microsimulation models should, if possible, be built upon demand systems, which comprise highly disaggregated and fact-driven information on household behaviour.[70,71] Other aspects related to household behaviour, such as changes in household energy efficiency or possible rebound effects, are of importance as well.
- Because of the great variance in the needs, wants, abilities and capabilities of households, representative agents should not be used for the analysis of distributional effects. If possible, this type of analysis should be built on large sets of household data.
- Because of limited data availability, capacity building with respect to the generation of household data should be considered. This is of particular importance for many developing countries and emerging economies, but also for developed nations. Data should include prices and quantities of consumption for several types of goods, disposable household income, a proxy for savings, and socio-demographic variables. Household size, household composition, and the age structure are important information as well. Information on housing conditions and proxies for efficiency in energy use can help to assess poverty issues. This could include information on heating systems, glazing of windows, the age of the house, or subjective indicators of adequate space heating. Data must be representative for the overall population, possibly including "weights", so that the income distribution in the population is captured accurately. Data should be available over several periods in time so that changes in income, prices, and consumption can be observed.

- Continued exchange and capacity building with respect to methodological aspects of the analysis of distributional effects of environmental and energy taxation is advisable. This may include training programs and joint research programs in collaboration between developed and developing nations or national agencies and international organisations.
- The analysis of distributional effects should not only focus on changes in the distribution of income and wealth but should also include indicators of poverty and the affordability of energy. These indicators can be easily incorporated and can provide information on the existing levels of deprivation and changes in deprivation as a consequence of reform. They can help to design policies that prevent an increase in deprivation, whether related to income in general or to specific groups of goods, such as food, shelter, or energy. This is of particular importance for countries in which significant levels of deprivation and poverty exist in the first place. Adequate policy design even offers the chance for a reduction of poverty if revenues are generated from green growth policies and redistributed accordingly.

6. Household Behaviour and Green Growth Strategies

Understanding the response of households to green growth policies is the key to effective policy design and a requirement for adequate modelling of distributional consequences. This is because household behaviour in consumption partly causes distributional effects or even deprivation, so a better understanding of household behaviour in energy consumption can help to predict and prevent negative distributional effects. Two types of behavioural responses can be distinguished: (1) the household reaction to changes in prices of energy and other goods; and (2) the non-price behavioural aspects, such as behaviour related to attitudes, social norms, culture, or aspects related to general socio-demographic characteristics of households.[72]

Price related behaviour is relevant for the modelling of green growth policies such as carbon taxes. The effects of interest pivot around price and income elasticities. This is how households change consumption if prices for energy and other goods are changed or when disposable income or the consumption budget is changed. Microsimulation models with demand systems are able to capture such effects in great detail.[70,71] This high degree of detail is one of the major advantages of microsimulation vis-à-vis other types of economic models. Microsimulation models can also be expanded so that they include taxes and benefits and labour supply by households.[14]

Additional effects can be of importance, such as the ability of households to adjust energy consumption patterns over time. Adjusting energy consumption in response to changes in prices takes time.[73] Thus, long-term and short-term elasticities differ and should be distinguished and accounted for in economic models. If longer periods of time are considered, and changes in the economy as a whole are of importance, then the linking of microsimulation to CGE models is a useful approach.[45]

The elasticities of demand for energy are identified in the literature. For example, short-term and long-term elasticities for electricity demand in the US based on a large set of household expenditure data.[74,75] For the US, electricity demand is dependent on income.[76] Short-term and long-term elasticities of electricity and natural gas demand were estimated also for the state of Califormia.[77] A 2007 study on G7 countries estimates short-term and long-term elasticities of residential electricity demand.[78] Short-term and long-term domestic electricity demand price elasticities were also estimated for Switzerland.[79] A study on Norway showed that domestic electricity demand elasticities do not differ much in the short-term vis-à-vis the long term.[80] There are also studies considering electricity demand in Australia.[81,82] A recent study examined domestic electricity demand in China.[83] A metastudy from 2004 comprises results from numerous empirical studies.[84] A recent analysis on electricity demand elasticities and income elasticities from across eleven OECD countries exist. The study also reports significant non-price behavioural response of households.[85] However, a more comprehensive survey of this strand of literature clearly is beyond the scope of this paper.

When it comes to non-price behaviour in the short-term, it was shown for Dutch households that the demand for space heating can be highly correlated with the characteristics of dwellings while demand for electricity is driven by household composition.[86] Changes in energy consumption are also related to psychological variables (e.g. attitudes, norms, awareness of consequences, or ascription of responsibility).[87] For the cases of Germany and the UK, it was shown that house ownership is an important driver for energy efficiency retrofits and general improvements in energy efficiency in the private housing sector.[88–90]

Overall income and prices determine residential energy consumption, attached price and income elasticities, but other non-price related behavioural aspects can be of great importance as well.[91–93] Consideration of non-price behavioural aspects in the design of green growth policies can potentially increase effectiveness.[94] For example, this could be "soft policies" to raise awareness of environmental aspects in energy consumption.

To account for both effects, non-price related and price related aspects, models for the analysis of distributional effects can be augmented so that they distinguish types of households or groups within the society (e.g. by age, household composition, education etc). Many of the above mentioned studies took such an approach in addition to the examination of distributional effects along the income distribution. This, however, requires the availability of real-world microeconomic data which actually contain such information. Availability of data that includes information on consumption, income, prices, and socio-demographic variables is crucial here.

7. Affordability of Energy Services and Poverty

The above mentioned studies focus mostly on changes in the shares of expenditure on energy goods relative to disposable income or the disposable consumption budget. These changes are compared between households along the income distribution or between households of different types. This allows an assessment of potential regressivity of certain policies which occurs when low income households take over larger relative burdens as compared to wealthier households. In order to avoid contributing to strong and dynamically growing disadvantages of poorer households over time, green growth policies should show no regressive effects.

However, such relative comparisons do not carry much information on the *absolute position* of households. The absolute position of households is related to the question: "can households afford adequate consumption of energy services at all"? In developed countries, this perspective mainly refers to three domains in consumption: space and water heating; electricity consumption; and mobility. Space heating is of great importance to guarantee healthy living conditions during the winter in many countries.[73,95–98] Indoor air pollution from heaters and stoves fired by solid or biomass fuels remains a serious issue in many less developed countries.[99] Electricity consumption allows the use of appliances at home which are standard and inevitable for participation in society in many developed countries such as stoves, fridges, radios, and computers or even TV sets. Mobility often is crucial for participation in the labour market but is of importance with respect to the general participation in society as well.

In developing countries energy poverty is commonly understood as inadequate access to energy. In developed countries and some emerging economies, energy poverty could be understood as non-affordability of (required or adequate) energy services. Since the latter is highly relevant with respect to environmentally motivated taxation of energy, we focus on the aspect of non-affordability in what follows.[10,11]

Non-affordability of energy has several dimensions. It can be related to low disposable income and high prices for energy but also to low domestic energy efficiency and the individual requirements of households.[98,100] Three main types of measures of energy poverty or affordability can be distinguished.

- Affordability measures often focus on the expenditure share for a certain good, such as energy or water, relative to disposable income.[101] An example is the 10% measure that is used in the United Kingdom to evaluate the incidence of fuel poverty.[9,100,102] Alternatively, such measures can occur with the double criterion of low income and high cost.[103,104] These types of measures have been criticised for lacking scientific foundation and international comparability.[98,102] The low income high cost indicator further has poor dynamic properties, meaning that it is unable to capture changes over time in a proper way.[105]
- Budget standards or minimum income standards try to assess what it costs to live a decent life.[106–108] Minimum or adequate budgets for several groups of goods are defined for different types of households. Energy related deprivation or energy poverty would be indicated if disposable income after the costs for energy services falls below the budget standard for all other goods.[102] Definitions of basic social security payments can be based on similar techniques, for example in Germany, where basic security allowances are calculated with reference to the average expenditure of lower income households over different groups of goods. A disadvantage of such approaches is that they likely neglect the needs of specific types of households. Elderly people, disabled persons, or families with young children will, for example, often require more space heating or higher indoor temperatures compared to the average household.
- Consensual measures allow simultaneous consideration of multiple aspects of deprivation, including housing conditions, energy efficiency, income, or expenditure on energy services.[98,109] Different household characteristics jointly define the incidence and severity of energy poverty or energy related deprivation. Consensual measures allow for a comparison between countries if adequate data is available.

A comparison of energy poverty in 14 EU countries, published in 2004, used European Union Household Panel data and applied consensual measures.[98] It was found that lone parents and lone pensioner households are most likely to face energy related deprivation. Income plays an important role with respect to energy poverty since pensioners, the unemployed or households relying on other benefits consistently face a higher risk of energy poverty as compared to others. However, housing conditions and domestic energy efficiency are also of great importance. A recent update with additional focus on Eastern European countries revealed that the incidence of fuel poverty is very significant in countries such as Bulgaria, Romania, Portugal, and Cyprus. Severe conditions are also found in Poland, Latvia, Lithuania, Hungary, and Greece. The incidence of energy poverty seems to be by far lower in North-Western European countries as compared to countries in the south or east of the EU.[109] This is in line with previous findings and there is a clear link between low domestic energy efficiency, bad housing conditions, low disposable income, and the resulting assessment of the risk of energy related deprivation and poverty.[110]

Indicators of affordability and energy related deprivation can provide important information for an assessment of the distributional consequences of energy related taxation. The analysis of the incidence of taxes is able to reveal distributional aspects along the income distribution. This is of great importance to avoid persistent negative effects of energy taxes for poorer households, which can have very severe implications over time.

Indicators of energy poverty can be used to gain an understanding regarding the current situation of the poor, including aspects of energy affordability or domestic energy efficiency. They can also reveal households that are exposed to high risks of energy related deprivation differentiated by socio-demographic variables. This can help to identify the most vulnerable types of households and to design green growth policies that prevent adverse distributional effects.

Thus, the analyses of the incidence of energy taxes and indicators of energy poverty are complements rather than substitutes in the assessment of the distributional effects of green growth policies. Although both approaches differ strongly in terms of methods and data requirements, both are of relevance for applied policy design since indicators of energy poverty focus on the initial state of consumption at the household level while the analysis of the tax incidence is mostly concerned with the comparison of households along the income distribution.

Currently, the lack of data limits the applicability of such indicators. Furthermore, comparability of results is limited, i.e. between developed and developing countries. Further work on conceptual issues related to energy poverty and increased data availability certainly is a challenge for future research.

8. Lessons Learned: Future Challenges for Green Growth

There are two key findings for takeaway from the extensive review of the literature on distributional effects of energy and carbon taxation. Firstly, direct energy and carbon taxation is regressive in many cases. This implies that low-income households are responsible for proportionally larger tax burdens as compared to wealthier households. Secondly, these negative distributional effects can be neutralised or even reversed if appropriate changes are made to existing tax and benefit schemes in response to the new energy or carbon tax. In this case, poorer households could even benefit from the reform.

Direct taxation of electricity and space heating tends to be regressive. This is because electricity and space heating are necessities in advanced economies. Taxation of transportation fuels often tends to be progressive or neutral. Private car ownership is less pronounced among poorer households so that the taxation of transportation fuels affect poorer household to a smaller extent. Distributional effects as a result from energy and carbon taxation should be considered carefully to avoid negative distributional consequences and deprivation with respect to energy consumption as a consequence of reforms.

While revenue recycling is in principle able to eliminate negative distributional effects, there seems to be an efficiency-equity trade-off. This is related to the idea of the double dividend of environmental tax reforms. Energy or carbon taxation will lead to a decrease in carbon emissions and fossil resource dependency (first dividend). If revenues are recycled so to reduce existing distortional taxes (e.g. labour taxes or non-wage labour costs), it will strengthen economic growth and prosperity (second dividend). The existence of both dividends was demonstrated in some of the studies reviewed above. However, successfully achieving a double dividend depends on the careful design of policies that reflect country-specific aspects and considerations, including economic circumstances.

If revenues are recycled to mitigate distributional effects, they are likely not available to lower other distortional taxes that could strengthen economic growth. This is the efficiency-equity trade-off.

However, some studies conclude that both the mitigation of distributional effects and the fostering of growth are possible through adequate revenue recycling. This would even represent a third dividend of environmental tax reforms in the form of decreased inequality and poverty in society.

The analysis shows that revenue raising policies are essential for any meaningful green growth policy and for the avoidance of negative distributional consequences. Existing evidence suggests that subsidies can in principle be used to achieve environmental goals or promote the development and deployment of new technologies but they may result in negative distributional consequences if alternative resources cannot be found to address distributional impacts.

Microsimulation represents a powerful tool for counterfactual and forward-looking policy assessments, i.e. with respect to the distribution of costs and benefits of energy and carbon tax reforms. There are some methodological challenges, such as the evidence-based disaggregated description of consumer behaviour or the linkage of microsimulation models with advanced worldwide modelling approaches on the macroeconomic level. Additional evidence on the consequences of energy and carbon tax reforms in developing countries is needed as there are gaps in the literature.

Dedicated action with respect to green growth policies is needed to ensure the wealth and welfare of current and future generations. As justice is the first virtue of social institutions, the poor should not be left in limbo when it comes to reforms and changes in the structure of the economies. As this survey has shown, it is possible to make our economies greener and foster growth while protecting the poor and preventing negative distributional consequences. All three aspects are of relevance for finding support for green growth policies and to ensure long-term success. Successful policy design needs to take into account the individual characteristics of the respective economy and the wants and needs of people in society. Thoughtful analysis of planned and ongoing reform is the key for understanding such effects. This is not necessarily limited to economic modelling, but may also include poverty research in a broader perspective as well as participation of citizens in many stages of the process of reform.

9. Appendix: Detailed Results by Country

9.1. Developed Countries

An application of microsimulation (MS) – computable general equilibrium (CGE) to the **Spanish** economy examined the case of an environmentally motivated increase in Spanish energy taxes and a simultaneously implemented revenue-neutral decrease of value added taxes (VAT).[30,111] The authors combine CGE with MS, where a demand system for several goods and household types is first specified in an empirical analysis, following the methodology of Deaton and Muellbauer.[70] The methodology is built upon a system of demand for several goods dependent on household income and prices for goods including cross-price elasticities. Using such a methodology allows for the endogenous evaluation of demand. This is of importance in order to account for aspects such as differences in the availability of public transport systems in urban versus rural areas or the differences in fuel use in space (e.g. district heating, natural gas etc.).[30] Such aspects can also be of great importance in developing countries where rural areas often lack public infrastructure.[52] As it was shown in the case of Spain, uncompensated own-price elasticities differ significantly when estimated for the whole sample (all households without differentiation) and for sub-samples, e.g. with spatial differentiation in three dimensions: rural areas, villages, and cities.[30] Using undifferentiated elasticity parameters will often lead to a loss of precision of results.

The Spanish MS-CGE analysis examined an increase of energy related direct taxes (electricity, refined oil products, natural gas and coal) by 20%, accompanied with a revenue-neutral decrease of VAT on other goods. Energy goods are regarded as household necessities. This gives additional justification for the use of MS models in order to capture detailed effects of the reform at the household level. On the aggregated level, the reform would lead to an increase of the Gross Domestic Product (GDP) by about 1%, accompanied by a decrease of carbon dioxide emissions of about 5.7%. Aggregated effects, including price effects at the household level from the CGE model are subsequently incorporated into the MS model which captures energy demand and other consumption effects in a detailed way. As a consequence of the reform, expenditure on electricity, public transport, food and beverages as well as other non-durables would decrease while expenditures on natural gas and car fuels would increase. Two main conclusions can be drawn from the analysis. Firstly, direct taxes on energy have regressive effects since energy goods are necessities (with the exemption of taxation of car fuels). This is in line with findings by the OECD.[4] Secondly, regressive effects can be offset by a reduction of the VAT. Following the VAT reduction, the green tax reform would have a moderate progressive impact along the income distribution. A caveat applies to some specific groups of the population, such as families with several children at the age of 15 or below or households living in cities. Such households benefit less compared to others after the green tax reform with neutral recycling of revenues. The author's emphasis that having children or living in a city is positively correlated with income in the case of Spain; and having higher income leads to less benefits from reduced VAT in this particular study, all other things equal. Thus, when effects are described by idiosyncratics rather than income, families with children or households loving in cities gain less compared to other groups. Overall, the tax reform produces a welfare increase which is more pronounced among lower deciles of the income distribution. There are a number of related studies on Spain.[111–113]

For the **United States**, a CGE model with a large number of households assumes a carbon price of 20 USD and different revenue recycling schemes. The study finds that carbon taxation is neutral or progressive dependent on the revenue recycling scheme. There is a trade-off between efficiency and the distributional considerations in the choice of the actual revenue recycling scheme.[114] A recent study on the incidence of carbon taxes in the US in a linked MS-CGE framework comes to similar conclusions.[36] It is shown that revenue recycling matters decisively for the resulting distributional effects of carbon taxes. In addition, there is an efficiency-equity trade-off. Lump-sum transfers or labour tax reductions are able to make carbon taxes progressive. There are also considerable regional differences with respect to the revenue recycling schemes that are dependent on the predominant sources of income in the regions.

For the case of **Ireland**, it was shown that direct carbon taxes are regressive but that these effects can be offset by moderate increases in welfare payments in the lower half of the income distribution.[27] The modelling approach builds on a MS model (SWITCH) without combination to other model types. Compensation of households would not require a fully revenue-neutral recycling but only about 65% to 80% of the revenues generated by the carbon tax. In accord to other studies, direct taxation of transportation fuels is less regressive compared to taxation of heat and power. Overall a carbon tax is regressive but well defined changes to the existing tax and benefit scheme in Ireland could offset regressive effects. One important aspect is that the design of the revenue recycling scheme matters with regard to the question of which households along the income distribution will benefit the most. In the case of Ireland, it appears that a mixed strategy of increased social welfare and child benefit payments and an increased tax credits would be the most favourable for lower income households.

For the case of the **United Kingdom**, the impact of a carbon tax on income and consumption in private households was examined in the framework of an MS-Input-Output(IO) model.[33] The model approach combines Input-Output analysis to determine direct and indirect price effects in the economy and an MS model with an endogenous demand system estimated from the pooled Family Expenditure Survey. The model takes own-price and cross-price elasticities into account as well as household characteristics. The analysis considers a carbon tax in order to reduce carbon dioxide emissions in the UK by about 20%. Budget neutral recycling of revenues generated by the tax in form of VAT reduction and increased benefit payments is considered. In the absence of revenue recycling, the reform has regressive distributional impacts. Low-income households are most affected in terms of changes in disposable expenditure. The model predicts that revenue recycling in terms of VAT reduction will mitigate negative distributional effects to some extent but will not be sufficient to eliminate them. Regressive effects of the carbon tax could be eliminated by a benefit reform according to the model. The study was carried out in the early 1990s and predicts rather high carbon dioxide mitigation costs ranging from 240 to 444 Pound Sterling. Since the MS model was calibrated using data from 1986, the model results will likely overstate the impact of a carbon tax on UK households vis-à-vis the current situation because of technological progress and changes in the structure of the economy.

Another MS study of the effects of a carbon tax in the **United Kingdom** from 2006 uses data from the English Housing Condition Survey and the Family Expenditure Survey.[34] The study brings in an interesting perspective that is missing in most other studies: the perspective of fuel poverty or energy poverty. The study assumes a levy for electricity and gas at the household level. Without revenue recycling the carbon tax shows clearly regressive effects with a focus on tax burdens relative to disposable income. The study tests a larger set of direct benefits on their ability to compensate low income households. Surprisingly, the study finds that compensation via benefits will not allow for adequate compensation of low income households in the UK. Incentives for (private) efforts to increase domestic energy efficiency are identified as an important part of anti-poverty policies with respect to energy consumption. A caveat applies with respect to the specific structure of benefits and taxes in the UK where special benefits for “fuel poor” households are available. Therefore, the results will not necessarily apply to other countries. The paper also gives an example of the importance of taking into account the interactions of environmental taxes with existing tax and benefit schemes.

For **Italy**, a MS model study of a proposed carbon tax has found that the tax burden is distributed progressively even in the absence of revenue recycling.[42] A key aspect is that the carbon tax predominantly aimed at transportation fuels which have turned out to be of less relevance with respect to distributional issues. A main reason for this finding is that poorer households are less likely to own a car and are therefore less likely to be negatively affected by the carbon tax. The model builds on data from 1985 to 1996 and uses an endogenous demand system. Income and price elasticities for Italy are presented in the paper without particular differentiation of households or income groups. Studies focussing on the distributional effect of energy sector liberalisation in Italy did not find significant negative distributional effects.[115,116]

The distributional impact of an increase in the **Belgium** mineral oil tax (mainly transportation fuels) was examined using a MS-CGE approach in the EUROMOD MS model framework.[43,44] About 45% of the overall tax burden is directly borne by households. Two scenarios of revenue recycling were considered. Firstly, an increase in welfare payments by around 5%. Secondly, a reduction of employers social security payments of about 2% points. If revenues are used to increase welfare payments, lower income households tend to gain from the policy. Regressive effects are observed if the revenues are used to lower social security payments (and hence labour cost) for employers. While the analysis falls short of presenting a rigorous assessment of distributional impacts along the income distribution, it highlights the use of combined MS-CGE analysis since relative factor prices in the economy seem to be an important driver of distributional effects. While many other studies find that taxes on transportation fuels tend to be progressive[4], this study finds that they can be regressive dependent on the revenue recycling scheme.

A study relying solely on a CGE model without an MS component found that carbon taxes will have a progressive impact at the regional level of the **Susquehanna River Basin in the United States**.[37] Revenue recycling, i.e. as lump-sum transfers, still has positive impacts on the post-tax income distribution and is favourable for lower income brackets. It is quite likely that the finding of progressivity in the study is an artefact of the less advanced and less detailed modelling of households in the CGE-only framework as compared to MS approaches. The model includes nine stylised households ordered by income. In contrast, MS model often rely on ten thousands of observations which are clustered in a bottom-up manner. Another reason could be that carbon taxation takes place in an upstream manner in the model. Taxes are levied on coal, crude oil, and natural gas. Thus, effects on households could be less pronounced compared to direct taxation at the household level.

A survey focussing mostly on CGE and IO models in **northern European countries**, the UK, and Ireland conclude that macroeconomic studies find regressive effects of carbon taxation.[24] Regressive effects occur if other distortional taxes are reduced by revenue recycling. However, if revenues are recycled lump-sum, carbon taxation tends to be progressive. Thus, there seems to be a trade-off between efficiency and equity in the choice of the revenue recycling scheme.

The impact of the environmental fiscal reform introduced in **Germany** in 1999 was examined using a MS-CGE-IO model approach.[25] Taxes on transportation fuels, electricity, and natural gas were introduced in order to incentivise emission reductions. Revenues were recycled by a reduction of charges for the public social security scheme which reduced payments of employers and employees. Although the costs of the reforms in terms of decreased disposable income of households are moderate, the reform turned out to be regressive.[117] Thus, low income households faced larger decreases of incomes relative to medium or high-income households. The result holds for all types of households. The study also confirms that a double dividend was realised by the reform. Overall, the design of the revenue recycling scheme seems to be the driving force of the observed moderately negative distributional effect caused by the reform. Another MS study of the incidence of the German environmental fiscal reform also finds moderate regressive effects after revenue recycling.[26] Transportation fuels tend to have a progressive impact whereas the remaining parts of environmental taxation tend to be regressive.

An empirical simulation (ES) based on representative household data from Germany examines the distributional effects of the German renewable energy promotion scheme (Erneuerbare-Energien-Gesetz).[47] The scheme builds on subsidies for renewable energy carriers. Costs are passed through to households and companies by a surcharge on the electricity price (about 6.2 Euro cents as of 2014). The study uses several indicators of inequality to assess distributional consequences of the policy. It was found that renewable energy subsidies clearly have a regressive impact on German households in all of the applied indicators of inequality. One reason for this is that there is no compensation scheme associated with the subsidy scheme. Since the subsidy scheme is a non-revenue raising policy, offering compensation to mitigate regressive effects of the subsidy would trigger additional and likely significant costs for the public budget. Other studies came to similar conclusions.[48,118]

A study examining an increase in **Swedish** carbon taxes using MS and macroeconomic modelling finds moderately regressive impacts after revenue recycling.[32] Revenues are recycled either by public transport subsidies or a reduction of the VAT. Most importantly, the study finds that households in rural areas carry larger burdens after the reform. This effectively implies distributional effects in space rather than along the income distribution.

An MS-based analysis of the tax system in the **Czech Republic** with focus on a proposed environmental tax reform revealed that the Czech tax system overall is slightly progressive and that an environmental tax reform would have a rather neutral impact after revenue recycling.[20,117] In line with other studies, that study finds, that taxation of transportation fuels tends to be progressive while taxation of other energy sources tends to be regressive.

A MS study from **Norway** compared different revenue recycling schemes in response to the introduction of environmental taxation. The study concludes that more direct forms of revenue recycling, such as increased child and family benefits, are very effective in preventing regressive effects in Norway. The least distributional effects are observed after revenue recycling via the income tax scheme. Reductions of the VAT turned out to be relatively inefficient.[29]

An ES of existing **Danish** environmental taxes show that regressive effects result from these taxes in the aggregate.[21] Environmental taxes are relatively ambitious in Denmark. Taxation impacts heating, transport fuels, electricity, water, waste, plastic bags, registration of cars, and car ownership. Data for 1997 including detailed tax information are combined with additional data from 1999 which cover additional environmental taxes. The study exclusively focusses on existing taxes so that the behavioural response by households is reflected in the data. Distributional effects are measured as tax payments relative to disposable income. Overall, environmental taxes in Denmark tend to be regressive. Taxes on transport fuels and registration duties for cars are progressive. In another combined IO and micro-data study for Denmark it was shown that direct taxation of energy tends to be regressive.[119]

A **pan-European** study using an MS like approach based on the Eurostat household expenditure survey finds overall positive effects of environmental tax reforms.[23] A tax reform with increased carbon taxes and decreased income taxes would lead to increased incomes and increased employment across the EU. While the reform would have regressive effects without revenue recycling, these effects are mitigated after a decrease in income taxes. Several socio-economic groups where considered: five income quintiles; six groups differentiated by employment status; and urban as well as rural households. While there is variation of the impact of the reform over socio-economic groups, rural households would likely be strongly affected by the reform because of the need to drive further and more frequently compared to urban households. This represents non-negligible distributional effects in space. Changes in household incomes after revenue recycling also differ between EU member states. While there are no cases in which the reform has total negative effects on income in the five quintiles, some member states profit more than others.

A study focussing on the impact of carbon mitigation policies in **Australia** aims to evaluate distributional effects in a forward looking perspective (2005 to 2030) in a MS-CGE model.[45] The Australian Carbon Pricing Scheme, which was introduced in 2012 under the Labour government, was repealed in July 2014 under the liberal coalition government inter alia because of concerns regarding distributional aspects. The study examines the long-term distributional effects of an emissions trading scheme in Australia based on information from the Garnaut Review.[120] The MS-CGE approach taken in the study is of great importance as macroeconomic effects and employment changes can be significant in the period until 2030. The dynamic CGE model also captures inter-state migration and immigration into the country which is relevant for Australia. The MS part is used to model the impact of climate policy in Australia at the household level in detail. Despite a slightly negative effect on projected real household income, the introduction of the emissions trading scheme shows positive distributional effects. These effects go back to the assumed recycling of revenues from the trading scheme to households via lump-sum transfers. An earlier study using MS for the case of Australia also found that direct carbon taxation tends to decrease the progressivity of the tax scheme and tends to increase inequality. Transfer payments can reduce regressive effects without decreasing total revenue of the carbon tax.[18]

An ES by the **New Zealand** Treasury examined the potential impact of a carbon tax on households in the country.[28] A linear expenditure system was used. Distributional effects with respect to income where ambiguous. Based on the application of inequality measures, the carbon tax was found to cause small regressive effects. It was emphasised that the consumption basket of low income households is relatively carbon intensive compared to higher income households. Thus, low income households tend to be vulnerable with respect to direct carbon taxation.

A MS-study from **Estonia** examined the incidence of existing environmental taxes in the country.[22] The analysis is based on the Estonian household budget survey from 2008. The share of existing environmental taxes was about 0.8% of GDP in 1995, 1.7% in 2000, and 2.2% in 2006. The lions-share of about 98% of revenues is generated by taxation of transportation fuels. Overall, environmental taxes in Estonia turned out to be progressive in 2000 to 2007. This result is driven by large share of revenues generated from taxes on transportation fuels. An electricity charge introduced in 2008 will reduce progressivity of overall environmental taxation as the electricity charge itself generates clearly regressive effects. Similar effects, but much smaller in overall magnitude, are found for taxes on district heating and natural gas in Estonia.

An empirical study assesses the distributional consequences of taxes on transportation fuels in a very broad setup. The study takes seven **European countries** into account: France, Germany, the United Kingdom, Italy, Serbia, Spain, and Sweden.[40] The Suits Index is used as a measure of progressivity.[121] The index relies on “concentration curves” which follow a similar logic as the well-known Gini-Index. Similar concepts have been used previously for the analysis of the incidence of taxes.[122–124] Using data from the European household budget survey, the study concludes that taxation of transportation fuels tends to have a neutral impact on the distribution of incomes. Moderate regressivity is found for the cases of Sweden and the UK. Progressivity is found for the case of Serbia. A likely reason is that cars are a luxury good in Serbia. When expenditure is used (as proxy of lifetime income) instead of disposable income, fuel taxes are progressive in Germany and Sweden while it is proportional on average. Overall, the empirical evidence is that taxation of transportation fuels tends to be neutral or progressive.

An ES study based on a car-use model from **France** examined the impact of increased taxation of transportation fuels.[41] The study finds that if there was no revenue recycling of increased taxes on transportation fuels, the policy would be rather neutral in terms of its distributional impact. Using lump-sum or car-size based revenue recycling rules will lead to strong progressive effects of the tax. Wealthier households stand to contribute more to the tax, and benefit less, relative to lower income deciles. However, an income based revenue recycling scheme would result in regressive effects of the tax. This again highlights that the actual revenue recycling scheme matters for the final distributional outcome of an environmentally motivated tax.

A study from the **Netherlands** compares direct taxation of CO2 emissions vis-à-vis the case of taxation of a broader set of greenhouse gases using IO models and household data.[38] It was found that the direct taxation of CO2 and greenhouse gases clearly has regressive effects but the overall distributional impact is less pronounced when a broader set of greenhouse gases is taxed. Similar results were obtained for the case of a CO2 tax vis-à-vis a multiple greenhouse gas tax in the UK.[39]

A CGE study from **Finland** examined the impact of the EU energy package.[46] The costs of implementing all necessary actions were assessed to be about one to two percent of GDP. Costs were assessed to be rather equally distributed across different groups in society. An exemption includes farmers who are expected to take over larger burdens relative to other groups. This again represents a spatial dimension of distributional effects as rural areas are most affected.

A MS study from **Cyprus** showed that increases in energy prices will have regressive effects and will affect small and urban households most severely relative to others.[19] The study highlights that there are limited options to substitute energy with other goods which will cause negative welfare effects if prices for energy increase.

9.2. Detailed Results for Developing Countries

Chinas economy has developed rapidly in recent years. The country will likely play a major role with respect to global energy consumption and carbon emissions in the future.[125] Energy consumption in private households is an important driver for this development. There is evidence that the use of appliances by Chinese households will grow significantly.[126] An ES found that a carbon tax in China could have progressive impacts if revenues are recycled in a lump-sum fashion.[53] One important reason for this is the difference in energy use in rural vs. urban areas. Poor rural areas would be over-compensated by a lump-sum revenue recycling scheme. A recent study has come to a different result using a CGE approach without detailed household structure. The study concludes that a carbon tax will decrease income and welfare of rural and urban households and will have regressive effects. The authors, however, emphasise that revenue recycling by reduced indirect taxes and increased benefits for rural households will cause the least negative distributional effects. Another IO-study concludes that a carbon tax in China would be regressive in urban areas but progressive in rural areas.[54] A feasible option for revenue recycling to offset negative distributional effects would be a reduction in household electricity prices.

In a CGE model, the impact of a carbon tax on the economy of the **Philippines** was examined. It was found that a carbon tax could be progressive and decrease poverty if revenues where used to decrease labour taxes.[58] The study did not use detailed microeconomic information on households.

A CGE analysis for **Chile** examined the social implications of taxes on PM_{10}, SO_2, and NOx to decrease ambient air pollution.[127] As in the case of carbon taxes, it was found that the taxes on PM10, SO_2, and NOx tend to be regressive. The resulting distributional effects again depend on how revenues are recycled. Combined environmental and social policies could decrease distributional impacts and improve acceptability of environmental policies. However, in the case of direct social policies the final result depends on how efficient the government can implement such policies in order to reduce poverty and increase welfare.

Increased fuel prices in **Indonesia** where shown as being regressive in a CGE model with ancillary microdata.[62] The reform targeted transportation fuels as well as heating fuels. Regressive effects could have been avoided if only transportation fuels would have been subject to the reform. However, a carbon tax in Indonesia could be progressive if revenue recycling would take place in a lump-sum fashion. This again highlights the importance of revenue recycling for efficiency and the distributional consequences of carbon taxes. Overall, the study concludes that carbon taxes can be beneficial for developing countries.[56]

In a study focussing on **Senegal**, the impacts of climate change are modelled along with (assumed) increases in world energy prices.[128] Negative impacts of climate change on crop yields are assumed and will likely increase poverty. The authors state that subsidies for electricity consumption could mitigate negative distributional effects to some extent.

In a CGE framework, the impact of a carbon tax was analysed for the case of **South Africa**.[59] Although households are not modelled in detail, low income households will likely be negatively affected by decreasing wages and increasing prices. Low income households will also be affected because of their higher relative carbon intensity when compared to high income households. Revenue recycling again plays a crucial role for the resulting distributional effects. There seems to be the option for a triple dividend by carbon taxes if the poor receive assistance to afford necessities such as food.[60] An MS-IO study examined the distributional impact of increased oil prices in South Africa.[61] An increase in heating fuels is shown to be regressive and affects the poor most severely. Increased prices in transportation fuels affect higher income groups and have less regressive effects.

A study using microdata focussed on a 10% increase in transportation fuels in **Costa-Rica**.[63] It was found that price increases for gasoline tend to be progressive while price increases for diesel tend to be regressive leading to an overall slightly regressive effect of the policy. This is mostly because public transport relies on diesel and is predominantly used by lower income households. This is an interesting example where taxation of transportation fuels leads to regressive effects dependent on the type of fuel that is taxed.

In a relatively simple CGE framework, the impact of carbon taxation is studied for the case of **Mexico**.[57] Households are divided into five income classes to assess distributional effects. Two revenue recycling schemes are compared: (1) the reduction of manufacturing taxes, versus (2) the introduction of food subsidies. The carbon tax is regressive if manufacturing taxes are reduced while it is progressive if food subsidies are provided. A key insight of the paper is the importance of relative carbon intensity of households for the resulting distributional effects of the carbon tax. Carbon intensity of households will likely differ between developed and developing countries but also in space, i.e. in rural vs. urban areas in developing countries.

Annual **global road-sector gasoline and diesel subsidies** amount to about 110 billion USD (year 2012). Global annual dead weight losses from these subsidies are estimated to be about 44 billion USD.[129] Subsidies play a relatively prominent role in developing countries and economies in transition. There clearly is a lack of knowledge about distributional effects of transportation fuel subsidies. Existing evidence suggests that they are a very poor instrument with respect to distributional effects. Wealthier households tend to profit to a strong extent from fuel subsidies while subsidies fail to assist the poor, i.e. in developing countries.[64] Thus, subsidies cannot be considered an adequate measure to mitigate negative distributional effects of exogenously rising transportation fuel prices.[130]

Table 1: The literature on distributional effects of environmental taxation by country

Country (Model)	Policy	Distributional Effects	Source
Australia (MS-CGE)	Emissions trading	Progressive after lump-sum revenue recycling to households.	45
Australia (MS)	Carbon Tax	Carbon tax tends to be regressive but revenue recycling can eliminate regressive effects.	18
Belgium (MS-CGE)	Direct carbon tax (transportation fuel)	Direct taxation of transportation fuels tends to be regressive dependent on the revenue recycling scheme.	43,44
Chile (CGE)	Tax on PM10, SO2, NOx	Potential regressive effects. Revenue recycling matters.	127
China (ES)	Carbon tax	Can be progressive after lump-sum revenue recycling.	53
China (CGE)	Carbon tax	Likely regressive effect mitigated by decreased indirect taxes and increased benefits for rural households.	55
China (IO)	Carbon tax	Regressive in urban areas, progressive in rural areas. Offset of distributional effects by reduction in household electricity price suggested.	54
Costa-Rica (ES/MS)	Increase in transportation fuel	Overall regressive. Gasoline taxation progressive, diesel taxation regressive.	63
Cyprus (MS)	Increased energy prices	Regressive effects (no compensation scheme is assumed).	19
Czech Republic	Direct carbon tax	Neutral after revenue recycling.	20
Denmark (ES)	Existing environmental taxes	Overall regressive because of missing revenue recycling. Taxes on transport fuels and car registration duties are progressive.	21
Denmark (IO)	Direct carbon tax	Tend to be regressive.	119
Developing Countries	Transportation fuel subsidies	Poor effectiveness in mitigating negative distributional effects.	64
Estonia (MS)	Existing direct taxes on energy	Progressive for transportation fuels, regressive for electricity, natural gas, and district heating.	22
EU several countries (ES)	Tax on transportation fuels only	Tend to be neutral or progressive.	40
EU (simple MS)	Direct carbon tax	Neutral after revenue recycling by decreased income taxes with positive	23

		effects on income and employment.	
Finland (CGE)	EU energy package	Rather neutral distributional effects across different groups of society.	46
France (ES-simulation)	Tax on transportation fuels only	Tend to be progressive after revenue recycling and dependent on the chosen recycling rule.	41
Germany (MS-CGE-IO)	Direct carbon tax	Moderate regressive impact after revenue recycling.	25
Germany (MS)	Direct carbon tax	Moderate regressive impact after revenue recycling. Taxes on transportation fuels tend to be progressive.	26
Germany (ES)	Renewable energy subsidies	Regressive because of lacking compensation for low income households.	47
Indonesia (CGE-MS)	Increased fuel prices	Regressive if heating fuels are included. Progressive for transportation fuels only.	62
Indonesia (CGE)	Carbon tax	Can be progressive dependent on revenue recycling.	56
Ireland (MS)	Direct carbon tax	Neutral after up to 80% revenue recycling.	27
Italy (MS)	Direct carbon tax (transportation fuel)	Carbon tax with predominant focus on car fuels tend to be progressive without revenue recycling.	42
Mexico (CGE)	Direct carbon tax	Effect depends on revenue recycling scheme. Progressive if food subsidies are provided.	57
Netherlands (ES)	CO2 vs. broader greenhouse gas tax	Regressive effects are found, but less pronounced for broader taxation of greenhouse gases.	38
New Zealand (ES)	Direct carbon tax	Small regressive effect (no revenue recycling).	28
Northern European Countries, UK, Ireland (CGE and IO)	Direct carbon tax	Effects dependent on revenue recycling scheme. Lump-sum recycling tends to cause progressive effects.	24
Norway (MS)	Comparison of revenue recycling types	Recycling via income tax scheme or benefits more effective compared to reduction of VAT.	29
Philippines (CGE)	Carbon tax	Could be progressive after revenue recycling by reduced labour taxes.	58
South Africa (CGE)	Carbon tax	Potential regressive effects by decreased wages.	59
South Africa (CGE)	Energy taxes	Potential positive effects if revenues are (partly) recycled to assist the poor, e.g. by food subsidies.	60
South Africa (MS-CGE)	Increase oil prices	Price increase for heating fuels regressive. Price increase for transportation fuels progressive.	61
Spain (MS-CGE)	Direct carbon tax	Progressive after reduced VAT.	30,31,111
Sweden (MS-CGE)	Direct carbon tax	Moderately regressive after revenue recycling by reduced VAT or public transport subsidies. Distributional effects in space are present.	32
UK (MS-IO)	Direct carbon tax	Neutral after full revenue recycling	33

		via benefit reform.	
UK (MS)	Direct carbon tax	Regressive. Revenue recycling via benefits not effective. Energy efficiency improvements important.	34
UK (ES)	CO2 vs. broader greenhouse gas tax	Regressive effects are found but less pronounced for broader taxation of greenhouse gases.	39
USA (CGE)	Carbon price	Can be neutral or progressive dependent on revenue recycling.	114
USA (MS-CGE)	Carbon tax	Can be progressive dependent on revenue recycling scheme.	36
USA regional (CGE)	Direct carbon tax (upstream orientated)	Progressive, revenue recycling (lump sum) is beneficial for lower income households.	37

Table 2: Survey articles and selected key publications with relevance for distributional effects by year of publishing

Year	Content	Source
2000	Distributional effects of carbon taxes	15
2000	Distributional effects of environmental tax reforms	17
2004	Study on energy poverty in Europe	98
2004	Literature survey with section on distributional effects of carbon taxes	131
2006	Technical introduction to microsimulation models and methods	14
2006	Distributional effects of environmental policies	6
2008	Household behaviour and environmental policy	7
2010	Technical paper on sequential linking of MS and CGE models	65
2011	Book on modelling environmental tax reforms including technical aspects	117
2011	Distributional effects of climate policy in developing countries	52
2011	Inequality in OECD countries	132

References:

1. Bovenberg, A. L. Green tax reforms and the double dividend: an updated reader's guide. *International Tax and Public Finance* **6,** 421–443 (1999).

2. Goulder, L. H. Environmental taxation and the double dividend: a reader's guide. *International Tax and Public Finance* **2,** 157–183 (1995).

3. Mill, J. S. *Principles of Political Economy*. (1848).

4. OECD. *The Distributional Effects of Energy Taxes: Preliminary Report*. (2014).

5. Buchs, M., Bardsley, N. & Duwe, S. Who bears the brunt? Distributional effects of climate change mitigation policies. *Critical Social Policy* **31,** 285–307 (2011).

6. OECD. *The Distributional Effects of Environmental Policy*. (Edward Elgar, 2006).

7. OECD. *Household Behaviour and the Environment: Reviewing the Evidence*. 264 (2008).

8. Young, H. P. Progressive Taxation and Equal Sacrifice. *American Economic Review* **80,** 253–266 (1990).

9. Boardman, B. *Fuel Poverty: From Cold Homes to Affordable Warmth*. (Belhaven Press, 1991).

10. Snell, C. & Thomson, H. in *Social Policy Review 25* (eds. Ramia, G., Farnsworth, K. & Irving, Z.) 23–45 (Policy Press, 2013).

11. Heindl, P. Measuring Fuel Poverty: General Considerations and Application to German Household Data. *ZEW Discussion Paper* **Nr. 13-046,** (2013).

12. Fullerton, D. Six Distributional Effects of Environmental Policy. *Risk Analysis* **31,** 923–929 (2011).

13. Voigt, S. & Heindl, P. *Employment effects on regional sustainability indicators. Sustainable Development* **2011,** 1–52 (2011).

14. Bourguignon, F. & Spadaro, A. Microsimulation as a tool for evaluating redistribution policies. *The Journal of Economic Inequality* **4,** 77–106 (2006).

15. Baranzini, A., Goldemberg, J. & Speck, S. A future for carbon taxes. *Ecological Economics* **32,** 395–412 (2000).

16. Barker, T. & Kohler, J. Equity and Ecotax Reform in the EU: Achieving a 10 per cent Reduction in CO2 Emissions Using Excise Duties. *Fiscal Studies* **19,** 375–402 (1998).

17. Bosquet, B. Environmental tax reform: does it work? A survey of the empirical evidence. *Ecological Economics* **34,** 19–32 (2000).

18. Cornwell, A. & Creedy, J. Carbon Taxation, Prices and Inequality in Australia. *Fiscal Studies* **17,** 21–38 (1996).

19. Pashardes, P., Pashourtidou, N. & Zachariadis, T. Estimating welfare aspects of changes in energy prices from preference heterogeneity. *Energy Economics* **42,** 58–66 (2014).

20. Bruha, J. & Scasny, M. Distributional Effects of Environmentally-Related Taxes: Empirical Applications for the Czech Republic. *Working Paper* (2008).

21. Jacobsen, H. K., Birr-Pedersen, K. & Wier, M. Distributional Implications of Environmental Taxation in Denmark. *Fiscal Studies* **24,** 477–499 (2003).

22. Poltimäe, H. & Võrk, A. in *Discussions on Estonian Economic Policy - 17* (ed. Raudjärv, M.) **17,** 196–211 (Berliner Wissenschaftsverlag GmbH, 2009).

23. Ekins, P., Pollitt, H., Barton, J. & Blobel, D. The implications for households of environmental tax reform (ETR) in Europe. *Ecological Economics* **70,** 2472–2485 (2011).

24. Bye, B., Kverndokk, S. & Rosendahl, K. E. Mitigation costs, distributional effects, and ancillary benefits of carbon policies in the nordic countries, the U.K., and Ireland. *Mitigation and Adaptation Strategies for Global Change* **7,** 339–366 (2002).

25. Bach, S., Kohlhaas, M., Meyer, B., Praetorius, B. & Welsch, H. The effects of environmental fiscal reform in Germany: a simulation study. *Energy Policy* **30,** 803–811 (2002).

26. Bork, C. in *The Distributional Effects of Environmental Policy* (eds. Serret, Y. & Johnstone, N.) 139–170 (OECD Publishing, 2006).

27. Callan, T., Lyons, S., Scott, S., Tol, R. S. J. & Verde, S. The distributional implications of a carbon tax in Ireland. *Energy Policy* **37,** 407–412 (2009).

28. Creedy, J. & Sleeman, C. Carbon Taxation, Prices and Household Welfare in New Zealand. *New Zealand Treasury Working Paper* **04/23,** (2004).

29. Aasness, J., Benedictow, A. & Hussein, M. F. *Distributional Efficiency of Direct and Indirect Taxes*. (2002).

30. Labandeira, X., Labeaga, J. M. & Rodríguez, M. An integrated economic and distributional analysis of energy policies. *Energy Policy* **37,** 5776–5786 (2009).

31. Labandeira, X., Labeaga, J. M. & Rodríguez, M. Green Tax Reforms in Spain. *European Environment* **14,** 290–299 (2004).

32. Brännlund, R. & Nordström, J. Modelling Consumer Demand and Household Labour Supply: Welfare Effects of Increasing Carbon Taxes. *Umea Economic Studies Working Paper* **571,** (2001).

33. Symons, E., Proops, J. & Gay, P. Carbon taxes, consumer demand and carbon dioxide emissions: a simulation analysis for the UK. *Fiscal Studies* **15,** 19–43 (1994).

34. Dresner, S. & Ekins, P. Economic Instruments to Improve UK Home Energy Efficiency without Negative Social Impacts. *Fiscal Studies* **27,** 47–74 (2006).

35. Rausch, S., Metcalf, G. E. & Reilly, J. M. Distributional impacts of carbon pricing: A general equilibrium approach with micro-data for households. *Energy Economics* **33,** S20–S33 (2011).

36. Williams, R. C., Gordon, H., Burtraw, D., Carbone, J. C. & Morgenstern, R. D. The Initial Incidence of a Carbon Tax. in *Paper presented at the 5th World Conference of Environmental and Resource Economists in Istanbul, Turkey* (2014).

37. Oladosu, G. & Rose, A. Income distribution impacts of climate change mitigation policy in the Susquehanna River Basin Economy. *Energy Economics* **29,** 520–544 (2007).

38. Kerkhof, A. C., Moll, H. C., Drissen, E. & Wilting, H. C. Taxation of multiple greenhouse gases and the effects on income distribution. *Ecological Economics* **67,** 318–326 (2008).

39. Feng, K. *et al.* Distributional effects of climate change taxation: the case of the UK. *Environmental Science & Technology* **44,** 3670–3676 (2010).

40. Sterner, T. Distributional effects of taxing transport fuel. *Energy Policy* **41,** 75–83 (2012).

41. Bureau, B. Distributional effects of a carbon tax on car fuels in France. *Energy Economics* **33,** 121–130 (2011).

42. Tiezzi, S. The welfare effects and the distributive impact of carbon taxation on Italian households. *Energy Policy* **33,** 1597–1612 (2005).

43. Vandyck, T. Efficiency and Equity Aspects of Energy Taxation. *Euromod Working Paper Series* **No. 12/13,** (2013).

44. Vandyck, T. & Regemorter, D. Van. Distributional and regional economic impact of energy taxes in Belgium. *Energy Policy* **72,** 190–203 (2014).

45. Buddelmeyer, H., Hérault, N., Kalb, G. & van Zijll de Jong, M. Linking a Microsimulation Model to a Dynamic CGE Model: Climate Change Mitigation Policies and Income Distribution in Australia. *International Journal of Microsimulation* **5,** 40–58 (2012).

46. Honkatukia, J., Kinnunen, J. & Marttila, K. Distributional effects of Finland's climate policy: Calculations with the new distribution module of the VATTAGE model. *Gov. Inst. of Econ. Res. Working Paper* **II,** (2009).

47. Grösche, P. & Schröder, C. On the redistributive effects of Germany's feed-in tariff. *Empirical Economics* **46,** 1339–1383 (2013).

48. Neuhoff, K., Bach, S., Diekmann, J., Beznoska, M. & El-Laboudy, T. Distributional Effects of Energy Transition: Impacts of Renewable Electricity Support in Germany. *Economics of Energy & Environmental Policy* **2,** (2013).

49. Heindl, P., Schüßler, R. & Löschel, A. Ist die Energiewende sozial gerecht? *Wirtschaftsdienst* **94,** 508–514 (2014).

50. Löschel, A., Flues, F. & Heindl, P. Verteilungswirkungen des Erneuerbare-Energien-Gesetzes - Das Erneuerbare-Energien-Gesetz in der Diskussion. *Wirtschaftsdienst* **92,** 515–519 (2012).

51. Heindl, P. Ökonomische Aspekte der Lastenverteilung in der Umweltpolitik am Beispiel der Energiewende - Ein Beitrag zum interdisziplinären Dialog. *ZEW Discussion Paper* **14-061,** (2014).

52. Boccanfuso, D., Estache, A. & Savard, L. The Intra-country Distributional Impact of Policies to Fight Climate Change: A Survey. *Journal of Development Studies* **47,** 97–117 (2011).

53. Brenner, M., Riddle, M. & Boyce, J. K. A Chinese sky trust? Distributional impacts of carbon charges and revenue recycling in China. *Energy Policy* **35,** 1771–1784 (2007).

54. Sun, W. & Kazuhiro, U. The Distributional Effects of a China Carbon Tax : A Rural – Urban Assessment. *The Kyoto Economic Review* **80,** 188–206 (2011).

55. Liang, Q.-M. & Wei, Y.-M. Distributional impacts of taxing carbon in China: Results from the CEEPA model. *Applied Energy* **92,** 545–551 (2012).

56. Yusuf, A. A. & Resosudarmo, B. P. On the Distributional Effect of Carbon Tax in Developing Countries: The Case of Indonesia. *Working Paper in Economics and Development Studies - Padjadjaran University* **05,** (2007).

57. Gonzalez, F. Distributional effects of carbon taxes: The case of Mexico. *Energy Economics* **34,** 2102–2115 (2012).

58. Corong, E. L. Tariff Reductions, Carbon Emissions, and Poverty: An Economy-wide Assessment of the Philippines. *ASEAN Economic Bulletin* **25,** 20–31 (2008).

59. Alton, T. *et al.* The economic implications of introducing carbon taxes in South Africa. *WIDER Working Paper* **46,** (2012).

60. Van Heerden, J. *et al.* Searching for Triple Dividends in South Africa: Fighting CO2 Pollution and Poverty while Promoting Growth. *The Energy Journal* **27,** 113–142 (2006).

61. Fofana, I., Chitiga, M. & Mabugu, R. Oil prices and the South African economy: A macro–meso–micro analysis. *Energy Policy* **37,** 5509–5518 (2009).

62. Yusuf, A. A. & Resosudarmo, B. P. Mitigating Distributional Impact of Fuel Pricing Reform: The Indonesian Experience. *ASEAN Economic Bulletin* **25,** 32–47 (2008).

63. Blackman, A., Osakwe, R. & Alpizar, F. Fuel tax incidence in developing countries: The case of Costa Rica. *Energy Policy* **38,** 2208–2215 (2010).

64. Arze del Granado, F. J., Coady, D. & Gillingham, R. The Unequal Benefits of Fuel Subsidies: A Review of Evidence for Developing Countries. *World Development* **40,** 2234–2248 (2012).

65. Hérault, N. Sequential Linking of Computable General Equilibrium and Microsimulation Models: A Comparison of Behavioural Reweighting Techniques. *International Journal of Microsimulation* **3,** 35–42 (2010).

66. Dissou, Y. & Siddiqui, M. S. Can carbon taxes be progressive? *Energy Economics* **42,** 88–100 (2014).

67. Townsend, P. *Poverty in the United Kingdom: A Survey of Household Resources and Standards of Living*. *The American Political Science Review* **75,** 1216 (Penguin Books Ltd, 1979).

68. Sen, A. Poor, Relatively Speaking. *Oxford Economic Papers* **35,** 153–169 (1983).

69. Rawls, J. *The Law of Peoples*. (Harvard University Press, 1999).

70. Deaton, A. & Muellbauer, J. An Almost Ideal Demand System. *American Economic Review* **70,** 312–326 (1980).

71. Banks, J., Blundell, R. & Lewbel, A. Quadratic Engel Curves and Consumer Demand. *Review of Economics and Statistics* **79,** 527–539 (1997).

72. Kriström, B. in *Household Behaviour and the Environment: Reviewing the Evidence* 97–115 (OECD Publishing, 2008).

73. Kriström, B. Residential Energy Demand. *Encyclopedia of Energy, Natural Resource, and Environmental Economics* **1,** 218–224 (2013).

74. Fell, H., Li, S. & Paul, A. A new look at residential electricity demand using household expenditure data. *International Journal of Industrial Organization* **33,** 37–47 (2014).

75. Alberini, A. & Filippini, M. Response of residential electricity demand to price: The effect of measurement error. *Energy Economics* **33,** 889–895 (2011).

76. Dergiades, T. & Tsoulfidis, L. Estimating residential demand for electricity in the United States, 1965–2006. *Energy Economics* **30,** 2722–2730 (2008).

77. Garcia-Cerrutti, M. L. Estimating elasticities of residential energy demand from panel county data using dynamic random variables models with heteroskedastic and correlated error terms. *Resource and Energy Economics* **22,** 355–366 (2000).

78. Narayan, P. K., Smyth, R. & Prasad, A. Electricity consumption in G7 countries: A panel cointegration analysis of residential demand elasticities. *Energy Policy* **35,** 4485–4494 (2007).

79. Filippini, M. Short- and long-run time-of-use price elasticities in Swiss residential electricity demand. *Energy Policy* **39,** 5811–5817 (2011).

80. Halvorsen, B. & Larsen, B. M. The flexibility of household electricity demand over time. *Resource and Energy Economics* **23,** 1–18 (2001).

81. Narayan, P. K. & Smyth, R. The residential demand for electricity in Australia: an application of the bounds testing approach to cointegration. *Energy Policy* **33,** 467–474 (2005).

82. Fan, S. & Hyndman, R. J. The price elasticity of electricity demand in South Australia. *Energy Policy* **39,** 3709–3719 (2011).

83. Shi, G., Zheng, X. & Song, F. Estimating elasticity for residential electricity demand in China. *The Scientific World Journal* (2012).

84. Espey, J. A. & Espey, M. Turning on the Lights: A Meta-Analysis of Residential Electricity Demand Elasticities. *Journal of Agricultural and Applies Economics* **36,** 65–81 (2004).

85. Krishnamurthy, C. K. B. & Kriström, B. Energy demand and income elasticity: a cross-country analysis. *CERE Working Paper* **5,** (2013).

86. Brounen, D., Kok, N. & Quigley, J. M. Residential energy use and conservation: Economics and demographics. *European Economic Review* **56,** 931–945 (2012).

87. Abrahamse, W. & Steg, L. How do socio-demographic and psychological factors relate to households' direct and indirect energy use and savings? *Journal of Economic Psychology* **30,** 711–720 (2009).

88. Meier, H. & Rehdanz, K. Determinants of residential space heating expenditures in Great Britain. *Energy Economics* **32,** 949–959 (2010).

89. Rehdanz, K. Determinants of residential space heating expenditures in Germany. *Energy Economics* **29,** 167–182 (2007).

90. Achtnicht, M. & Madlener, R. Factors Influencing German House Owners' Preferences on Energy Retrofits. *ZEW Discussion Paper* **12-042,** (2012).

91. Nguyen-Van, P. Energy consumption and income: A semiparametric panel data analysis. *Energy Economics* **32,** 557–563 (2010).

92. Reiss, P. C. & White, M. W. Household Electricity Demand, Revisited. *Review of Economic Studies* **72,** 853–883 (2005).

93. Reiss, P. C. & White, M. W. What changes energy consumption? Prices and public pressures. *The RAND Journal of Economics* **39,** 636–663 (2008).

94. Allcott, H. & Mullainathan, S. Behavioral science and energy policy. *Science* **327,** 1204–1205 (2010).

95. Healy, J. D. Excess winter mortality in Europe: a cross country analysis identifying key risk factors. *Journal of Epidemiology and Community Health* **57,** 784–9 (2003).

96. Clinch, J. P. & Healy, J. D. Housing standards and excess winter mortality. *Journal of Epidemiology and Community Health* **54,** 719–20 (2000).

97. Liddell, C. & Morris, C. Fuel poverty and human health: A review of recent evidence. *Energy Policy* **38,** 2987–2997 (2010).

98. Healy, J. D. *Housing, Fuel Poverty and Health: A Pan-European Analysis*. (Ashgate Publishing, 2004).

99. Duflo, E., Greenstone, M. & Hanna, R. Indoor air pollution, health and economic well-being. *SAPI EN. S. Surveys and Perspectives Integrating Environmanet and Society* 1–22 (2008).

100. Boardman, B. Fuel poverty synthesis: Lessons learnt, actions needed. *Energy Policy* **49,** 143–148 (2012).

101. Gawel, E., Sigel, K. & Bretschneider, W. Affordability of water supply in Mongolia: empirical lessons for measuring affordability. *Water Policy* **15,** 19 (2013).

102. Moore, R. Definitions of fuel poverty: Implications for policy. *Energy Policy* **49,** 19–26 (2012).

103. Hills, J. *Fuel Poverty: The problem and its measurement - Interim Report of the Fuel Poverty Review*. (2011).

104. Hills, J. *Getting the Measure of Fuel Poverty: Final Report of the Fuel Poverty Review*. (2012).

105. Schüßler, R. Energy Poverty Indicators: Conceptual Issues - Part I: The Ten-Percent-Rule and Double Median/Mean Indicators. *Centre for European Economic Research (ZEW) Discussion Paper* **14-037,** (2014).

106. Saunders, P. Budget Standards and the Poverty Line. *The Australian Economic Review* **32,** 43–61 (1999).

107. Saunders, P. *Updated budget standard estimates for Australian working families in September 2003*. (2004).

108. Bradshaw, J. *et al. A Minimum Income Standard for Britain*. 64 (2008).

109. Thomson, H. & Snell, C. Quantifying the prevalence of fuel poverty across the European Union. *Energy Policy* **52,** 563–572 (2013).

110. Tirado Herrero, S. & Ürge-Vorsatz, D. Trapped in the heat: A post-communist type of fuel poverty. *Energy Policy* **49,** 60–68 (2012).

111. Labandeira, X., Labeaga, J. & Rodriguez, M. in *Microsimulation as a tool for the evaluation of public policies: methods and applications* (ed. Spadaro, A.) (Fundación BBVA, 2007).

112. Labandeira, X. & Labeaga, J. Combining Input – Output Analysis and Micro-Simulation to Assess the Effects of Carbon Taxation on Spanish Households. *Fiscal Studies* **20,** 305–320 (1999).

113. Rodriguez, M. & Labeaga, J. M. Microsimulating the Effects of Household Energy Price Changes in Spain. *Nota di Lavoro, Fondazione Eni Enrico Mattei* **No. 161,** (2004).

114. Rausch, S., Metcalf, G. E. & Reilly, J. M. Distributional impacts of carbon pricing: A general equilibrium approach with micro-data for households. *Energy Economics* **33,** 20–33 (2011).

115. Miniaci, R., Scarpa, C. & Valbonesi, P. Distributional Effects of Price Reforms in the Italian Utility Markets. *Fiscal Studies* **29,** 135–163 (2008).

116. Miniaci, R., Scarpa, C. & Valbonesi, P. Measuring the Affordability of Basic Public Utility Services in Italy. *Giornale Degli Economisti e Annali di Economia* **67,** 185–230 (2008).

117. Ekins, P. & Speck, S. *Environmental Tax Reform (ETR): A Policy for Green Growth*. (Oxford University Press, 2011).

118. Neuhoff, K., Bach, S., Diekmann, J., Beznoska, M. & El-Laboudy, T. *Steigende EEG-Umlage: Unerwünschte Verteilungseffekte können vermindert werden*. (2012).

119. Wier, M., Birr-Pedersen, K., Jacobsen, H. K. & Klok, J. Are CO2 taxes regressive? Evidence from the Danish experience. *Ecological Economics* **52,** 239–251 (2005).

120. Garnaut Climate Change Review. Methodology for modelling climate change impacts. *Technical Paper* **4,** (2008).

121. Suits, D. B. Measurement of Tax Progressivity. *The American Economic Review* **67,** 747–752 (1977).

122. Yitzhaki, S. & Slemrod, J. Welfare Dominance: An Application to Commodity Taxation. *American Economic Review* **81,** 480–496 (1991).

123. Araar, A., Dissou, Y. & Duclos, J.-Y. Household incidence of pollution control policies: A robust welfare analysis using general equilibrium effects. *Journal of Environmental Economics and Management* **61,** 227–243 (2011).

124. Yitzhaki, S. & Thirsk, W. Welfare dominance and the design of excise taxation in the Cote D'ivoire. *Journal of Development Economics* **33,** (1990).

125. Auffhammer, M. & Carson, R. T. Forecasting the path of China's CO2 emissions using province-level information. *Journal of Environmental Economics and Management* **55,** 229–247 (2008).

126. Auffhammer, M. & Wolfram, C. D. Powering up China: Income Distributions and Residential Electricity Consumption. *American Economic Review: Papers and Proceedings* **104,** 575–580 (2014).

127. O'Ryan, R., de Miguel, C. J., Miller, S. & Munasinghe, M. Computable general equilibrium model analysis of economywide cross effects of social and environmental policies in Chile. *Ecological Economics* **54,** 447–472 (2005).

128. Boccanfuso, D., Estache, A. & Savard, L. Distributional impact of developed countries CC policies on Senegal: A macro-micro CGE application. *University of Sherbrooke Working Paper* **11,** (2009).

129. Davis, L. W. The Economic Cost of Global Fuel Subsidies. *American Economic Review: Papers and Proceedings* **104,** 581–585 (2014).

130. Coady, D. *et al.* Petroleum Product Subsidies: Costly, Inequitable, and Rising. *IMF Staff Position Note* **10/05,** (2010).

131. Zhang, Z. & Baranzini, A. What do we know about carbon taxes? An inquiry into their impacts on competitiveness and distribution of income. *Energy Policy* **32,** 507–518 (2004).

132. OECD. *Divided We Stand: When Inequality Keeps Rising*. (OECD Publishing, 2011).