BLUEPRINT SERIES 29

DISTRIBUTIONAL EFFECTS OF CLIMATE POLICIES

by Georg Zachmann, Gustav Fredriksson and Grégory Claeys

bruegel

DISTRIBUTIONAL EFFECTS OF CLIMATE POLICIES

Georg Zachmann, Gustav Fredriksson and Grégory Claeys

Research assistance by Daniel Huang and Rachel Bagnall is gratefully acknowledged.

This report was produced with the financial support of Fondazione Cariplo.

CONTENTS

EXECUTIVE SUMMARY

To limit the global temperature increase to well below two degrees Celsius above pre-industrial levels, mankind needs to stabilise the concentration of greenhouse gases in the atmosphere by the middle of this century. That is, industry and agriculture cannot emit more carbon dioxide and other greenhouse gases than will be absorbed. This will require a massive shift in our economies. Heating, transport, electricity and industry will have to be transitioned to a world without fossil fuels. Agriculture and industry will have to find new ways to reduce emissions.

These shifts might be eased by societal and technological shifts, such as urbanisation, and digitalisation, but decarbonisation will likely remain an uphill battle, with reduced fossil fuel consumption translating into lower fossil fuel prices, and hence a continued need for incentives to avoid using the remaining fossil resources.

Consequently, climate policy will play a substantial role in this deep transformation. Given the challenge, policies need to be quite intrusive. Such intrusive policies will likely have substantial side effects, including distributional effects. Depending on (1) the policy tool, (2) the sector addressed, (3) the design of the policy, and (4) the initial socio-economic conditions in the country, individual climate policy measures can have very different distributional effects. To combat increasing inequality and improve the political acceptability of decarbonisation, these distributive effects need to be addressed. Should this not occur, there is a real possibility that decarbonisation policies will face a political backlash.

We focus on the impact of specific climate policies on households with different income levels. Policies that make low-income households better off, relative to high-income households are called progressive. Policies that have the opposite effect are called regressive. And policies that equally affect high and low-income households are called proportionate. We argue that households with lower incomes are affected differently by individual climate polices compared to higher-income households because they:

1) Face budget constraints that lead them to prefer different consumption baskets;
2) Have higher discount rates/feature borrowing constraints that prevent them from procuring more efficient durables;
3) Have different skill endowments and hence wages; and
4) Earn less income from capital and land.

We find that key climate policy tools such as carbon taxes for different fuels, certain mandatory standards, subsidies and regulatory tools, can be regressive. For other climate polices, such as trade policies, public investment and agriculture policies, the effects are less clear. And for fuel taxes on aviation, for example, the effect might be progressive. As the example of the current feed-in tariff designs and the allocation rules in the European Union's emission trading system demonstrate, the detailed policy design matters.

While climate policies can have adverse distributional effects, non-action cannot be the answer. Non-action would make everybody worse off and would affect low-income households more than high-income households. There is hence no trade-off between climate and equity. The question is how we design climate policies to minimise any adverse distributional effects.

Table 1: Summary of our assessment of the distributional effects of climate policies (see sections 2 and 3)

Climate policy	**Distributional impact**	**Our confidence**
Carbon pricing on…		
… Road fuel	Mixed evidence, as low-income households are less likely to own cars, but those that do spend a larger share of their income on fuel	Medium
… Electricity	Regressive, due to low-income households spending higher shares of their income on electricity and because of inelastic demand (eg because of a limited financial ability to replace old electric appliances with efficient ones)	Medium

… Heating	Regressive, although the extent to which low-income households are disproportionately hurt compared to electricity taxes is less clear	Medium
… Air transport	Likely progressive, as air transport is used above-proportionately by high-income households	High
… Maritime transport	Might be slightly regressive, as low-income households spend a higher share on imported goods. However, less maritime trade might benefit low-skilled manufacturing labour	Low
Subsidies on low-carbon technology	Can be regressive, as, for instance, clean vehicle, building-insulation and rooftop-solar subsidies mainly go to high-income households	High
Public investment in low-carbon technology or complementary infrastructure	Mixed evidence, as it depends on whether it increases demand for capital or low-skilled labour, and whether it is mainly used by low-income households (eg city buses) or high-income households (eg high-speed rail)	Low
Higher tariffs on high-carbon imports	Mixed evidence, as low-income households are more dependent on high-carbon imports, but low-skilled workers might benefit from protections for high-carbon industries (eg coal mining)	Low
Vehicle standards	More regressive than fuel taxes	High
Agriculture (eg standards or taxes)	Limited distributional impact	Low
Effect of climate policies on the labour market	Likely regressive because of the skill bias in green industries; however, energy efficiency measures in buildings might create construction jobs	Low
German feed-in-tariffs	Regressive, as they increase household electricity prices, while industry is exempted and benefits from a ‘merit-order’ effect	High

EU ETS	Regressive, as firms have benefited from free allowances, cheap international credits and indirect cost compensation at the expense of consumers and governments	High

Source: Bruegel. Note: Regressive (red/orange): low-income households are hurt more or benefit less than high-income households. Proportionate: low-income households are hurt or benefit as much as high-income households. Progressive (green): low-income households are hurt less or benefit more than high-income households. The level of our confidence in the last column is based upon the availability of corresponding literature, the degree of consensus in the surveyed literature and, where applicable, on the findings from our own analysis.

We argue that the distributional effects of many effective climate policies can be remedied by:

(i) Compensating lower-income households for any adverse effects of climate policies;

(ii) Designing the specific policy measures in a way that reduces adverse distributional effects; and

(iii) Introducing climate policies that have progressive features.

Based on our analysis we derive five conclusions:

1) Invest more in research

More should be invested in gathering data and researching the distributional effects of individual climate policies. In particular, new research should go beyond the partial analysis of individual drivers and assess the aggregate distributional effects of individual policies. This can ultimately allow policymakers to make better informed choices when designing a suite of climate policies that is effective in mitigating emissions, while maximising welfare and social justice.

2) Making policies less regressive

We already know that decarbonising certain sectors has less-adverse distributional effects (eg aviation), that certain policies are less regressive than others (eg taxes compared to standards), and that certain design elements make policies less regressive (eg auctioning emission permits instead of grandfathering them to polluters). Policymakers should factor such known distributional effects more prominently into their policy choices.

3) Actively develop climate policies that benefit lower-income households

There are climate polices – such as support for energy-efficiency investment in social housing – that can bring benefits to lower-income households. Policymakers should become more creative in developing such measures, not least to increase public acceptance of climate policies.

4) Compensation is feasible – but needs to be done

To achieve the ambitious decarbonisation targets, developed countries will have to resort to some degree to regressive carbon taxes on basic needs (eg heating fuel). But recycling the revenues from such schemes – such as through lump-sum transfers – can largely mitigate the distributional concerns, and should be forcefully implemented.

5) An international approach can make domestic climate policies fairer

Policymakers should continue to fight for a globally synchronised decarbonisation effort. This will create space for less regressive national policies as it would alleviate the competitiveness concerns of domestic industry, which currently are an excuse for instruments that benefit high-income households at the cost of low-income households.

This would allow the undesirable distributional effects of climate policies to be better addressed and would thus increase the political backing necessary for the forceful climate policies that are needed to achieve the ambitious decarbonisation pathway to prevent global warming from getting out of hand.

1 INTRODUCTION

In order to avoid disastrous consequences from global warming, greenhouse gas emissions need to be reduced drastically in the coming decades. In the Paris Agreement, 195 countries agreed to "reach global peaking of greenhouse gas emissions as soon as possible" and "achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century" (UNFCCC, 2015). Such a deep decarbonisation process will have wide-ranging implications for the European Union. By about the middle of the century, no EU country will be able to use coal, oil or gas to warm houses, propel cars or generate electricity, unless this is compensated for by negative emissions. Major industrial sectors will have to find ways of reducing the greenhouse gas emissions that are now intimately linked to their production processes. The agricultural sector, which has so far largely been neglected, will have to play a much more prominent role in decarbonisation. And we will have to discuss what "negative emission technologies"[1], which are now mostly theoretical, could look like in reality.

Such a massive transition of our economy will only come about based on intrusive policies, most notably through putting a meaningful price on emissions, but also through fostering public support for the deployment of low-carbon technologies and through bans on inefficient technologies. Modelling exercises show that carbon prices up to $1,000 per tonne of emitted carbon dioxide[2] will be needed in 2050 to keep the temperature increase well below two degrees Celsius above pre-industrial levels. While such price levels currently do not appear very realistic, they indicate the intrusiveness of the

---

[1] Negative emissions technologies remove emissions from the atmosphere. They include carbon capture and storage (CCS) technologies and approaches that increase the natural absorption of CO2, such as afforestation.

[2] However the range of estimates on necessary carbon prices is extremely wide – ranging from $45 to $1000 for 2050; and $140 to $8300 for the year 2100. See http://pure.iiasa.ac.at/id/eprint/14685/.

policies (eg deployment support) that will be needed to bring about a transformation that essentially reduces emissions from electricity generation, transport and industry to close to zero.

Such broad policies are likely to have a number of sizeable side effects. One important consideration is that such policies will affect different parts of the population differently. And given the scope of the transformation, the distributional consequences could be significant.

The distributional consequences are likely to be a major driver of future climate policies. Policymakers will not accept forceful decarbonisation policies if they lead to visibly increasing inequality within their societies. The distributive effects of climate policies therefore need to be addressed. Furthermore, policy is not only driven by actual distributional effects, but also its public perception (Dluhosch, 2018). This highlights the need to make sure that the public discourse provides a realistic picture of the distributional effects of climate policies.

However, the distributional impact of decarbonisation has received relatively limited attention so far in academic and policy discussions. There have been a number of studies on carbon pricing that have focused on the higher share of carbon-intensive products in the consumption baskets of lower-income groups[3]. But these studies – which typically find carbon pricing to be regressive – often do not account for other channels, such as the household income side. Studies that look into the distributional impact of other climate policies, and those that take a more holistic perspective, are very rare[4].

This report provides a selective review of recent academic literature and experience on the distributional effects of climate policies. It seeks to explore different channels of distributional effects, for

---

[3] See summaries by Heindl and Löschel (2014), McInnes (2017) and Flues and Thomas (2015).

[4] Robinson *et al* (2014), for example, argue that distributional aspects are undervalued in decisions on environmental regulation in the US.

different types of climate policies in various sectors. While it is outside our scope to provide a comprehensive account of all studies on the distributional effects of climate policies, our selective approach allows us to reach a number of clear conclusions. We can identify consensus in the reviewed literature on crucial drivers; we also observe contrary results in other areas; and we identify where gaps in the literature exist. Furthermore, our own data-based assessments allow us to make educated guesses on likely effects in areas we did not find literature on.

We want to clearly distinguish our research question ('What are the [within-country] distributional effects of climate policies?') from two related – and more widely studied – questions. The first is the **global distributional implications of climate change and climate policy**, which touches on academic disciplines ranging from economics to moral philosophy and has the goal of providing guidelines on how to spread the global decarbonisation effort in a 'fair' way between countries[5]. A second area of research is the discussion of **energy poverty**, which examines the distributional consequences of the current energy system (which can be huge; see section 3.1).

Thus, we do not focus on the distribution of mitigation costs between countries and the vulnerability of households to energy price shocks under current polices. Our purpose is rather to focus on the distributional impact in advanced economies (such as EU countries) of the additional climate policies that we need to devise in order to achieve the goals of the Paris Agreement.

We first describe key general drivers that explain the distributional effects of different climate policies in different sectors (such as differences in consumption of high-income and low-income households). Second, we discuss the distributional effects of individual climate policies – sometimes in individual sectors, such as the impact of a carbon tax on heating costs for households of different income classes. We then look at two major European climate policies

---

[5] See, for example, McCarthy *et al* (2001).

– renewables support and emissions trading – to demonstrate how complex real-world policies affect inequality. Fourth, we show that climate change itself might also have distributional consequences between countries and between income groups, and thus that non-action would be heavily regressive. Fifth, we provide some recommendations on how to prevent climate policies from increasing inequality. We conclude with policy recommendations.

2 DRIVERS OF THE DISTRIBUTIONAL EFFECTS OF CLIMATE POLICIES

2.1 Analytical framework

A major drawback of climate policies is that their burden can fall disproportionately on lower-income groups. A policy that is paid for disproportionately by low-income households is termed regressive. If the burden falls more heavily on the high-income households it is called progressive, and if the cost is distributed equally across income groups it is called proportionate.

Each household is different and climate policies will affect each of them differently. But households with relatively similar characteristics will likely be affected in fairly similar ways. A number of characteristics determine how households are affected by a given climate policy. For example, a fuel tax puts a higher burden on rural households than on urban households[6]. Other characteristics that could play a role include gender, nationality, wealth, income, ethnicity, region, job and educational level.

In research and politics, income is typically emphasised as a factor. We therefore focus our attention on how households of different income levels are impacted differently by climate policies. It is important to note, however, that income is correlated with other characteristics. For instance, low-skilled households tend to have lower incomes. Hence, we do not only look into the direct impact of climate policies on households of different incomes, but also consider the indirect ways in which climate policies can alter the income distribution (eg by changing the demand for low-skilled workers relative to high-skilled workers, which indirectly alters the skill

[6] The rural/urban divide is correlated with income but in a non-linear way. In the US, for example, rural households have 3.5 percent lower median income, while the poverty rate is significantly higher for urban households (16 percent versus 13.3 percent for rural households). The picture gets even more complex when looking at different regions. For example in the Northeast US, rural households also had the higher median income. See https://www.census.gov/newsroom/blogs/random-samplings/2016/12/a_comparison_of_rura.html.

premium and relative wages). It should be mentioned that assessing overall effects is challenging, since it often requires complex modelling. Many studies consequently limit their scope to studying partial effects (ie the direct effect) of climate policies. Future research would benefit from modelling both the direct and indirect impacts of climate policies, to fully assess their distributional consequences.

In order to understand how climate policies affect households we refer to a very stylised model of the economic welfare of households.

2.1.1 Income side

Households can generate income from employing the production factors they possess (capital, land[7] and skills). The income that can be drawn from employing these production factors might change as a consequence of climate policies. The owner of a coal mine might see his related capital income decline because of carbon pricing[8], while a biotech engineer might expect to draw a higher income from his skills when investment in advanced biofuels is publicly promoted. Consequently, the value of specific skills and capital can be:

- 'Green' – more valuable in a decarbonising world;
- 'Brown' – less valuable in a decarbonising world; or
- 'Grey' – unimpacted by decarbonisation.

We expect capital to be mainly grey. However, the capital that is influenced by climate policies is more likely to be brown than green, because decarbonisation has only recently begun[9]. For labour, we

---

[7] Many models treat land as a form of capital. We single it out here, as the value of land might significantly increase because of decarbonisation (for example, as space for wind turbines, solar panels, biomass-planting, afforestation and other mitigation options).
[8] This in turn will also reduce the value of the capital itself, as capital should be valued according to the future income stream.
[9] FTSE Russell (2014) puts the market value of fossil-fuel companies as a share of total market valuation at 9-12 percent. But wider definitions might also include bonds of some highly fossil-fuel export dependent countries, energy inefficient real estate or the value of patents in fossil technology.

again expect the grey share to dominate, but it is hard to make an informed guess whether the brown or green share is greater. We expect the value of most land to increase with decarbonisation policies. Planting of biofuel crops, renewables installation and reforestation should increase the demand for rural land, while reduced noise and air pollution might increase the value of currently disadvantaged urban land plots[10]. Hence, land is mainly green or grey. We would assume that the green, brown and grey shares in capital and land are similar for high-income and low-income households.

Lower-income households generally own less production factors – in particular land and capital – than those with high incomes. Even though the market value of the skills of low-income households is typically lower than that of high-income households (eg in terms of formal education), labour represents a much higher share of the total income of low-income households.

The effect of decarbonisation policies on the valuation of skills is unclear, and will likely depend on the decarbonisation pathway and other megatrends (eg automatisation, globalisation). Lower-income households are overrepresented in low-skilled sectors. But low-skilled sectors can be clearly brown (eg coal mining) but also grey (eg many services) or clearly green (eg construction in the context of increased renovation rates needed to improve the energy efficiency of the building stock).

The main effect of decarbonisation on the production factor and income side will thus likely arise from high-income households receiving a greater share of their income from land and capital, while low-income households will receive a greater share of their income from skills. If capital is generally browner than skills, this might make decarbonisation progressive. If, however, decarbonisation increases

---

[10] Some land plots might become less valuable because of changing transport systems (such as close to airports, should aviation decarbonisation result in fewer passengers), and there are some radical scenarios in which, for example, suburbia becomes less desirable because of rising transport and heating costs.

the returns to capital more than the returns to labour, decarbonisation could be regressive.

Households can use their budgets to invest in production factors. They might buy land and capital assets or engage in education (which has direct and indirect costs[11]). High-income households are more likely to find that such investment will increase their overall utility over their expected lifetime, while low-income households might draw more utility from meeting their basic current needs. There are several reasons for this: High earners have significantly longer expected lifetimes. In Germany, people in the highest income group (earning €4500 or more per month) are expected to live almost nine years longer than those in the lowest income group (earning €1500 or less) (Lauterbach *et al*, 2006), which gives them more time to draw more utility from investments. High-income households also tend to value the expectation that they will receive a certain amount in ten years more than low-income households, because high-income households have already met all of their basic current needs while low-income households can substantially increase their wellbeing by spending this amount today (Table 2). Furthermore, the ability of high-income households to invest larger amounts makes investment more profitable by reducing the relative share of transaction costs[12]. By contrast, low-income households might shy away from investments with high upfront costs (for example, rooftop solar panels) because of a concern that they might lose too much if the investment goes wrong. The greater propensity to invest means high-income households should be able to adjust more easily to the economic shifts induced by decarbonisation over time.

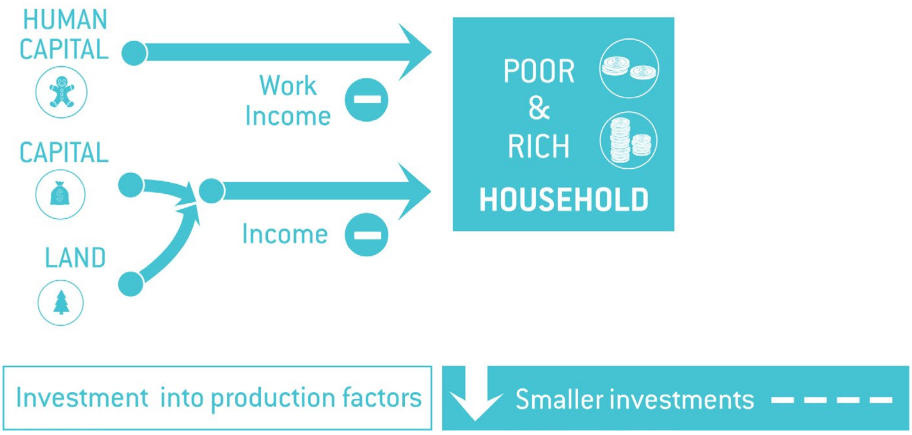
Low-income households might also find it more difficult to make optimal use of their resources, because, for example, they might not be able to wait and search for the optimal job for their qualification if

[11] Opportunity cost of the hours not worked.

[12] This includes the cost involved in searching and studying different investment opportunities.

they do not have enough savings (or capacity to borrow) to search for a job for an extended period.

Figure 1: Income side



2.1.2 Expenditure side

Households spend money to acquire goods and services for immediate consumption, such as food, and durable goods from which they will benefit over a period, such as furniture. In addition, the government provides goods such as infrastructure, and services such as health care that have some utility for individual households. Finally, the quality of the environment also contributes to the well-being of households.

Households will try to acquire the combination of goods and services that maximises their individual utility. This is far from trivial because it will depend on each household's: (i) preferences for individual goods and services, (ii) borrowing constraints, and (iii) total budget. High and low-income households differ in all three respects.

A **household's preference** for individual goods and services includes:

(a) Very personal preferences (eg a vegetarian vs. a meat-eater)[13];

(b) The so-called time preference, or the extent to which the household prefers current consumption over future consumption (for example, having an inefficient second-hand car today instead of a new electric vehicle in some weeks/month/years). As shown by the example of Denmark (Table 2), low-income households have significantly higher discount rates, meaning a much stronger preference for immediate consumption over future consumption compared to richer households; and

(c) How the utility of certain goods and services to a person depend on the other goods and services a household already consumes. Some products together have a greater utility than individual products alone, ie they are complements, such as cars and fuel, while others are substitutes such as a transport season ticket and a car.

[13] It is an interesting question whether low and high-income households also have different individual preferences. One might hypothesise that social groups might develop preferences based on optimal responses to budget constraints, and that they maintain these over long time periods even when those budget constraints vanish. There is, for example, some literature that indicates that the time and risk preferences of representatives of different ethnic groups are systematically different, even when controlling for socio-economic factors. The same might hold for other characteristics (eg rural/urban) that also correlate to income. In this report we largely ignore differences in preferences (apart from section 2.7, where we look into food consumption).

Table 2: Example: discount rates by income group in Denmark

Low-income	32.9
Lower middle	30.1
Upper middle	22.7
High-income	22.5

Source: Bruegel based on Harrison *et al* (2002). Note: A discount rate indicates how much value is attached to present consumption relative to future consumption. A discount rate of zero reflects indifference between present and future consumption, while positive discount rates imply greater preference for present consumption. In the table, the discount rate is highest for the low-income group, meaning these individuals place the greatest value on immediate relative to future consumption.

Low-income households face **borrowing constraints**. Borrowing is important because people can increase their utility by borrowing money to smooth out their consumption or to invest in durables. However, low-income households have lower credit scores on average and no collateral to borrow against, and might therefore experience borrowing constraints.

Finally, the **total budgets** of low-income households are significantly smaller than those of high-income households. Observed differences in consumption by high-income and low-income households can be largely attributed to this last element: high-income households consume different (often more expensive) goods and services than low-income households simply because they have higher budgets. This, for example, allows them to buy more efficient durables (eg refrigerators or cars) to achieve greater utility in the future. Consequently, while low-income households have lower immediate consumption, a disproportionately high share of their immediate consumption is brown.

Table 3 corroborates the notion that expenditure patterns can vary depending on income. The table is based on Engel curve slope estimates[14] from Fajgelbaum and Khandelwal (2016) and shows sectors in which low-income individuals on average spend a greater share of their income (red), sectors in which high-income individuals on average spend a greater share of their income (green), and sectors in which no statistically significant expenditure differences appear across income groups[15]. The table suggests that, on average, low-income individuals spend a greater share of their income in some food and manufacturing sectors (eg textiles), but a lower share in several service sectors (eg real estate or air transport).

Table 3: Relationship between income and share of expenditure in various sectors

Food sectors* and manufacturing sectors	Service sectors
Printing and publishing	Sale, repair of motor vehicles
Agriculture	Air transport
Food, beverages, and tobacco	Other auxiliary transport activities
Mining	Real estate activities
Textiles	Renting of Renting of machinery and equipment
Leather and footwear	Education
Coke, refined petroleum, nuclear fuel	Health and social work
Chemicals and chemical products	Private households with employed persons
Rubber and plastics	Inland Transport
Other nonmetallic minerals	Electricity, gas, and water supply
Transport equipment	Construction
Wood products	Wholesale trade and commission trade
Basic metals and fabricated metal	Retail trade

[14] Engel curve slopes indicate how expenditure on a particular good or service varies with income. Goods with a positive slope are consumed relatively more by high-income individuals, whereas low-income individuals spend a greater share of their income on goods with a negative slope.

[15] To be precise, Fajgelbaum and Khandelwal (2016) estimated the sectoral expenditure shares for *countries* of different income levels, and assumed that the expenditure differences hold for *individuals* of different income levels. To test this assumption, they also used micro-level data to estimate how sectoral expenditure shares vary across individuals of different income, and found similar results.

Machinery	Hotels and restaurants
Electrical and optical equipment	Water transport
Manufacturing, nec	Post and telecommunications
	Financial intermediation
	Public admin and defence

Source: Fajgelbaum and Khandelwal (2016). Note: *The food sectors are ‘Agriculture’ and ‘Food, beverages, and tobacco’, while the remaining sectors in the first column are manufacturing sectors. Green indicates that the share of expenditure in the particular sector is lower for low-income individuals. Red indicates that the share of expenditure in the particular sector is higher for low-income individuals. No colour indicates no significant relationship (on a 10 percent level) between the share of expenditure in the particular sector and income. The relationship between income and the sectoral expenditure share is statistically significant on at least a 10 percent level for the sectors coloured in green or red.

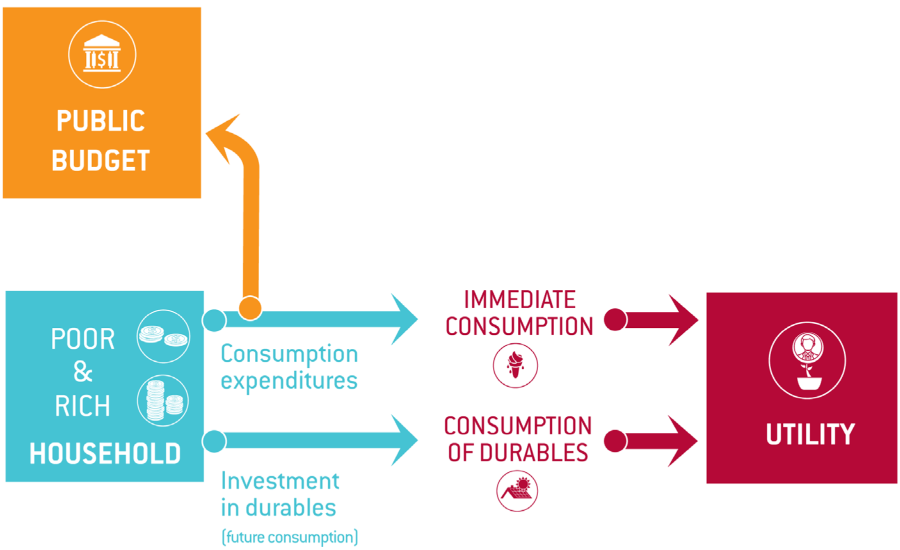
In terms of consumption of public goods, we have no clear evidence but our intuition would be that at least for transport infrastructure, high-income households consume a greater brown share (roads, airports), while low-income households would consume more green components (public transport).

On the expenditure side, climate policies will mainly affect prices and availability of individual goods and services (for example, carbon taxes that are passed through to final products, or environmental standards that result in bans on certain products). Basic goods (such as heating or food) form a much higher share of low-income households’ consumption baskets than of high-income households’ consumption baskets. According to the Engel curve estimate (Table 3), climate policies that, for example, increase the price of food or petroleum would be regressive because low-income households spend a greater fraction of their incomes on these goods.

Climate polices might make expenditure on durables that reduce the carbon footprint of households very beneficial. Such policies might include subsidies for low-carbon purchases, such as electric vehicles or solar panels, or for investments in energy efficiency. Policies might also increase the cost of high-carbon durables such as inefficient vehicles, fridges or houses. Households with different incomes might be differently affected, because they own different types of durables and have different capacities for adjusting their stocks of durables.

Existing assets – such as a detached house – might allow high-income households to benefit from climate policies such as rooftop solar subsidies or energy efficiency retrofit credits. Low-income households might not be able to make such investments. As many low-carbon investments are expensive (eg an electric vehicle), the necessary expenditures might be out of reach for low-income households because of budget constraints. They might also not be beneficial because of lower usage or too risky as they would severely unbalance the asset/durables portfolios of low-income households.

Figure 2: Expenditure side



2.1.3 Government side

The government receives taxes on the income from capital, labour and land, and from consumption (including of durable consumer goods). The government budget is used to provide public goods such as public transport and transfers such as social security[16].

Most actual and discussed fiscal climate policies seek to put a price on carbon. While the companies that emit the carbon typically pay this to the tax authority (or the allowance auction office), the cost is passed through to consumers in the form of higher prices. Hence, in our stylised scheme these costs would show up as consumption taxes and the relative prices of consumption goods would change, which can have distributional effects.

Another fiscally relevant climate policy is provision of subsidies for certain consumption goods (which would show as a reduction in corresponding consumption taxes) or assets (which would show as a reduction in corresponding income taxes). Hence the relative prices of consumption goods or incomes from assets would change, which can have distributional effects.

Finally, the provision of green public goods is another fiscally relevant climate policy.

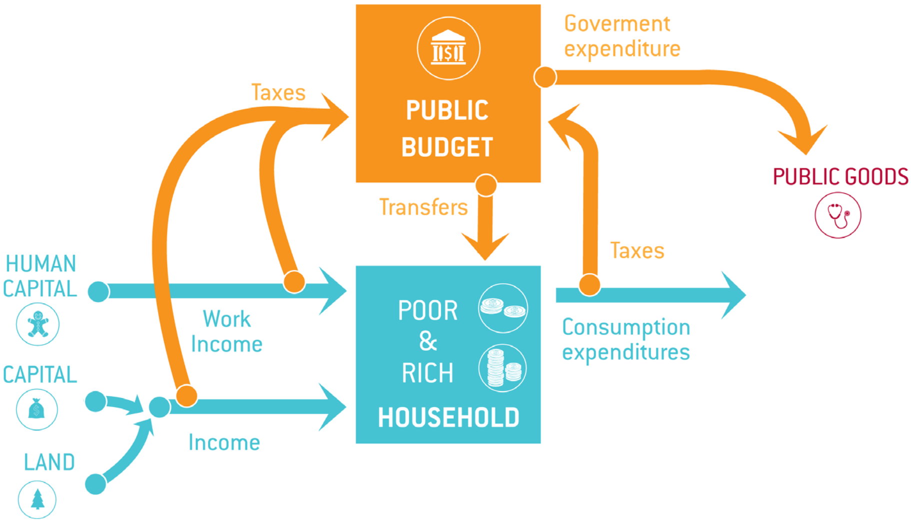
Climate policies that generate government income would allow a government to reduce other taxes and/or increase the provision of transfers and public services. In theory, the government would be able to offset each distributional impact of a climate policy using targeted lump-sum transfers[17], or could at least mitigate the effect by reducing other taxes. As the government is relatively free to use climate-policy related incomes either in a progressive way (such as through lump-sum transfers or reductions in labour taxes) or a

[16] In our highly stylised model, the government budget is meant to also include 'parafiscal' implicit schemes such as emissions trading or renewables levies.
[17] Perfect compensation might require perfect information, which is not available. One might argue that information is costly (a lot of reporting and monitoring required as taxpayers cannot be trusted to declare their true economic situations – they might prefer to incur costs themselves to appear less rich, eg by offshoring) and hence there seems to be a trade-off between the lower cost of organising transfers and the degree to which they are targeted.

regressive way (such as reductions in capital taxes) we do not discuss this 'recycling' here, but in the chapter 5, on remedies.

Thus, whether such fiscal offsets are progressive or regressive depends on how progressive or regressive the initial fiscal system is[18].

Figure 3: Government side



2.1.4 Summary

Climate policies can affect the welfare of households through multiple channels, such as their income or the value of their assets. Structural differences in the economic activities of low- and high-income households (see Figures 4 and 5 for a comparison using our stylised

---

[18] If a country with a very regressive fiscal structure collects carbon taxes and gives them back through reduced VAT, it might make the system less regressive, while the same policy in an initially very progressive fiscal structure might turn this system less progressive. That is, depending on the initial fiscal structure the same instrument might be progressive or regressive.

framework) imply that certain policies affect households differently. To obtain fair policy guidance, it is important to analyse the distributional effect of a given climate policy on each economic activity, because focusing only on one side might severely bias the results. For example, a policy that might have a disproportionate cost for lower-income households on the expenditure side, might only negatively affect the returns to production factors held by high-income households on the income side, making the overall distributional effect roughly proportionate.

The type of policy (eg standards, taxes or subsidies), the targeted sector (eg agriculture or aviation), the concrete policy design (eg thresholds or exceptions) and the characteristics of the economy (eg initial inequality, sector structure or whether the fiscal system is progressive) matter for the direction and extent of the distributional impact.

Figure 4: Stylised model of the economic activities of a high-income household

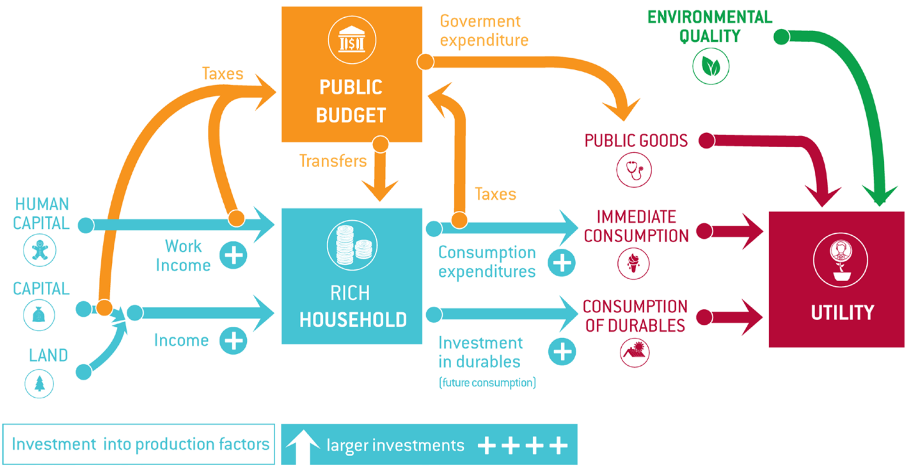
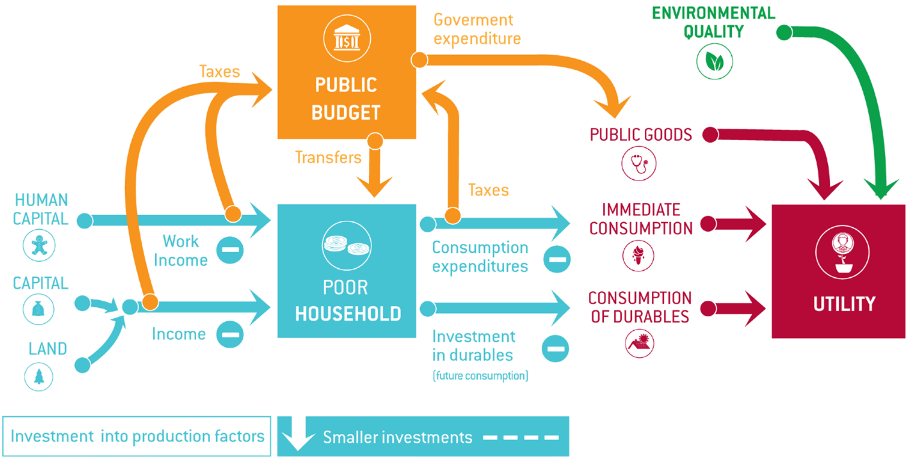


Figure 5: Stylised model of the economic activities of a low-income household



+++

Box 1: Measuring distributional effects

It would be very handy to have a unique indicator in order to be able to compare the distributional effects of different climate policies. Such a unique indicator would, for example, allow calculation of whether one climate policy (eg a carbon tax on road fuels) increases inequality less than another (eg car emission standards). But distributional effects are too complex to be summarised by such a one-number indicator. The main reason is that households have multidimensional socio-economic characteristics, such as annual or lifetime incomes, wealth, annual expenditures, region, ethnic/racial backgrounds, gender and income sources[19]. Consequently, a policy might improve the welfare of a household with a low income and high wealth and reduce the welfare of another household with relatively higher income

[19] Thus, Rausch *et al* (2011), for example, use a model with a large number of households to consider distributional impacts over different sub-populations.

and lower wealth. That is, the same policy might increase wealth inequality and reduce income inequality. Most studies focus on income or sometimes on expenditure.

When looking into the income distribution the observation period is important. Transitional low-income earners (students, pensioners) might look extremely vulnerable to carbon prices, while the same persons only spend a small fraction of their lifetime income on carbon taxes[20].

Distributions of a single characteristic can be summarised in inequality indicators such as the Gini coefficient[21], ratios for different percentiles (99/1, 75/25)[22], shares of income or wealth in the hands of the poorest segment of society or the Theil index[23]. Each of these indicators attaches a different weight to differences in income at the tails of distribution.

In addition, even within one characteristic (eg income) the effects are often not linear. Very low-income earners that typically own no car and very high-income earners that often do not have to commute long distances are less affected by fuel taxes than middle-income owners that commute with their cars. Inequality indices – such as the Gini coefficient – would be unable to properly reflect such distributional effects. We observe that many studies on the distributional impacts of climate policies do not report a single figure, but rather report how the

---

[20] *"Suppose that as people grow old their energy consumption becomes a larger share of their total consumption, and suppose, as well, that over a lifetime the energy tax has a proportional incidence, then using current consumption to measure lifetime income, the energy tax would appear regressive"* (Hassett *et al*, 2009).

[21] The Gini coefficient takes a value of 0 when all individuals exhibit identical income or wealth and a value of 1 when total income or wealth is held by a single individual or household.

[22] These attach a greater weight to differences in income at the tails of distribution.

[23] The Theil index is an entropy index which measures deviation from perfect income inequality. It has the desirable property of being decomposable so that inequality within a group (intra-group inequality) and between groups (inter-group inequality) can be estimated.

analysed policy changes the expenditure/income/welfare for each decile of the income or expenditure distribution.

Overall, we observe significant differences in the way different studies measure distributional effects. This makes it very difficult to compare the size of the distributional effect or even aggregate the results of different studies.

+++

2.2 Carbon pricing

Putting a sensible price on emissions is seen by many economists as the most economic way to reduce emissions (eg Cramton *et al*, 2017). A carbon price can be implemented through price-based instruments such as taxes or quantity-based instruments whereby a limited number of emissions allowances are issued after which the emissions price is determined by the market. There are systems that foresee a single carbon price for all sectors (eg the EU emissions trading system, see section 3.2), and a set of schemes that determine different prices for different sectors (such as aviation emissions, see section 2.2.4).

Impact of sectoral carbon prices is a proxy for other sectoral climate policies

Policies other than an explicit price on emissions in a particular sector can have relatively similar effects to a carbon price. For example, electricity taxes or road fuel prices – even if not explicitly tied to emissions – act in the same way as a carbon price. Furthermore, many regulatory tools to tackle emissions have broadly similar distributional consequences to putting a price on carbon. For example, emission standards for particular production technologies (eg power plants) increase the cost of the corresponding products (eg electricity) for consumers and reduce the value of corresponding capital for producers. In contrast to carbon pricing, standards generate no direct income for governments and instead of only discouraging the most emitting activities, many standards outright ban technologies even if used in less-polluting modes (eg coal-fired power plants used as back-up).

The empirical literature on the distributional impact of climate policies other than (implicit) carbon prices – such as subsidies or standards – is relatively sparse. Hence, the more numerous studies on the distributional impact of putting an implicit or explicit price on carbon discussed in this section can also serve as a good first approximation of the distributional impact of other non-fiscal measures.

General effect

A carbon price has two effects: (1) it raises product prices, by making it costlier for producers to pollute, and (2) it alters returns to factors of production (specifically, capital and labour). The first effect is typically regressive, as lower-income households spend a larger share of their income on many emissions-intensive products (eg heat and electricity) than higher-income households, and lower-income households have less opportunity to switch to less emissions-intensive substitutes. The second effect is more likely than not slightly progressive, as emissions-intensive capital assets that lose value in the transition will be predominantly held by high-income households. However, high-income households will also hold those capital assets that might increase in value thanks to increasing carbon prices, such as shares in wind turbine manufacturers.

Effects differ by sector

The effects of carbon prices will differ for different sectors. First, the so-called incidence of the carbon price –how it is split between consumers and producers – depends on the targeted product. For products for which consumers can easily switch to alternative low-carbon products, the high-carbon producers will have to pay the carbon tax, or lose the consumers. By contrast, for products where no low-carbon alternatives are available, producers can pass through the carbon price to final consumers. Furthermore, the ability of producers to reduce prices determines the carbon price incidence. For products that cannot be offered at lower prices, consumers will have to pay the carbon price if they want to have the product, while for products that producers would even offer if the price were much lower, the producer will have to absorb a higher share of the carbon price[24].

Second, some products/services, such as electricity, take a higher share of low-income households' expenditures and putting a tax on them will likely be regressive. Other products/services, such as aviation, are in much higher demand from high-income households and a tax on them might be progressive (see Table 4).

In the following, we review the literature on the distributional effects of carbon prices (equivalent fiscal measures) for road fuel, electricity, heating, air transport and maritime transport.

[24] That is, in economics jargon, the carbon tax incidence depends on the relative elasticity of supply and demand for the product.

Table 4: Summary table of greenhouse-gas emissions and share of overall household consumption expenditure for sectors affected by carbon pricing

Category name in our report	Share of total emissions (EU28)	Share of expenditure on sector/product in overall household expenditure (Italy)			Engel curve slope estimate†
		Lowest 20%	Average HH	Highest 20%	
Air transport	3.7%	0.1%	0.3%	0.5%	0.07*
Road fuel	12.1%	5.6%	4.7%	3.9%	-0.89***
Agriculture	9.7%	21.8%	16.4%	12.0%	-1.25***
Electricity	23.0%	3.9%	2.0%	1.3%	-0.33
Heating		3.5%	2.4%	1.8%	-

Source: Bruegel based on Eurostat (n.d.) (which sourced from the EEA), Italian National Institute of Statistics (2017), and Engel curve slope estimates from Fajgelbaum and Khandelwal (2016). Note: †Multiplied by 100. An Engel curve slope estimate indicates how the expenditure on a particular good or service varies with income. Goods with a statistically significant positive slope estimate are consumed relatively more by high-income households (green), whereas low-income households spend a larger share of their income on goods with a statistically significant negative slope estimate (red). ***Significant at 1 percent level; **significant at 5 percent level; *significant at 10 percent level. All data besides the Engel curve slope estimates are for 2016. The category names in each source are reported in Table A in the annex.

2.2.1 Road fuel

Road transport emissions account for about a fifth of EU emissions[25]. Road transport will therefore be a main area for decarbonisation policies; putting a price on carbon emissions from road fuels is a

[25] In 2015, all transport emissions accounted for 25.8 percent of EU emissions, of which road transport was responsible for 72.8 percent.

much-discussed idea. The European Commission in 2011, for example, proposed a CO2 component as part of the EU Energy Taxation Directive that would also cover road fuels[26]. While there is little empirical evidence on adding specific carbon taxes to road fuels, ample academic literature exists on the distributional effects of general road fuel taxes. We will refer to this literature, as general gasoline and diesel taxes have similar effects to specific carbon taxes on road fuels[27].

Figure 6: Stylised scheme of the distributional effect of a carbon tax on road fuel

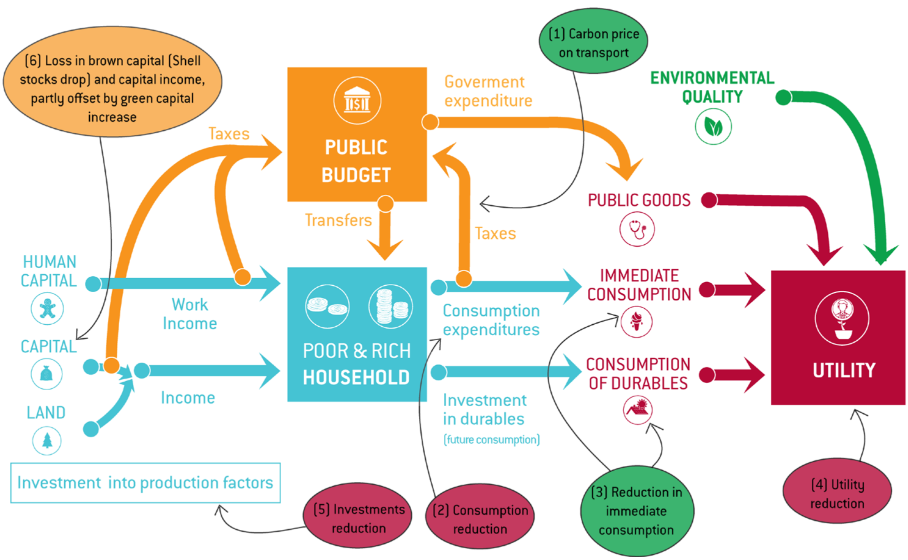


Figure 6 summarises, in a simplified way, the effects of a carbon tax on the flows of a household. The arrows represent various flows: the government raises money to spend in the public budget by taxing

---

[26] Because of opposition from EU countries this proposal was, however, withdrawn in 2015.

[27] In contrast to gasoline taxes, toll systems might privilege larger and more inefficient cars.

income and consumption, which is then reinvested as government expenditure (eg on public goods) or given back to households in the form of transfers. The household represented, instead, can decide to consume its budget in different ways: immediate (food, petrol, an airplane ticket etc) or by purchasing durable goods (eg a car or solar panels); or can invest it in production factors (human capital, capital, land). The household derives a direct utility from consumption of the different type of goods, as well as from the environmental quality.

In Figure 6, we represent the effect on transport of a carbon tax levied by the government. Immediate consumption (for example of fossil fuel) is reduced as a result of the increased price, whereas the household will have a greater incentive to invest in an electric car. This shifting effect will still reduce the overall utility of the household. On the investment side, the investment in brown capital will be reduced in favour of green capital.

Early studies generally found that gasoline taxes are regressive (Dumagan and Mount, 1992; Brännlund and Nordström 2004; West and Williams III, 2004). However, Tiezzi (2005) suggested that high-income households in Italy lost disproportionately more from a carbon tax introduced in 1999. As the tax increased the price of transport fuels, Tiezzi (2005) suggested that the disproportionate impact might arise because high-income households were more likely to own a car. Moreover, Flues and Thomas (2015) found that taxes on road-fuel consumption in 21 OECD countries were, on average, progressive.

In a limited meta-analysis Davis and Knittel (2016) observed that Burtraw *et al* (2009), Fullerton *et al* (2012) and Hassett *et al* (2009) found gasoline taxes to be regressive, while West (2004) and West and Williams III (2004) found that gasoline taxes were progressive for low-income households and regressive for high-income households.

Taken together, the literature generally indicates mixed results about whether putting a carbon price on road fuel is regressive.

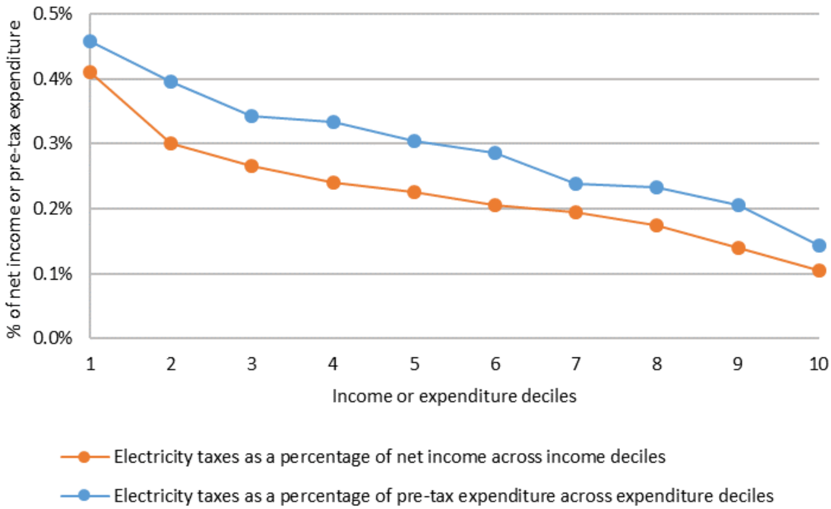
2.2.2 Electricity

In 2013, electricity and heat accounted for 31 percent of global emissions (Center for Climate and Energy Solutions, 2018). World electricity demand increased by around 3 percent in 2017, which was significantly higher than the overall increase in energy demand (International Energy Agency, 2018).

In a study of 21 OECD countries, Flues and Thomas (2015) showed that electricity taxes are regressive on average[28], on both an expenditure basis and an income basis. Figure 7, replicated from Flues and Thomas (2015), shows this. The downward sloping orange line indicates that, on average, those earning less spend a greater share of their income on electricity taxes. Similarly, the negatively sloped blue line suggests that, on average, the share of expenditure on taxes is higher for households with low overall spending. However, the income spent on electricity in the study is between 0 and 2 percent, which suggests that the taxes' regressive impact in absolute terms is limited.

[28] Though the degree to which electricity taxes are regressive varies across countries in the study.

Figure 7: Average electricity taxes (21 OECD countries) as a percentage of net income or pre-tax expenditure



Source: Flues and Thomas (2015).

A later study by Tovar Reaños and Wölfing (2018) found supporting evidence for Flues and Thomas (2015). The analysis, performed for Germany, is special because it employed both a novel econometric method and a highly detailed dataset. The dataset allowed the researchers to model demand for electricity and heating separately, which is typically difficult. They found that an increase in the electricity price has regressive consequences. A 20 percent increase in electricity prices raises inequality by around 0.24 percent (as measured by the Gini index). Low-income households are also found to reduce their electricity consumption to a greater extent than high-income households in response to price increases.

In essence, therefore, there is evidence that electricity taxes are regressive. Flues and Thomas (2015) suggest several reasons why:

1. **Inelastic demand**. All modern households require a minimum amount of electricity, for fridges, freezers, televisions, lamps and

other appliances. This restricts the ability of households to reduce consumption in response to a price increase. Further, it is difficult to switch to substitutes for electricity as few exist. Such 'inelastic' demand means that households only reduce electricity consumption by a little if the price increases. Since low-income households spend a greater share of their income on electricity, a tax disproportionately hurts them.

2. **Credit constraints.** Low-income households might own older electrical appliances that consume more electricity. They might also lack the financial means to buy new efficient appliances.

2.2.3 Heating

Flues and Thomas (2015) and Tovar Reaños and Wölfing (2018) also analysed the distributional effects of taxes on residential heating. Both studies found that heat taxation is regressive. Tovar Reaños and Wölfing (2018) estimated that heat taxes bring about a welfare loss two to three times greater than that resulting from electricity taxes. Flues and Thomas (2015), in contrast argued that electricity taxes tend to be more regressive than taxes on heating fuel.

The notion that heating taxes are extremely regressive might seem intuitive because low-income households might live in poorly insulated houses. However, as noted by Flues and Thomas (2015), these taxes might actually only be slightly regressive because the low-income households are more likely to:

1. Live in smaller dwellings that require less heating;
2. Live in apartment blocks that require less heating compared to detached houses; and
3. React to increasing cost by using less heat, since they can heat to lower temperatures, heat only part of their houses or switch off the heating when leaving the house.

Thus, though heating taxes are likely regressive, the extent to which they disproportionately hurt low-income households compared to, for instance, electricity taxes, is unclear.

2.2.4 Air transport

Direct emissions from aviation account for about three percent of the EU's total greenhouse gas emissions and for more than two percent of global emissions. If global aviation was a country, it would be one of the world's ten largest emitters[29].

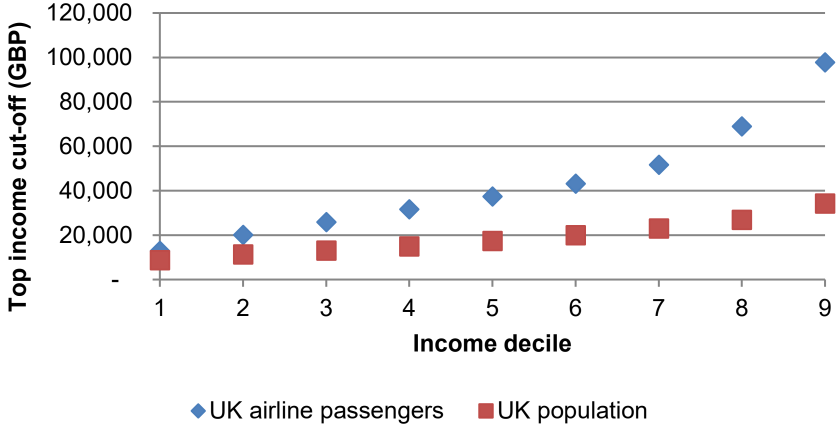
The distributional effects of air transport have not been extensively studied, but the evidence suggests that air transport taxes are unlikely to be regressive (Leicester and O'Dea, 2008). It seems intuitive that high-income households are more likely to fly and spend larger portions of their incomes on air travel. Jones (2007) shows that in the UK, the lowest income quintile spent about 0.08 percent of their income on an air transport tax, compared to 0.1 percent for the highest quintile.

Figure 8 suggests that people who travel by plane are wealthy. The figure compares the upper boundaries of the income deciles of UK airline passengers with those of the UK population. While the poorest 10 percent of travellers have similar incomes to the poorest 10 percent of the UK population, the income disparity grows for higher income deciles. The richest 10 percent of travellers, for instance, earn at least £80,000, compared to £35,000 for the richest 10 percent of the UK population. The figure suggests that a typical air traveller is richer than a typical citizen. Thus, an air travel fuel tax would be unlikely to be regressive, since it would primarily hit high-income households.

---

[29] See https://ec.europa.eu/clima/policies/transport/aviation_en. According to SWD(2017) 31 final, the EU is currently responsible for 35 percent of global aviation emissions.

Figure 8: Upper cut-off points of the income deciles of UK airline passengers and the UK population in 2016



Source: Bruegel based on Civil Aviation Authority (2016) and Eurostat. Note: The UK airline passenger income data is only available in intervals and, consequently, the average value of the cut-off interval corresponding to each income decile is used.

2.2.5 Maritime transport

Maritime transport encompasses both goods and passengers. We focus on the transport of goods because this accounts for the greatest share of maritime emissions [30]. Maritime trade activity depends on transportation costs, but these costs are expected to increase when carbon emissions need to be drastically cut. Maritime transport emitted 2.2 percent of global greenhouse gases in 2012 but could be responsible for 17 percent of global CO2 emissions in 2050 if left unregulated, according to Cames *et al* (2015). A first agreement was reached in April 2018, when more than 100 nations attending the United Nations International Maritime Organization (IMO) reached an

[30] Ferries and passenger ships account for only 0.3 percent of the dead-weight tonnage of all ships (UNCTAD, 2017, p.25).

agreement to halve their greenhouse gases emissions from shipping by 2050[31].

A carbon price for maritime emissions[32] would incentivise firms to reduce emissions but would also increase the shipping costs for goods. Global maritime transport accounts for around one billion tonnes of CO2 per year[33], implying that a carbon price of €25 per tonne of CO2 would increase annual sea-borne transport costs by €25 billion. This corresponds to approximately 12 percent[34] of global maritime fuel costs.

An increase in transport costs could translate into higher prices for imported products. If domestic substitutes exist, demand for imports might decrease and thereby suppress the volume of trade. According to Shapiro (2016), bilateral trade could decrease by eight percent if trade costs rise by one percent[35]. In theory, one might expect an especially severe contraction in the trade in bulky low-value goods, since shipping costs make up a large share of their final price (Kollamthodi *et al*, 2013). We, however, found no clear evidence that such goods constitute a disproportionate share of low-income households' expenditures. Kollamthodi *et al* (2013) found no significant effect from the introduction of a maritime carbon price on

[31] See International Maritime Organisation (2018) 'UN Body adopts climate change strategy for shipping', retrieved from http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx.
[32] Introducing a carbon price, through a maritime Emissions Trading System, was presented as one of the medium to long-term options to reduce European maritime emissions by the European Commission in 2013.
[33] See https://ec.europa.eu/clima/policies/transport/shipping_en.
[34] The global maritime fuel costs were calculated manually. In 2016, oil demand from bunkers was 7.7 million barrels per day (International Energy Agency, 2017a), equal to 2.8 billion barrels per year. Assuming a price per barrel of €70, annual global maritime fuel costs were around €200 billion. A carbon cost of €25 billion corresponds to approximately 12 percent of this amount.
[35] It should be noted that this relationship between trade volumes and trade costs is for trade *in general*, and not specifically for maritime trade. Indeed, Shapiro (2016) combines data on trade by sea, air, rail and road. Though the analysis is not only restricted to maritime trade, it suggests maritime trade would decrease if a carbon price were introduced in this sector.

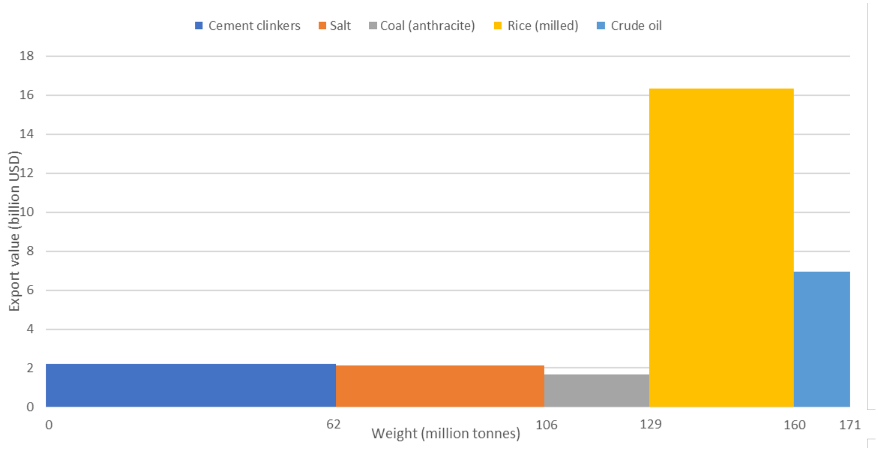
the prices of various commodities (including fuel) in 2030. According to Kollamthodi *et al* (2013), the disposable income of all socioeconomic groups would be largely unaffected.

There is thus some evidence that a maritime carbon price might not be regressive. However, estimating the distributional impact is a complex task that requires careful modelling for two major reasons:

First, the cost of imported intermediate goods will affect final goods prices in complex ways (eg substitution in the value chain). Predicting the effect of a maritime carbon tax on product prices is therefore challenging.

Second, transportation costs per value vary greatly for different goods. Products such as cement clinker and salt are heavy and thus are likely to be costlier to transport and have a relatively low trade value (Figure 9). This suggests that transportation costs are a large part of their product price. However, crude oil has a high trade value, suggesting transport costs are a smaller proportion of its final price. A maritime carbon price would likely affect demand for different goods differently, depending on how much of the product price is made up of transport costs. This suggests that care should be taken when drawing conclusions about the overall distributional impact of a maritime carbon price.

Figure 9: Global export volumes and weights of five commodities (ordered by export value per weight)



Source: Bruegel based on UN Comtrade.

2.3 Subsidies

To pursue climate objectives, many governments provide incentives for investment in low-carbon technologies or for consumption of goods and services that are produced by such technologies. These incentives can be direct subsidies, such as for R&D into carbon capture and storage, tax breaks, such as for purchase of electric vehicles, or para-fiscal instruments such as feed-in tariffs, for example for roof-top solar.

Investment subsidies are often found to be regressive, because only companies or high-income households have the capital to invest in new low-carbon assets.

Early evidence from West (2004) showed that subsidies for new vehicles are more regressive than taxes on gasoline. By comparing a gasoline tax to a new vehicle subsidy in California, she found that the gasoline tax (or equivalently the mileage tax) was only regressive above a certain income level. This is because many low-income households do not own vehicles and, in response to a price increase, lower-income households reduce miles by more than wealthy households. The subsidy, on the other hand primarily benefits high-income households that buy new cars. Therefore, the subsidy had more negative distributional effects than the gasoline tax.

Grösche and Schröder (2014) analysed the German feed-in tariff system, which uses a levy on electricity consumption to subsidise households' use of solar panels. They found that the tariff was regressive, but only mildly so.

In 2016, Germany implemented a €4,000 subsidy for the purchase of electric vehicles. The subsidy is financed through increased fuel prices. Tovar Reaños and Sommerfeld (2018) showed that the subsidy is regressive and resulted in a greater welfare loss for lower-income households. The reason for this is that only higher-income households benefited from the subsidy because lower-income households would not buy an expensive new electric vehicle even if subsidised.

The same probably holds true for tax breaks and preferential loans for energy efficiency investments in the building sector, which will mainly benefit the typically higher-income households that own a house and can afford to modernise it.

In essence, many low-carbon subsidies are regressive because they reduce the price of goods that are primarily bought by higher-income households. Subsidising clean vehicles, for instance, benefits those who can afford to buy the vehicles, while the less affluent gain little[36].

2.4 Public investment

Another support scheme for low-carbon technologies is direct investment by governments in low-carbon technologies or

---

[36] In Norway, where electric cars make up one third of the car market, there is a debate on the nature of the incentives for electric vehicles. Reportedly they primarily helped wealthy people who could afford to buy an electric car as a second vehicle. See Milne (2017) 'Reality of subsidies drives Norway's electric car dream', Financial Times, retrieved from https://www.ft.com/content/84e54440-3bc4-11e7-821a-6027b8a20f23.

complementary infrastructure, such as public transport or charging infrastructure for electric vehicles. The literature on the distributional effects of such investment in developed countries is scarce. However, for developing countries, several studies indicate that public investment can reduce inequality.

Dercon (2014) examined public investment in developing countries and discussed its likely impact on low-income households. One policy he discusses is moving investment away from long-distance transport and allocating it to local development. According to Dercon, this could hurt marginalised communities because they might lose access to cheaper products they consume and markets for their local products. This indicates that the distributional impact depends on both the details of the particular investment project and the economic context. It is, for example, quite conceivable that increasing spending on urban transport at the expense of spending on long-distance transport could have the reverse effect to that found by Dercon (2014) in countries with different spatial settings.

In an International Monetary Fund report, Furceri and Li (2017) found that increased public investment reduces income inequality. However, the effect of public investment on inequality depends on whether infrastructure generates productivity gains only in the sector involved or also in other sectors. The authors concluded that public investment improves the income distribution and also has positive macroeconomic consequences, such as raising output and crowding-in private investment.

Evidence from De Ferranti *et al* (2004), Fan and Zhang (2004) and Calderón and Servén (2004) from China and Latin America, suggests that public investment in infrastructure such as roads, dams, and telecommunications has contributed toward the alleviation of inequality and poverty.

By contrast, Chatterjee and Turnovsky (2012) found that while government spending on public capital leads to a persistent increase in wealth inequality in terms of income dispersion, it also increases growth and average welfare. Furthermore, access to paved roads has had limited distributional benefits in rural Bangladesh, according to Khandker and Koolwal (2007).

To summarise, the distributional consequences of public investment depend on several factors. Investment that disproportionately benefits high-income households can exacerbate inequalities. However, there is also a need to consider the indirect benefits of the investment. If the investment is 'productive' and generates spill-over benefits for low-income households, the adverse distributional consequences can be mitigated. Finally, the way in which the investment is financed matters. A tax on capital can mean that high-income households pay relatively more for the investment. On the other hand, if the investment is financed by a tax on goods consumed relatively more by low-income households, it would be more likely to be regressive.

2.5 Trade policy

Around 22 percent of global CO2 emissions stem from the consumption of goods that are produced in another country (Peters *et al*, 2012). Using 2004 trade data, Davis and Caldeira (2010) furthermore found evidence of substantial CO2 flows from China into the US, Europe and Japan. Moreover, in that year, the US was a net exporter of CO2 to Europe, with the CO2 intensity of its exports exceeding that of its imports.

Trade policy is a decarbonisation instrument that is not massively used at present, though it has been widely discussed. Countries could impose trade restrictions to reduce imports from countries with less-stringent climate policies[37]. The rationale would be: (1) to avoid placing domestic producers, which must abide by stricter environmental regulation, at a competitive disadvantage, since this could lead them to relocate their production activities abroad; and (2)

[37] This might come in different forms. A very imprecise tool would be to not enter into trade agreements with countries that did not join (or do not comply) with the Paris Agreement. A much more sophisticated approach are so-called carbon border adjustments, where the carbon content of imported goods falls under an import tariff or consumption tax.

to encourage trading partners to reduce emissions. Alternatively, countries can promote decarbonisation by reducing trade restrictions on environmentally friendly goods[38].

The distributional impact of a tariff on carbon-intensive foreign products will on the expenditure side behave like a carbon tax. That is, consumers who spend a disproportionate share of their income on these imported carbon-intensive goods will be adversely affected, with the effect being stronger when there are no inexpensive substitutes. The issue is complicated by the fact that many carbon-intensive products are not directly consumed, but are intermediate goods (such as metallurgic and chemical products and cement), used in the production of final consumer goods. The distributional effect on the expenditure side will be shaped by the design of the policy, in particular the size of the tariffs on individual import goods[39].

Analysing trade data from 40 countries, Fajgelbaum and Khandelwal (2016) showed that low-income households gain most from trade on the expenditure side. Thus, if trade is restricted or limited, low-income households are also hurt the most. This is because, in the 2005-07 data used by Fajgelbaum and Khandelwal, low-income households spend a larger fraction of their income on goods that are likely traded. On the other hand, high-income households spend more on services, which are often produced domestically. Therefore, when trade is reduced, the consumption baskets of low-income households are more strongly affected.

On the income side, the owners of production factors that are required to produce substitutes for carbon-intensive imports will see their corresponding income increase. It is not only capital owners who might benefit from such protection; labour employed in these sectors might also benefit. New evidence seems to confirm that trade barriers

---

[38] Since July 2014, several members of the World Trade Organisation have been negotiating an Environmental Goods Agreement to remove barriers to trade in goods that are crucial for environmental protection and climate change mitigation.
[39] Design elements include differentiation by good and/or country of origin and if there are exemptions.

reduce the wage-premium for high-skilled labour[40]. The benefits for capital owners might be even greater in sectors where locking out foreign competitors enables individual domestic firms to assume dominant positions. Such firms can translate their newly acquired market power into mark-ups which would transfer wealth from consumers to these firms (and their owners). Without a proper quantitative analysis of a concrete policy proposal it is not possible to establish whether the gains of low-skilled workers in now-protected sectors or the gains of the corresponding capital owners will dominate.

Finally, the government can redistribute import tariff income either in a progressive or regressive way – dampening or exacerbating the initial distributional effect.

Table 5: Stylised distributional effects of trade barriers

	Low income	High income
Relative consumption expenditures	↑ (consumes more foreign products)	↓ (consumes more domestic services)
Wage-premium	↑	↓ (skill becomes relatively less scarce)
Capital income	↔ (has none)	↑ (less competition increases mark-up)
Redistribution of tariff income	↕ (depends on policy)	↕ (depends on policy)

Source: Bruegel. Note: Trade barrier improves/deteriorates relative welfare of this group along this channel.

[40] For across-the-board trade barriers, Borusyak and Jaravel (2018) argued that the college wage-premium is reduced by trade barriers. According to their analysis, college graduates work in industries that: (1) are less exposed to import competition; (2) export more; (3) are more income elastic; and (4) use fewer imported inputs. They find that a 10 percent increase in all import and export barriers generates a modest reduction in inequality between education groups. Welfare losses are 16 percent higher for college graduates than for individuals without a college degree.

The distributional impact of general trade barriers depends on the relative size of several individual effects (Table 5 shows some of them) that have not yet been unambiguously quantified. Accordingly, the distributional impact of trade barriers specifically on high-carbon products – that should follow the same general mechanics – is also unclear. But it is likely that, in the absence of compensation through revenue recycling, the regressive effects will dominate.

2.6 Standards

In our context, standards are mandates or regulations that discourage or ban products that do not meet certain characteristics, such as products that have too-high energy consumption or emissions. For example, the corporate average fuel economy (CAFE), discussed below, is a set of US and European standards for automobile fleet fuel efficiency.

Economists have long argued that taxes are more efficient than standards in reducing vehicle emissions (Levinson, 2016). Jacobsen (2013) found that the US fuel efficiency standards cost three to ten times as much as a gasoline tax per ton of carbon dioxide avoided. At a first glance, the US CAFE standard on new vehicles seems progressive, since the high-income buy more new cars and thus bear a heavier burden (Davis and Knittel, 2016). However, if one considers the impact on used vehicles, the standard can become regressive (Davis and Knittel, 2016; Jacobsen, 2013). Fleet standards encourage producers to ask for higher prices for less-efficient cars and to reduce the prices for more efficient cars, in order to meet their fleet standards. The price increase for less efficient cars trickles down to the second-hand market. Hence, the standard constitutes an implicit tax on cars that are preferred by less-wealthy households. By contrast, standards can be seen as subsidies on efficient cars as producers reduce their prices to sell more of them in order to reduce their fleet-average emissions in order to be allowed to sell more-polluting cars (Levinson, 2016).

There is also evidence that standards can be regressive even if they do not apply to used products. According to Levinson (2016), it is rational for high-income households to buy more expensive, energy efficient cars and for low-income households to buy less efficient cars – even if discount rates[41] are the same. As high-income households drive more, an energy-efficient car saves them a lot of energy and money over time. Low-income households, by contrast, might prefer a car that is cheaper up-front because they drive less. This suggests that wealthy households benefit more from vehicle energy standards because they have a stronger preference for efficient cars.

Standards for furnace fans[42] have also fallen under academic scrutiny. In a US Department of Energy cost-benefit analysis of furnace fan standards, the standards' benefits were found to outweigh their costs (DoE, 2014). However, Miller (2015) argued that the assumption of low and uniform discounting rate for all households is unrealistic. Low-income households tend to have higher discount rates because they place relatively more emphasis on present, as opposed to future, consumption[43]. A subsequent analysis by Miller (2015) argued that the costs of the furnace fan standards were greater than the benefits, and that the standards were regressive.

Beyond automotive or furnace fan standards, standards might in fact be regressive in all sectors – vehicles, household appliances and construction – according to Levinson (2016), and more regressive than carbon prices. This is because standards: (1) fall more heavily on less-frequent users (who often have higher incomes); and (2) do not allow for progressive revenue recycling schemes.

---

[41] See section 2.1 for a more detailed discussion of discount rates.
[42] Furnace fans use electricity to circulate air heated by the furnace into the living space.
[43] Quote from Miller (2015): *"only high-income households are adequately represented by a 3 percent discount rate, the rate DOE uses to calculate the benefits of energy efficiency standards. Even median-income US households have significantly higher discount rates of 27 percent for the purchase of energy-using durables, such as furnace fans (Hausman 1979, 53). It is worth noting that consumers reveal lower discount rates for air conditioners than for other energy-using durables such as furnaces (Ruderman et al, 1987, 114), meaning that median- and low-income households may have even higher discount rates for furnace fans than those found in Hausman's analysis"*.

Although much of the literature shows that efficiency standards are regressive, there are a few caveats. First, many studies do not account for the long-term effects of efficiency standards. For example, standards push engineers from various industries to innovate. Second, especially in developing countries, some governments find it very difficult to collect taxes while standards might be easier to enforce (Fullerton and Muehlegger, 2017).

2.7 Agriculture

Agriculture is, after the energy sector, the second largest emitter of greenhouse gases, accounting for about 10 percent of total global emissions in 2014[44]. Thus, decarbonisation policies will likely target the agricultural sector in the future. Beyond the direct cost impact of emissions reductions in agriculture, decarbonisation policies in other sectors might also substantially affect food prices. The production of biofuels can increase crop prices, though the range of estimates in the literature is wide[45]. Higher crop prices, in turn, lead to higher food prices. If, for example, bioenergy with carbon capture and storage and land-use based negative-emission technologies become key pillars of global decarbonisation, food prices might increase.

The highest-income households (top-fifth) only spend 19 percent[46] more on food than the lowest-income households (bottom-fifth), while their overall equivalent disposable income is more than 150 percent higher[47]. Hence, higher food costs arising from climate policies might affect low-income households relatively more than high-income households.

---

[44] Calculated manually using data from the CAIT Climate Data Explorer of the World Resources Institute, available at: http://cait.wri.org.

[45] https://www.epa.gov/environmental-economics/economics-biofuels.

[46] Calculated manually using data from the UK government *Family Food* 2016/17 survey, available at https://www.gov.uk/government/statistics/family-food-201617.

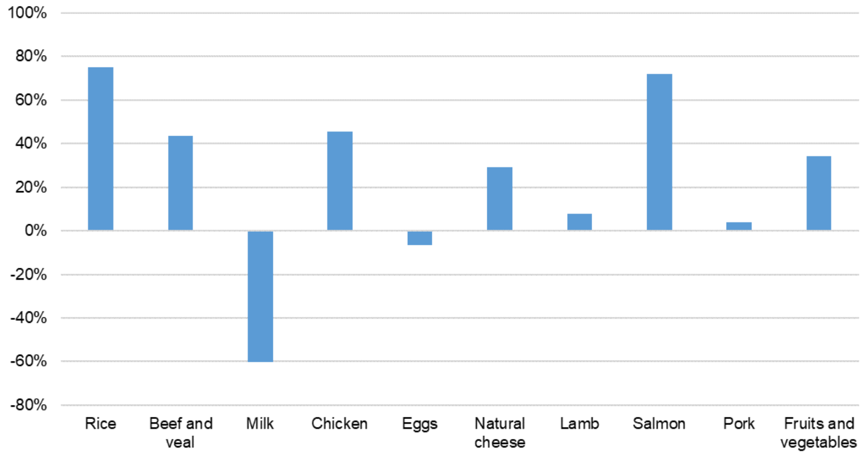
[47] Calculated manually using data from the UK Office for National Statistics, available at: https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/datasets/householddisposableincomeandinequality.

However, food preferences differ and climate policies will affect prices of various agricultural products differently. Carbon-intensive food products will likely become disproportionately more expensive when agricultural emissions are regulated[48]. For example, the greenhouse gas emissions that can be attributed to the production of one kilogram of beef can be up to 70 kilograms of CO2 equivalent (Opio *et al*, 2013)[49]. At a beef price of $4 per kilogram[50], a carbon price of $30 /tonne would thus increase beef prices by 7 percent. For vegetables, the effect of an equivalent carbon price would be barely noticeable.

In theory, this could have distributional implications because low and high-income households do not spend the same amount on all food products. This is shown in Figure 10, which compares the difference in expenditure for various food items of the highest-income households compared to the lowest-income households in the UK. The high-income households spend an additional 40 percent or more on rice, salmon, chicken and beef, while the low-income households spend more on milk.

[48] And land-intensive food products might become disproportionately more expensive when land demand increases because of land-use based decarbonisation approaches (such as biofuels or reforestation).
[49] Other studies find significantly lower values. A study for Canada (Desjardins *et al*, 2012) estimated less than 20 kilograms of CO2 equivalent per kilogram of beef.
[50] https://www.statista.com/statistics/675826/average-prices-meat-beef-worldwide/.

Figure 10: Differences in expenditure on food items by the richest relative to the poorest UK households

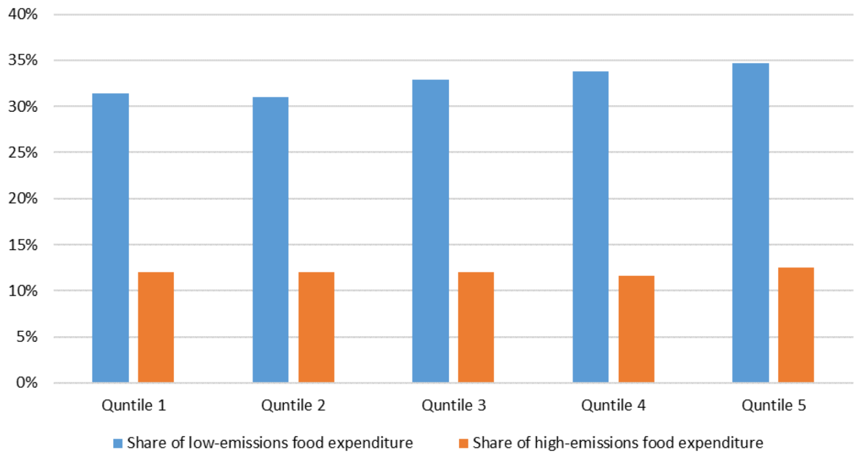


Source: Bruegel based on the Family Food 2016/17 survey of the United Kingdom (see Government of the United Kingdom, 2018). Note: The 'highest-income households' and 'lowest-income households' are those in income quintiles one and five respectively in the Family Food survey. The food items in the figure correspond to the categories in the Family Food survey as listed in Table B in the Annex.

In view of the price differences for some food items, a key question is how various consumer groups will be affected by changes in food prices resulting from climate policies. One hypothesis is that food prices will change differently for various consumer groups, meaning that some households might pay much more for food because of climate policies.

Figure 11 shows the shares of total expenditure on food that goes to food with low and high-carbon content per kilogramme for UK households. High-income households spend greater shares of their income compared to low-income households on low-emission food. However, low and high-income households spend equal proportions on high-emission food. This suggests that a carbon tax on food would not affect low and high-income households very differently.

Figure 11: Shares of low- and high-emissions food in total food expenditure, by household income quintile



Source: Bruegel based on the Family Food 2016/17 survey of the United Kingdom (see Government of the United Kingdom, 2018), FAOSTAT, and Hamerschlag and Venkat (2011). Note: The total expenditure used to calculate the shares in the figure correspond to the category 'Purchases for household supplies - Food and drink, excluding soft drinks, alcoholic drinks and confectionery' in the Family Food survey. 'Low-emissions food' comprises 'Rice', 'Milk', 'Chicken', 'Eggs', and 'Fruits and vegetables'. 'High emissions-food' are 'Beef and veal', 'Natural cheese', 'Lamb', 'Salmon', and 'Pork'. The authors grouped the food items into the two emissions categories based on their CO2 intensity (i.e. the kg CO2eq/kg product). Data on CO2 intensity were sourced for all food items except 'Fruits and vegetables' from FAOSTAT and Hamerschlag and Venkat (2011). CO2 intensity data for 'Fruits and vegetables' were unavailable and thus, this item was assumed to contain a low share of CO2. The food item names differed in the Family Food survey from the emissions intensity data sources, and thus had to be reconciled (see Table B in the Annex for the names in the sources).

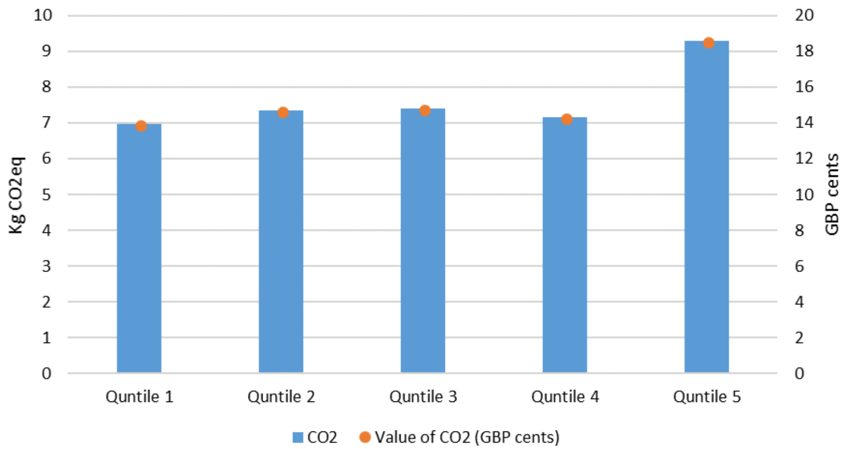
A limitation of Figure 11 is that it groups food items by their emissions intensity, and not by the carbon content of the food quantity actually consumed. If high-emission food is consumed in smaller amounts, total emissions from these food items might be small, even though their carbon intensity in CO2/kg is high.

To overcome this limitation, we calculated[51] the quantities consumed of most food items[52] by each household type, and multiplied the food quantities by the emissions intensity of each food item. Aggregating across all food items gives the total CO2 content in weekly food consumption per household type (blue bars in Figure 12). High-income households account for more carbon content in their food than low-income households. Multiplying the carbon content by an assumed carbon price of £20 per tonne gives the value of the carbon content (orange dots in Figure 12), which is naturally also higher for the high-income households.

[51] The quantity consumed of each food item was calculated as follows: data for 2017 on the weight (in kilograms) and trade value (in US dollars) of UK food imports were sourced from UN Comtrade. The trade value of the imports was converted into GBP (using an exchange rate of £1: $1.32357) and divided by the weight of the imports. This gives the price (in GBP) per kilogram for each imported food item. Because the imported food items do not correspond perfectly to the food items in Figure 10, we took a weighted average of the price/kg of the food items from UN Comtrade that relate to each food item in Figure 10 (see Table C in the Annex for the HS codes of the food items used from UN Comtrade). The resulting price/kg for the food items in Figure 4 was divided by the weekly expenditure amounts on each food item by each household quintile. This gave the average quantity of CO2 contained in the consumption of each food item by each household quintile. Summing up across all food items gives the quantity of CO2 contained in the weekly consumption of all food items by each household quintile.

[52] We do this for all food items in Figure 10 except for ‘Fruits and vegetables’, due to a lack of CO2 intensity data for this item.

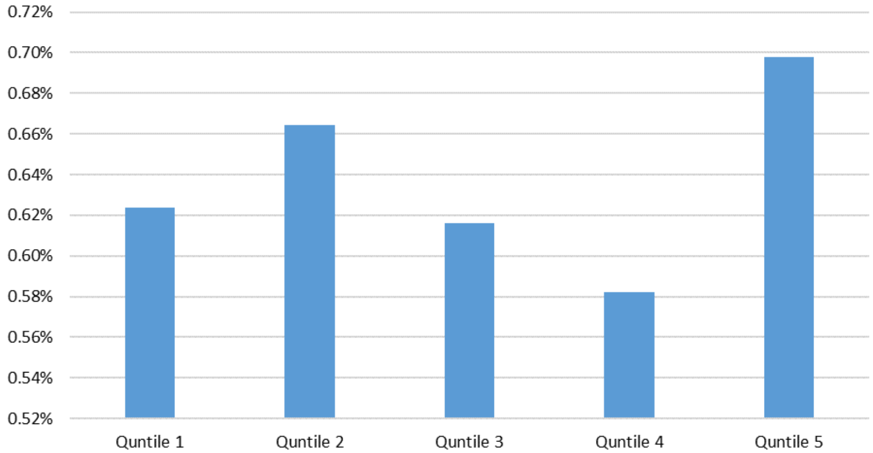
Figure 12: CO2 content in weekly consumption of selected food items by household income quintile



Source: Bruegel based on the Family Food 2016/17 survey of the United Kingdom (see Government of the United Kingdom, 2018), FAOSTAT, Hamerschlag and Venkat (2011), and UN Comtrade. Note: The value of the CO2 content is calculated assuming a carbon price of GBP 20 per tonne. See footnote 16 for a description of the methodology.

However, the higher carbon content of the food consumed by higher-income households is largely driven by higher overall expenditures on food. If we examine the share of carbon value in total food expenditure of each household type (Figure 13), the shares are similar for all household types. The figure suggests that for each pound spent on food, high-income households generate as much CO2 as low-income households. So, while the general climate-policy induced increase in food prices is regressive, the differentiated effects of climate policy on the cost of different food items, in our example, neither reduce nor exacerbate these distributional effects.

Figure 13: Share of the value of food CO2 content in total food expenditure by household income quintile



Source: Bruegel based on the Family Food 2016/17 survey of the United Kingdom (see Government of the United Kingdom, 2018), FAOSTAT, Hamerschlag and Venkat (2011), and UN Comtrade.

It is clear, however, that the results from this simple analysis should be interpreted with caution. The distributional effect of regulating emissions from agriculture has received little attention in the literature, and more research is needed on this topic. The agricultural sector will be significantly impacted by both climate change and climate policies, which makes it essential for policymakers to understand the distributional impacts (if any). A more advanced analysis than ours would therefore be valuable.

2.8 The effect of climate policy on land values

Climate policies might not only impact the value of coal mines and internal combustion engine patents, but also that of land. Land is a major asset class primarily owned by high-income households. For example, for Germany, Stölzel and Fischer (2018) estimated the value of all land at €5.5 trillion, or more than twice as much as the market capitalisation of all listed companies in Germany (less than €2 trillion in 2017 according to Statista, 2018). Therefore, increases in land prices might be regressive.

2.8.1 Increased land value due to land-demand from renewables

Both, Carrosio (2013) and Bartoli *et al* (2016) argued that subsidies for maize-fuelled biogas power plants led to a rise in agricultural land prices in Italy before a policy change in 2013 that shifted incentives towards manure. Nonhebel (2005) showed that biomass energy is the most land-intensive of the renewable energy options. She claimed that energy supply from biomass is not compatible with food supply because of land availability constraints.

Blanco Foncesca *et al* (2010) modelled the effect of the EU 2020 biofuel target on agricultural land use. They found that the target of 10 percent renewable transport fuel by 2020 would increase agricultural land use in the EU by 0.3-0.7 million hectares (less than 0.1 percent of total utilised agricultural area in the EU) and global land use by 5.2 million hectares (0.7 percent of the global total), compared to the reference scenario. However, under both the reference scenario and the policy scenario, land use in the EU is projected to decline. A study by UNCTAD (2009, p. 44ff) presented global scenarios for the year 2100 where 30 percent of energy demand is met by bioenergy and land area used for biomass production is equivalent to 44 percent of current agricultural land use in the case without specific climate policies, and 63 percent in case of enacted climate policies that aim to stabilise atmospheric greenhouse gases. However, because of relatively inelastic demand for food, the biomass area will mainly replace pasture, and the global crop area would not in either scenario be greatly affected by biomass expansion.

More recent studies have projected low impacts on competition for land because second-generation biofuel technologies use waste and by-products from food crop production to produce biofuel, and because policies are increasingly designed to support the type of biofuel production that has the least impact on land competition (International Energy Agency, 2017b).

Evans *et al* (2009) said that “renewable energy technologies are often claimed to compete with agriculturally arable land”. They ranked photovoltaics ahead of geothermal, wind and hydro power in terms of intensity of land use.

2.8.2 Increased land value due to reduction in air and noise pollution

Chiarazzo *et al* (2014) studied the impact of environmental quality on house prices in urban areas. They find that noise levels are negatively correlated with real estate values (and that coefficient is statistically significant in their econometric model). Furthermore, they find that in regions where air pollution is perceived as a dangerous issue (because of the level of air pollution in some areas), air quality has a negative effect on property prices.

Employing a more sophisticated approach Bajari *et al* (2012) found relatively large and statistically significant negative effects of air pollution measures on house prices in the California Bay Area between 1990 and 2006. As air pollution was reduced during that period, this can be interpreted as a proxy for consumers' willingness to pay for increased air quality.

Thus, decarbonisation might make cheap polluted land into more expensive less-polluted land. But this will increase the availability of less-polluted land and hence bring down the high mark-up of such land. Reducing pollution might therefore even reduce average land prices.

On the other hand, it has been argued that wind turbines in particular have adverse effects on residential property values. Vyn (2018) explored differences between municipalities that are opposed to wind energy developments and others that are not opposed. He finds that "wind turbines have negatively impacted property values in 'unwilling host' municipalities, while no significant impacts are found in unopposed municipalities".

On aggregate it is likely that climate policies will significantly increase the value of land. But we are not aware of studies that analyse either the size of this effect or its distributional impacts.

2.9 Macro and labour market effects

2.9.1 Aggregate macro effect of climate policies

The macroeconomic effects of climate policies on inequality are very complex and their net effect is quite difficult to determine.

From a theoretical perspective, a massive increase in capital expenditure resulting from a quick greening of the economy and of its capital stock would have a positive direct impact on GDP. However, it could also indirectly increase interest rates, which could in turn crowd out other investments and thus negatively affect GDP and employment. For instance, Förster *et al* (2012a and 2012b) estimated that successfully reducing EU greenhouse gas emissions until 2050 would require investment equivalent to around 1.5 percent of EU GDP per year. This number needs to be compared with the current annual level of investment across the EU, which is around 19 percent of GDP. However, given the secular decline in the level of interest rates across the world, the current level of unused resources and the low level of capital expenditure since the Great Recession, this potential crowding out effect of climate policies on GDP should not be overstated, at least in the near future. More generally, most simulations available in the literature consider that the effects via the interest rate channel would be limited (also because the effect should be moderated by the reduced investment in brown energies and because it should be compensated for by the direct effect on GDP of increased investment in clean technologies).

Climate policies (such as higher taxes on energy, or measures to promote energy efficiency) should result in a change in patterns of consumption of energy and of energy-intensive goods. This reduced consumption of energy (as a share of income) might lead to an increase in spending in other sectors which could have the opposite effect and boost GDP and employment in non-energy sectors, which could lead to structural shifts in the economy. In specific sectors that are capital rather than labour intensive, such as energy generation, there could be a potential positive substitution effect as imported energy (ie oil, gas and coal) would be replaced by locally-produced renewable energy. This would have an aggregate positive impact on domestic GDP and employment. In addition, measures intended to increase energy efficiency (in buildings for example) are generally labour intensive and could provide a boost to local labour markets.

Overall, given these various conflicting channels, the aggregate effect of climate policies is difficult to estimate precisely. Nevertheless, multiple attempts have been made in the literature, using diverse methodologies. Depending on the modelling strategies, the net effect estimated in the literature ranges from slightly negative to significantly positive. Simulations suggest overall modest aggregate effects on GDP and net employment. For instance, Cambridge Econometrics (2013) estimated that the 2050 Energy Road Map (European Commission, 2011) – setting out a reduction in CO2 emissions of 80-90 percent from 1990 levels – would increase employment by between zero and 1.5 percent compared to a continuation of current policies. The effects on GDP would be minor however. One model (GEM-E3) predicts an additional increase in GDP of 2 percent to 3 percent by 2050 on top of the baseline increase of 85 percent, whereas another model (E3ME) predicts a reduction in GDP of 1 percent to 2 percent.

These insights from modelling exercises are confirmed by case studies and empirical analyses. For instance, Markandya *et al* (2016) looked at the employment impact of the EU climate policies implemented from 1995 and 2009, and found that they have resulted overall in a net increase in employment in the EU of 0.24 percent – a positive but very small number. Even though the policies that will have to be implemented in the next decades to fight global warming effectively need to be more forceful than those put in place so far, these numbers are compatible with the predictions obtained through the modelling exercises discussed before.

2.9.2 Effects of climate policies on labour markets

However, what matters more for the distributional impact of climate policies is that, although the aggregate macro effects on GDP or on net employment might be small or even negligible, the distributional effects through labour market changes might be much greater. Again, we will describe the different channels from a theoretical perspective and try to quantify these changes using the literature on this issue.

Even if the net effect on total employment is small, there could be greater distributional effects: 1) from a sectoral perspective, because some sectors will be more affected than others by climate policies; 2) from a skills perspective, as low-skills brown jobs could be replaced by medium- to high-skilled green jobs; and 3) from a spatial perspective, because jobs at the local level could be displaced as a result of structural changes in the economy resulting from climate policies.

There will be winners and losers from a sectoral point of view. Jobs should increase in some sectors as a result of climate policies and the decarbonisation of the economy. This should clearly be the case in the renewable energy sector, which should see the creation of jobs on a permanent basis for the maintenance and operation of renewable technologies. This could also be the case in the agriculture sector if biofuels/biomass technologies play an important role in the decarbonisation process. In addition to permanent jobs, a significant number of jobs should also be created during the transition in the manufacturing and installation of new renewable technologies. The transition towards a low-carbon economy should also benefit employment in the construction sector because it will be necessary to implement energy-efficiency standards in housing and in buildings more generally (see for instance BPIE, 2011). In terms of manufacturing, several of the largest companies in the renewable energy sector – in terms of global sales – are based in Europe. This is visible in positive trade balances, especially in the wind turbine manufacturing sector, in which companies based in Denmark, Germany and Spain are amongst the most competitive in the World (Fragkos *et al*, 2017) and are building competitive advantages in these sectors thanks to specialisation that becomes self-reinforcing through a high level of R&D (Kalcik and Zachmann, 2018). If they maintain their comparative advantage, these companies should be able to employ more workers, given the higher demand for these technologies at the global level to fulfil the Paris Agreement objectives.

However, there will be jobs lost in other sectors. This will be particularly the case for power generation using fossil fuels (eg coal mines, fossil-fuel power plants, refineries), but will also affect energy-intensive manufacturing, the transport sector, the equipment sector for fossil fuel technologies, and retail sales of fossil fuels (eg gas stations). Nevertheless, these job destructions should be more than compensated for by the creation of jobs in other sectors. This is the case because the renewable energy sector has higher domestic job content than the fossil-fuel energy sector (Fragkos *et al*, 2017).

Workers' skill levels, and their flexibility, should thus play a crucial role in the transition to a decarbonised economy. Green jobs are very different in terms of skills requirements, wage levels and working conditions, so it is not clear if the transition towards a low-carbon economy will have an impact on the average level of skills needed or on job quality in general (see for instance European Foundation for the Improvement of Living and Working Conditions, 2012). However, jobs will be reallocated within sectors, as some emerging occupations will demand new educational requirements. For instance, in the motor vehicles industry, the move towards electric and hybrid vehicles, combined with the increased sophistication of cars, is likely to lead to an increased demand for workers with medium to high skills, such as software or electrical engineers. In the construction sector, however, there should be increasing demand for low-skilled workers to renovate buildings. Nevertheless, even if, in that case, low-skilled jobs are created, some reallocation of workers will take place and some retraining of the workforce might be necessary, given that the skills needed to make buildings energy-efficient tend to be quite specific.

From a spatial point of view, brown jobs destroyed tend to be concentrated in certain areas, such as around production site. For example, phasing out coal in Europe – and in particular coal mining – would lead to direct job losses in this sector. As suggested by Tagliapietra (2017), the issue would not be substantial on aggregate: the EU country with the highest number of coal mining jobs is Poland, with only around 115,500 people employed in coal mines and related businesses; second is Germany with only 27,075 people working in this sector. However, these jobs are heavily concentrated (for instance in Silesia, where they still represent 5 percent of employment) and therefore the negative effects at the local level could be significant from the economic and political perspectives, and would need to be taken into account by public authorities.

In practice, these factors mean climate policies will have varying effects on the workforce. Overall, model-based predictions suggest that the transition to a low-carbon economy should lead to a reallocation of 1.3 percent of EU jobs by 2050 (Fragkos and Paroussos, 2018, using the GEM-E3 model). This is not negligible, but it is not an exceptional number either, especially if you compare it with the total job reallocation expected during this period for other reasons (for comparison, between 1995 and 2005, the amount of job reallocation in OECD countries amounted to 20 percent of employment; see OECD, 2017). However, given the specific nature of the skills needed, combined with the EU's low labour mobility, between sectors and between geographical areas, the transition could result in severe bottlenecks in the economy, which could lead to transitional unemployment and to unfilled vacancies. This effect is, however, difficult to quantify because the general equilibrium models used in this field generally assume that jobs are immediately filled and that there are no frictions in job transitions.

3 CASE STUDIES

In the previous section, we mainly discussed the distributional impacts of climate policies as stand-alone interventions in 'laboratory' conditions. And even under such idealised conditions, the results were complex and often ambiguous. But real-world climate policies are almost never the simple interventions assumed in economic models. Policies – such as renewables support schemes or emissions trading schemes – contain hundreds of complex provisions and exemptions and they happen in a complex world characterised by overlapping policies and policy objectives.

In order to illustrate some aspects of the distributional effects of current climate policies, we provide case studies on two main elements of EU climate policy:

(1) The design of the electricity market, and

(2) The EU emissions trading system (ETS).

Climate policies are rapidly transforming the electricity sector. Electrification of transport and heating is expected to result in greater electricity demand, while decarbonisation of the electricity sector will require a system that reliably accommodates very high shares of electricity from wind, solar and other renewable sources. Already today, market design choices have a substantial impact on consumers. In Germany alone, explicit support programmes for renewable energies cost consumers €24 billion in 2017 (Bundesministerium für Wirtschaft und Energie , 2017).

The EU emissions trading system is a key policy tool to reduce greenhouse gas emissions from industrial firms and utilities. It is the world's largest cap-and-trade system and a model for other greenhouse gas emissions trading systems. The 2017 turnover of the ETS was about €10 billion[53].

---

[53] 1.8 billion allowances used in 2017 multiplied by an average price of €5.7 per allowance.

3.1 Case study: electricity market design

Investment and operation decisions in many sectors that need to decarbonise are strongly driven by regulatory decisions. High-emitting sectors such as the energy and transport sectors are heavily regulated. In Europe, complex rules were established to allow competing companies to offer electricity, gas, postal services or rail transportation to final consumers[54]. However, the incentives these companies have to invest are largely shaped by administratively-set sector rules. We will focus here on the electricity sector, as electricity is assumed to play a key role in decarbonisation.

It is likely that power generation will be largely decarbonised by the middle of the century, while heat and transport might be electrified. To do this in an efficient way, electricity sector regulation will matter a lot, as investment and operational decisions in this sector are strongly driven by regulatory decisions. For example, energy regulators have to approve the investment programmes of electricity network operators and decide on these projects' rates of return. Meanwhile, power-generation companies, for example, base their investment and operational decisions on an administratively-established market design. This market design sets requirements for products and the market participants that are allowed to buy and sell them. For example, capacity markets might require the transmission system operator to procure the right to ask for additional generation from eligible providers[55]. Depending on the detailed rules, these markets favour one solution over another (eg batteries, gas-fired power plants or demand response). Thus, the final price paid by electricity consumers is not the result of simple competition between electricity companies, but rather the outcome of a complex mixture of regulated payment streams to different participants.

---

[54] Those rules were necessary as these sectors are network industries with a natural tendency towards monopolisation.
[55] Some regulatory decisions reduce competition (eg by narrowly defining the technical criteria for capacity-products so that only few companies can provide them), and thus result in higher prices.

3.1.1 Status quo

Currently, the rules governing the functioning of the electricity sector have substantial distributional consequences. This is illustrated by the very different electricity prices paid by different consumer groups in different regions, and by the share of the price that goes to different industrial segments.

Prices for different consumer groups vary widely – depending on national tariff design

Households in the EU typically pay around 76 percent more than industry per kilowatt hour (kWh). Households with low power consumption pay 69 percent more per kWh than households with high power consumption (Table 6). There is some economic rationale for this. Industrial consumers are easier to serve, as they do not require low-voltage connections and have less-volatile load profiles. In addition, the share of the fixed-cost components (network connection, metering and billing) is relatively greater for low-consumption households.

However, the role of market design in distributing costs between various consumer groups also matters, as illustrated by the different ratios in different EU countries (Table 6, column 1). While households pay less than industrial consumers per kWh in Malta, they pay 50 percent more than industrial consumers in Italy, twice as much in Austria and more than three times as much in Denmark.

The difference in retail tariffs for typical low-income households with low electricity consumption, and typical high-income households with high consumption, is also highly dependent on the market design and differs widely in different countries (Table 6, column 2). While small households (with an annual consumption below 1,000 kWh) pay less per kWh than large households (annual consumption above 15,000 kWh) in Malta, small households pay 68 percent more in Germany, about twice as much in Slovakia and more than three times as much in Spain.

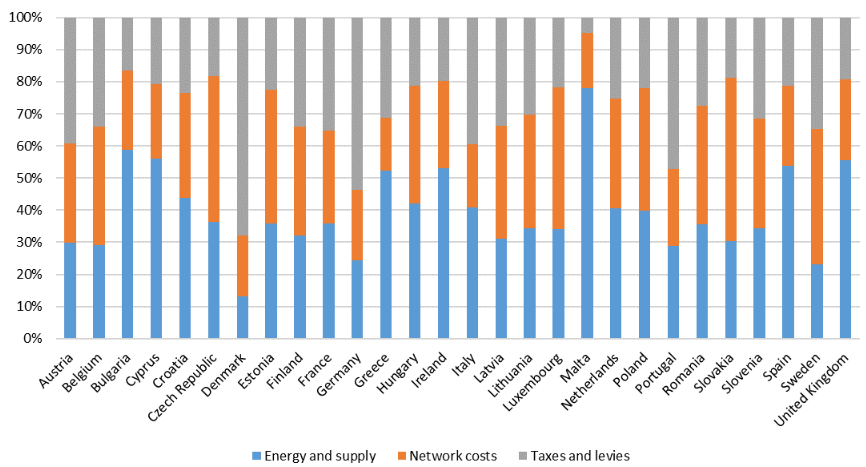
Table 6: Ratio of household to industry retail electricity price (2016 Semester 2; price incl. taxes and levies)

	(1) Medium household/industry	(2) Small household/large household
Austria	2.00	2.47
Belgium	2.37	2.23
Bulgaria	1.19	1.04
Cyprus	1.25	1.20
Croatia	1.52	1.69
Czech Republic	1.94	2.58
Denmark	3.30	1.75
Estonia	1.38	1.16
Finland	2.23	2.81
France	1.89	1.89
Germany	2.00	1.68
Greece	1.55	1.04
Hungary	1.41	1.13
Ireland	1.88	2.67
Italy	1.50	1.20
Latvia	1.35	1.17
Lithuania	1.33	1.14
Luxembourg	1.98	1.60
Malta	0.91	0.92
Netherlands	1.98	1.76
Poland	1.66	1.31
Portugal	2.03	1.83
Romania	1.60	1.08
Slovakia	1.38	2.19
Slovenia	1.96	1.47
Spain	2.22	3.02
Sweden	2.99	2.60
United Kingdom	1.43	1.71
EU average	1.76	1.69

Source: Bruegel based on Eurostat. Notes: Small household = annual consumption below 1,000 kWh; Medium household = annual consumption between 2,500 kWh and 5,000 kWh; Large household = annual consumption above 15,000 kWh; and Industry = annual consumption between 500 and 2,000 MWh.

The stark national differences in the sharing of electricity costs between different consumer groups arise partly from the composition of retail tariffs (Figure 14). There are major differences between countries. Energy and supply cost ranges from 13 percent (Denmark) to 78 percent (Malta). Taxes and levies (eg for renewables) make up more than 50 percent of the price in Denmark and Germany, but less than 20 percent in five countries. The share of network costs is fairly similar for all countries at about 30 percent. That is, in some countries, the unregulated components (energy and supply costs) account for the greatest share of the retail tariff, while in others, the share of the regulated components (taxes and levies) is greater.

Figure 14: Share of each component in the electricity price (medium households, 2016)



Source: Bruegel based on Eurostat.

Regionalisation of electricity prices – a policy choice

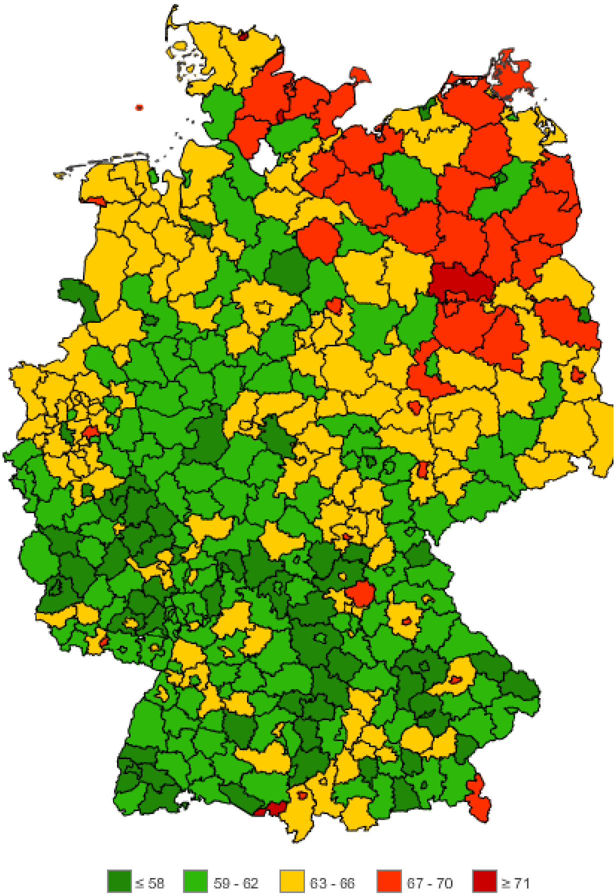
There can be significant regional variation in electricity costs. First, instead of constructing additional transmission lines and incurring transmission losses to bring electricity to distant regions, it is cheaper to use electricity where it is produced. Because of such economic cost considerations, some countries allow wholesale prices to differ by region (eg Italy; see Figure 15), while others do not (eg Germany and France).

Second, bringing electricity to households in rural areas is typically costlier than supplying consumers in more densely populated areas. In urban areas, more consumers can be served by a less-extensive network. Consequently, some countries allow different regional retail tariffs (eg Germany; see Figure 16) , while retail prices are similar for all consumers in other EU countries.

Figure 15: Average wholesale electricity price in Italian bidding zones in €/MWh in 2017

Source: Bruegel based on Terna (2017). Note: Wholesale prices shown.

Figure 16: Monthly electricity costs (€) for German households (using the price of the cheapest supplier)



Source: Heidjann (2018). Note: The figure shows the electricity costs per month for 1,437 locations in Germany. The costs are calculated assuming an annual consumption of 3,500 kWh and the price in the beginning of May 2018.

Domestic prices increase faster than industrial prices in Germany

Over the past decade, industry in Germany paid three to four times the wholesale price for electricity, with this ratio remaining largely stable. In the same period, the price paid by households rose from about five times the wholesale price to about eight times the wholesale price (Figure 17). In other words, household prices decoupled more and more from the value of electricity determined by the market, and became more and more driven by higher network costs, taxes and levies.

This finding can be largely explained by the German renewables policy. While households have to pay increasing renewables levies (currently 6.79 eurocents/kWh) and network costs, many industrial consumers are partly exempted from both. At the same time, the increasing feed-in of renewables reduces the wholesale market price for renewables. This again illustrates how market design choices in the electricity sector are already having observable distributional consequences.

Figure 17: Ratio of retail prices to wholesale price for large households (orange) and for large industry (yellow)

Source: Bruegel based on Eurostat and Fraunhofer Institute for Solar Energy Systems ISE (2018). Note: S1 refers to the average price across the first 6 months of the year; S2 refers to the average price across the last 6 months of the year. Large household = annual consumption above 15,000 kWh; and Large industry = annual consumption between 70,000 MWh and 150,000 MWh.

3.1.2 Impact of future climate policies on electricity prices and inequality

The European Commission's EU Reference Scenario 2016 (Capros *et al*, 2016) projects future electricity prices under currently adopted EU climate policies, including the 2020 greenhouse gas emissions reduction and renewable energy targets [56]. The projections are

---

[56] The projections do not take into account the 2030 Energy and Climate policy framework.

undertaken using PRIMES[57] modelling. Average electricity prices are projected to increase by 13 percent between 2010 and 2020 and by around 20 percent by 2050. The burden would be mostly borne by households and services, as their electricity prices increase between 2010 and 2050. Prices for industry, on the other hand, would remain fairly constant, reflecting their base-load profile and the small fraction of grid costs and taxes borne by industry.

Decarbonisation will change the requirements of the electricity system and hence the market arrangements will need to change. A cost-optimal approach can be highly regressive. We could see three trends: (1) connection payments increase; (2) electricity prices become more volatile; and (3) electricity provision might become more decentralised.

(1) Connection payments increase

Higher shares of renewables might lead to lower prices for the energy delivered (ie the kWh), as the system is overbuilt to ensure enough capacity is available when the sun does not shine and the wind does not blow. Hence, most of the time there would be excess generation capacities available, which would translate into low prices for the energy delivered. At the same time, we can expect the capacity part of the bill, ie the monthly connection charge, to go up because renewables require back-up capacities for the time when the wind is not blowing and the sun is not shining. This can either be financed through massive price spikes in times of scarcity (see the next sub-section) or through separate payments for capacity[58]. Capacity payments would typically be charged on the connection fee.

At the same time, higher shares of renewables will require more and smarter electricity networks in order to manage the increasing fluctuations. The network cost should ideally also be put on the connection charge, and not on the energy charge.

[57] PRIMES: Price-Induced Market Equilibrium System.
[58] Both approaches currently exist in parallel in the EU.

This shift from energy to capacity payments can be regressive, especially when the connection fee does not depend on the individual consumer's peak consumption. In this case, high-income households with typically higher electricity consumption and higher peak load would pay the same price as low-income households, with typically lower electricity consumption and lower peak load.

(2) Increasing volatility

With high shares of volatile renewables, the price per MWh on the wholesale market will become more and more volatile. If the market design permits, it would be efficient for this volatility to be passed through to consumers, so that they could respond by adjusting their consumption. But the corresponding investment in a smart meter would only be profitable for households with sufficiently large energy consumption, appliances that can adapt to different price patterns (eg heat pumps) and low time preference – in other words, high-income households. Such households could then benefit from lower prices at specific times by, for example, charging their electric vehicles or generating heating/cooling.

(3) Decentralisation

Some low carbon technologies can be deployed in a very decentralised manner. Rooftop solar[59] and micro-cogeneration plants for electricity generation, thermal energy storage systems and batteries for storage or heat pumps for heating, can all be deployed at small scale. In combination, these technologies allow household or communities to choose how they want to interact with the electricity system (or even to entirely decouple). This can be desirable as more local generation and local flexibility can reduce the need to extend distribution networks.

Network pricing, electricity taxation and specific leverages for renewables in most countries make all households pay depending on

---

[59] According to Ecofys, 73 percent of German installed PV capacity was below 100 kW.

their consumption from the grid. Allowing households that can afford a capital-intensive autonomous system to opt-out from the system – eg through self-consumption that is not subject to taxes, leverages or network costs – will have distributional consequences. Low-income and urban households will have to compensate for this shortfall of income from households that were able to invest in the aforementioned technologies.

(4) Merit-order effect

The shift towards more renewables also has distributional implications arising from the so-called 'merit-order' effect. In wholesale electricity markets, the price is determined by the intersection of the merit-order (supply) and demand curves[60]. As Figure 18 shows for a hypothetical electricity market, the merit-order curve is composed of various energy sources that differ in their production costs. Renewables generate electricity at virtually zero cost while coal and gas power plants are more expensive. The costs of the various technologies are depicted in Figure 18 by the height of the bars. The price is equal to P_1 and is determined by the intersection of the supply and demand curves. All units of electricity that can be produced at a cost below or equal to this price are sold.

Figure 19 shows the effect of increased production from renewables. The supply of electricity increases, shifting the merit-order curve to the right. Because the electricity from the additional renewables is so cheap, the renewables 'crowd out', or replace, more expensive power plants. The associated fall in the price is known as the merit-order effect.

---

[60] The price can be said to equal the cost of supplying the last unit of electricity to meet demand.

Figure 18: A hypothetical wholesale electricity market

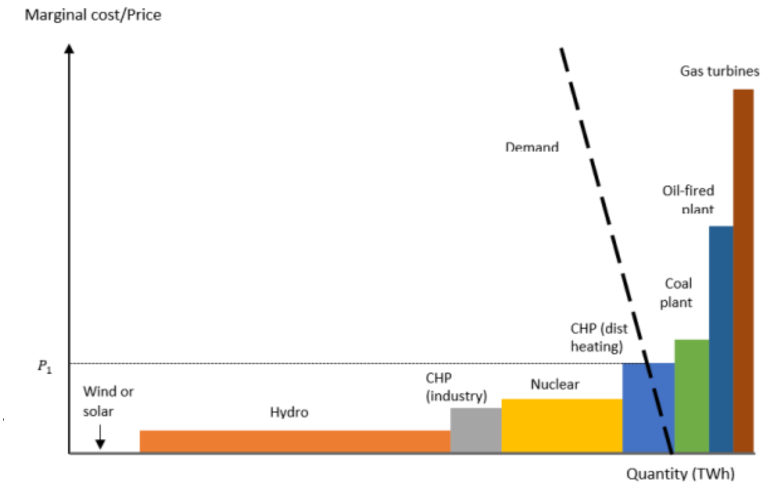
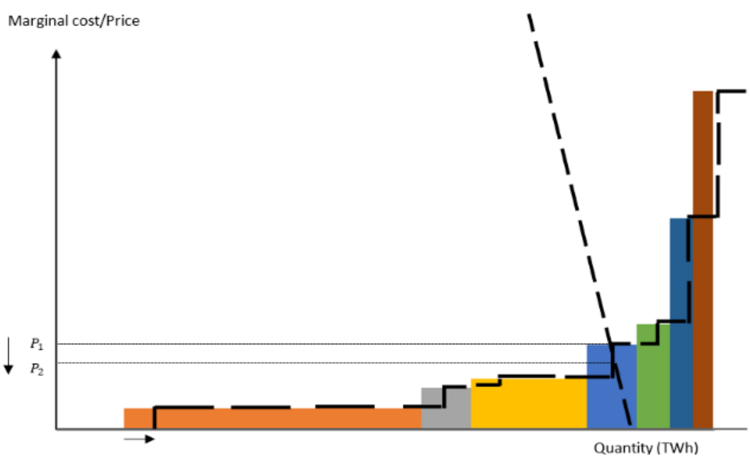


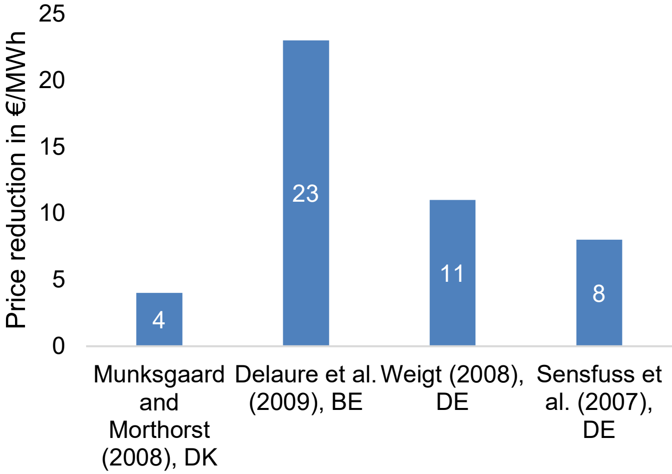
Figure 19: The merit-order effect



Source: Bruegel.

The merit-order effect has been widely observed in practice. Ray *et al* (2010) conducted a literature review on the impact of the increased penetration of wind power in European electricity markets. They concluded that most studies find a negative effect on wholesale prices. Figure 20 is replicated from Ray *et al* (2010) and shows the results of four of the studies.

Figure 20: Empirical findings on the reduction in the wholesale electricity price resulting from an increased supply of wind power in Belgium, Denmark and Germany



Source: Ray *et al* (2010).

Decreasing wholesale prices can translate into lower retail prices for consumers. However, it is unclear whether all consumer classes (eg households, firms) benefit equally. While electricity-intensive firms might pay less, household prices might remain unchanged if households bear the cost of integrating more renewables. This could occur if renewable support schemes are financed through mark-ups on the household price. Electricity-intensive firms, on the other hand, might be exempt from the price mark-up, implying that they pay less for electricity (Cludius, 2015). This suggests that there could be transfers between consumer groups when renewables are added to the electricity mix, as a result of the cost of renewable support schemes being borne solely by households.

Currently, however, such distributional effects are rarely quantified and addressed in the public discourse on regulatory changes.

3.2 Case study: market design of the EU ETS

The EU emissions trading system (EU ETS) is a core component of the EU's climate policy, covering more than 11,000 firms in the European Economic Area (EEA). The design of the EU ETS has a number of distributional implications. In particular, the EU ETS has led to a transfer of wealth from governments and households to the private sector. Below, we provide a brief overview of the EU ETS and then outline three major channels through which wealth has been transmitted. We conclude by summarising the overall distributional impact of the EU ETS and by highlighting the role of governments in redistributing wealth to consumers.

3.2.1 Overview of the EU ETS

Launched in 2005, the EU ETS covers around 45 percent of the EEA's greenhouse gas emissions. Industrial installations and power plants that participate in the EU ETS must surrender an allowance for every tonne of emissions generated. These allowances can be traded among participants, giving firms an incentive to reduce emissions if the allowance price exceeds the marginal abatement cost. A system-wide 'cap' (or limit) is placed on the overall number of allowances in the EU ETS. The cap is reduced over time to reduce total emissions. The EU ETS is currently in its third trading phase (2013-2020) and a fourth phase is scheduled for 2021-2030.

Allowances are distributed in two ways: by auctioning and free allocation. The power sector purchases all of its allowances in auctions, and therefore does not receive any allowances for free. The industrial sector was allocated 80 percent of its allowances for free in 2013; this share is expected to decrease to 30 percent by 2020. However, some industrial installations with significant energy costs receive all of their allowances for free.

The EU ETS has led to a transfer of wealth from governments and households to firms through three channels: creating low-cost allowances based on international projects, the allocation of free allowances and indirect cost compensation for electricity-intensive firms.

3.2.2 Channel 1: Private-sector seigniorage from international credits

Firms in the EU ETS can use international credits for compliance. Firms can obtain these credits either by investing in projects that reduce emissions in developing countries (Clean Development Mechanism credits) or by paying for projects that reduce emissions in other developed countries (Joint Implementation credits). The credits are cheaper than EU ETS allowances and, as such, firms have used them for compliance and sold any excess of freely obtained allowances on the EU ETS market. De Bruyn *et al* (2016) estimated that the availability of cheaper credits was highly beneficial for firms, and increased profits in 15 sectors in 19 EU countries by more than €630 million between 2008 and 2012. However, this possibility has been significantly reduced since 2013. International credits can no longer be used as compliance units in Phase 3 of the EU ETS. Instead, operators must exchange them for EU allowances, up to their individual cap, as set in the registry.

3.2.3 Channel 2: Allocation of free allowances

To safeguard their international competitiveness, manufacturing sectors receive a number of allowances for free, based on a relatively complex allocation scheme. Although free allowances encourage companies to remain in Europe, their issuance has distributional consequences. In particular, over-allocation of free allowances and the pass-through of their value in product prices have generated additional profits for firms at the expense of governments and consumers.

2a) Over-allocation of free allowances

European industry has benefited from the over-allocation of free allowances. Between 2008 and 2014, industrial firms (excluding those burning fuels[61]) received about 3.5 billion allowances for free, although about four-fifths of this amount would have covered their emissions[62]. Firms can sell their surplus allowances at a profit or use them for compliance at a later date. De Bruyn *et al* (2016) estimated that the over-allocation generated additional profits of more than €8 billion from 2008-14. Governments, in turn, have foregone revenue since the surplus allowances could have been auctioned. The over-allocation of free allowances can thus be considered a shift of wealth from governments to firms.

The design of the EU ETS was revised for phase 3 to reduce the over-allocation of free allowances. In contrast to phase 2, for which the allocation was determined by historical emissions, phase 3 uses a benchmarking approach that bases the allocation level on installations' emissions intensity. Efficient installations that generate low emissions relative to their output levels, receive most or all allowances for free, while less-efficient firms must either reduce emissions or purchase some of their allowances. In addition, a 'cross-sectoral correction factor' ensures that the number of free allowances remains below the emissions cap for industrial installations.

2b) Pass-through of the opportunity cost of free allowances

Firms have largely passed through the value of the allowances they used – irrespective of whether they received them for free or had to buy them – into product prices. The rationale is that, for all allowances, firms can sell them on the market or use them to comply with the EU ETS. Economic theory suggests that firms only use free allowances for compliance if they can recover the 'opportunity cost',

---

[61] Firms categorised under 'Combustion of fuels' in the EU Transaction Log, from which the emissions data for the analysis is sourced, are excluded because they comprise electricity producers not receiving any free allowances.
[62] The calculation is based on data from the European Environment Agency's EU ETS data viewer, available at: https://www.eea.europa.eu/data-and-maps/dashboards/emissions-trading-viewer-1.

which is the money foregone from not selling the allowances on the EU ETS market. Firms can recover the opportunity cost by increasing product prices by the market value of their used allowances. The carbon cost[63] would therefore be 'passed-through' into product prices. If such pass-through is possible, the allocation of free allowances can be considered a transfer of wealth from consumers to firms.

In practice, the degree of cost pass-through is considerable. Table 7 shows the estimated pass-through rates in six major sectors covered by the EU ETS, sourced from De Bruyn *et al* (2015). Between 2008 and 2014, about 60 percent of the products investigated by the report had positive pass-through rates. Some firms transmitted more than 100 percent of the carbon costs, implying significant price increases for consumers.

Table 7: Estimated cost-pass through (CPT) rates for various products

Sector	**Product**	**CPT rates from De Bruyn *et al* (2015)***
Cement	Clinker	35-40%
	Portland cement**	90-100%
	Total cement	20-40%
Fertiliser	Fertiliser and nitrogen compounds**	>100%
Glass	Fibre glass	NA
	Hollow and other glass**	40->100%
Iron and steel	Flat products**	55->100%
Petrochemicals	Ethylene	>100%
	Mono ethylene glycol	NA
	Propylene oxide	≈100%

[63] In the case of free allowances, the 'carbon cost' refers to the opportunity cost of the allowances, equal to their market value. This is the price that other firms must pay to acquire a free allowance on the market. Similarly, in the case of auctioned allowances, the 'carbon cost' is the cost of purchasing an allowance at auction.

	Propylene glycol ether Methanol, Butadiene, Propylene	>100% NA
Refineries	Diesel** Gasoil Petrol**	>100% >100% 80-95%

Source: Bruegel based on De Bruyn *et al* (2015) and De Bruyn *et al* (2016). Note: *The CPT rates in the column are those from the empirical analysis of De Bruyn *et al* (2015). They represent the average estimates of the percentage of carbon costs passed through in product prices for the cases when the CPT was statistically greater than zero (using a 10 percent significance threshold level). 'NA' indicates that no significant CPT was found by De Bruyn *et al* (2015). **Positive CPT rates were also found for these products in the literature (see De Bruyn *et al*, 2016, which summarises the CPT rates found in the literature, on the basis of a literature review by De Bruyn *et al*, 2015).

The pass-through of the value of free allowances has distributional consequences. Firms acquire free allowances at zero cost, yet incorporate some of their value in product prices. This means that consumers pay more while firms generate higher profits. In fact, European industry may have increased tis profits by more than €15 billion between 2008 and 2014 by passing through a share of the opportunity cost of free allowances into product prices (De Bruyn *et al*, 2016).

3.2.4 Channel 3: Indirect-cost compensation for electricity-intensive firms

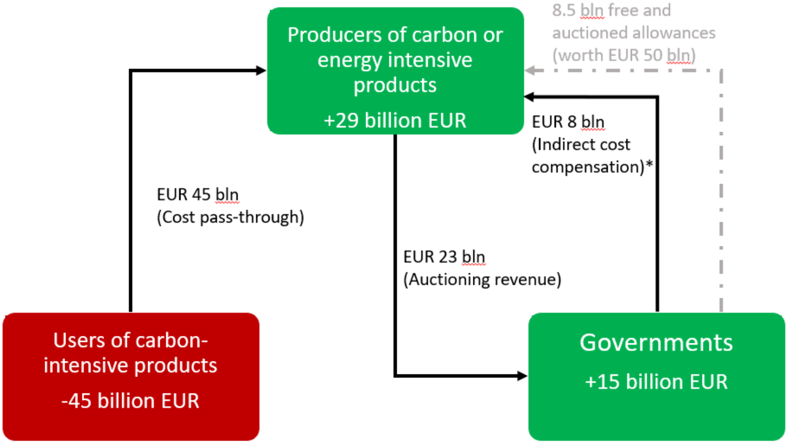
Compensation for 'indirect costs' is another channel through which wealth is transferred from governments to firms. The EU ETS has raised the costs of electricity-intensive firms, because electricity producers must purchase allowances. As electricity producers largely pass through the compliance costs into prices, firms using electricity as an input incur 'indirect costs' from the EU ETS by paying more for electricity. The indirect costs are substantial for electricity-intensive firms and, as such, some EU countries compensate them with auctioning revenues. About one third of member states have compensation schemes in place, though the level of compensation varies. In 2016, France, for instance, used 60 percent of auction revenues for compensation, while slightly above 30 percent was used in Germany and the Netherlands. The corresponding share in Greece was only about three percent (Marcu *et al*, 2018).

3.2.5 Overall distributional effects of the EU ETS

Figure 21 shows a simplified picture of the overall distributional impact of the EU ETS. The figure describes the monetary flows between consumers, firms and the government in phase 3, using allowance quantity and price data for 2013-17. For simplicity, a cost pass-through rate of 90 percent is assumed[64] and governments are assumed to transmit 34 percent of their auctioning revenues as compensation for electricity-intensive firms[65]. These assumptions might not hold in practice, but Figure 21 is merely intended to provide a rough indication of the transmission of wealth in the EU ETS.

[64] The cost pass-through rate in the power sector is likely to be close to 100 percent. For industrial installations, the rates range from zero to above 100 percent (De Bruyn *et al*, 2015). An average rate of 90 percent is thus assumed for simplicity.
[65] 34 percent was the share of indirect cost compensation in auctioning revenue in Germany in 2016 (Marcu *et al*, 2018).

Figure 21: A simplified picture of the monetary flows in the EU ETS (2013-17)



Source: Bruegel based on European Environment Agency data, available at: https://www.eea.europa.eu/data-and-maps/dashboards/emissions-trading-viewer-1.
*Note: The indirect cost compensation is directed towards electricity-intensive firms. 'Firms' include all stationary installations in the EU ETS (ie in both the EU and the EEA) in phase 3.

The EU ETS is therefore not only regressive on the household-expenditure side (carbon cost being passed through to products that make up a greater share in the consumption basket of low-income households) but also on the government side – with a compensation mechanism that benefits capital owning households. On the income side, the ETS reduces the (net of free allowances) value and wages of emitting companies, but increases the value and wages of companies that produce substitutes. This effect is likely to be progressive. The total distributional effect of the ETS has never been quantified, but should be slightly regressive in our view. A comprehensive analysis in the distributional effects of such a significant instrument (with a turnover of up to €40 billion per year)[66] is clearly warranted.

[66] 1.9 billion allowances were issued in 2018 and the current price (October 2018) is around €20 per allowance.

4 NON-ACTION

If not addressed, climate change will impair many livelihoods. Not everyone will be equally affected by climate change though, as those already at a disadvantage will be more likely to suffer harm. The disadvantage can stem from a lower socioeconomic status, demographic characteristics, weak political power, or inferior access to public resources (Islam and Winkel, 2017). For instance, there is evidence from Australia that rural male farmers are more prone to suicide during droughts (Hanigan *et al*, 2012). Moreover, low-income households might face relatively greater financial losses from hurricanes (Leichenko and Silva, 2014). In this chapter, we discuss why disadvantaged groups in developed countries [67] might be disproportionately hurt by climate change.

Disadvantaged groups suffer disproportionately from climate change because they are more exposed to the adverse effects. Their greater exposure arises partly from their housing location. Low-income households might, for instance, live in areas at risk of flooding because housing is cheaper there. Moreover, in a given area, the exposure can be greater for certain occupations. Those working outdoors can, for example, be more prone to heat-related stress if temperatures rise (Hallegatte *et al*, 2016; Graff Zivin and Neidell, 2014). Various inequalities between groups can also interact, further exacerbating differences in the exposure level. Mutter (2015) shows that a combination of economic and racial factors left African Americans in New Orleans especially vulnerable to Hurricane Katrina.

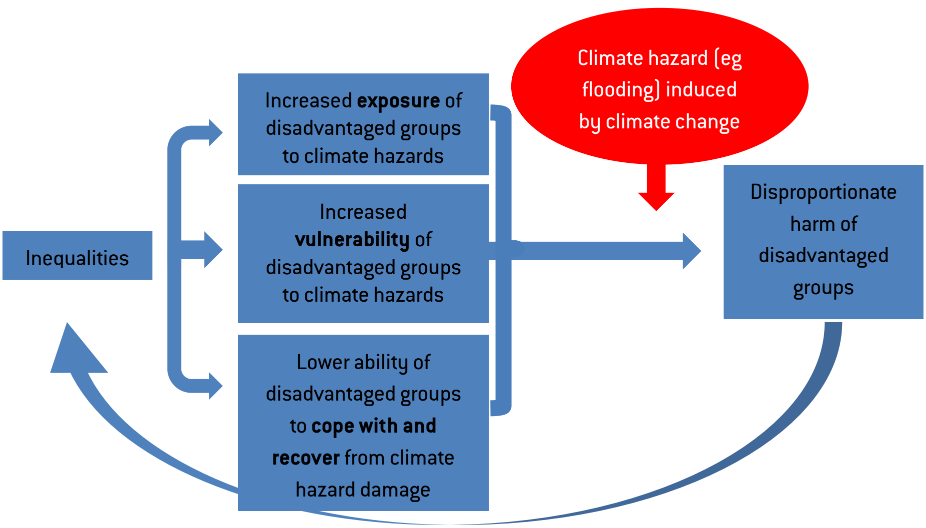
For a given level of exposure, disadvantaged groups are also more vulnerable to the damage caused by the adverse effects of climate change. For example, in areas prone to flooding, low-income households might be especially susceptible to flood damage if their houses are made of less durable material (Islam and Winkel, 2017). Differences in vulnerability are rarely due to a single cause, but rather

[67] Though we focus our attention on developed countries, the messages in this section are also relevant in the context of developing countries.

to a combination of various inequalities. For instance, discrimination based on race can increase income disparities, which can translate into differences in vulnerability (IPCC, 2014).

Disadvantaged groups might also be less able to cope and recover from the damage caused by climate hazards. Hurricane victims with low incomes might not be able to afford insurance and might therefore receive little compensation for destruction of their property. This reduced ability to cope and recover can in turn aggravate existing inequalities and make the disadvantaged even worse off (Figure 22).

Figure 22: The vicious cycle between climate change and inequalities



Source: Bruegel based on Islam and Winkel (2017).

While sections 2 and 3 showed that many climate policies can have adverse distributional effects, non-action cannot be the answer. Non-action would not only make everybody worse off, it would actually also affect low-income households more than high-income households. There is thus no trade-off between climate and equity, but the question is how climate policies should be designed to minimise adverse distributional effects. We discuss this in chapter 5.

5 REMEDIES

Chapter 4 showed that the distributional consequences of climate policies might be significant. Economically-efficient policies such as emissions standards for cars, renewables support financed through levies on households' electricity consumption or carbon pricing for heating fuels might disproportionately affect less-wealthy households, increasing inequality in society. But if policymakers are concerned about distributional consequences – which they should be (see chapter 1) – they do not have to discard effective climate polices. The distributional effects of many effective climate policies can be remedied by: (i) compensating lower-income households; (ii) designing the specific policy measures in a way that reduces the distributional effects; and (iii) introducing climate policies that have progressive features. This chapter provides some examples.

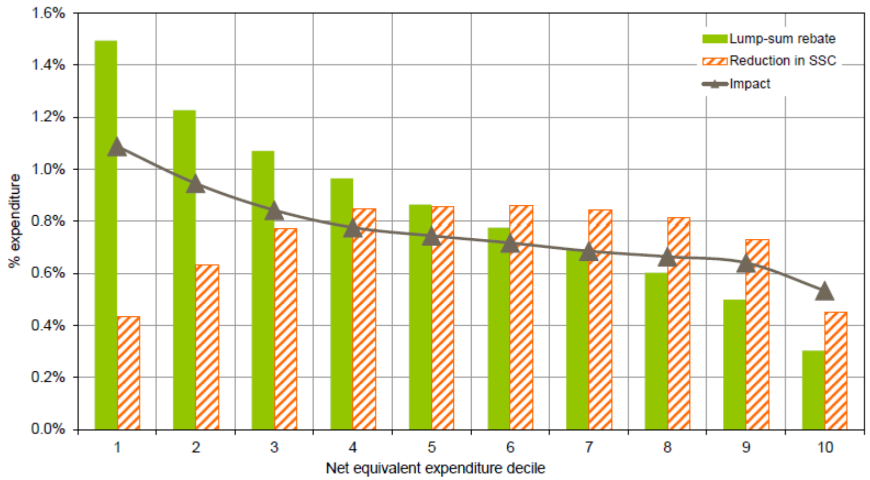
5.1 Compensation

There is a long-standing discussion about the regressive nature of carbon taxes (see chapter 2). Most research shows that using carbon taxes to compensate low-income households could entirely do away with the regressive effects. Governments could in theory compensate households for the pass-through by redistributing to them part of their auctioning revenues. Compensation might be especially important for lower-income households, which might be most hurt by the pass-through of carbon costs. Figure 23 shows the impact of the pass-through on households by expenditure level[68]. As shown in the figure, households in the lowest expenditure decile incurred additional costs of 1.1 percent of expenditure, compared to 0.5 percent for households in the highest decile. Cludius (2015) evaluates two ways in which the government could compensate households using its auctioning revenues: redistributing the revenues as lump-sum rebates or as a reduction in social security contributions. As shown in Figure 23, lump-sum rebates (green bars) more than offset the additional

[68] Sourced from Cludius (2015), who estimated the impact of the cost pass-through from electricity generating firms using German household data from 2013.

costs faced by lower expenditure households. For higher-income households, reducing social security contributions (red and white striped bars) appears more effective.

Figure 23: Impact of the EU ETS and revenue redistribution by household expenditure decile



Source: Cludius (2015). Note: SCC = social security contributions.

Such compensation can take different forms:

- **Lump-sum transfers** (ie fixed sums to each household) benefit low-income households for which such a transfer represents a higher share of income, compared to higher-income households. On the other hand, such transfers are expensive and it looks counterintuitive to also compensate high-income households. In practice, such lump-sum transfers are very rare.
- **Social policies**, such as targeted transfers to the households most in need. This can be a very effective way to compensate for the regressive effects of climate policies. The difficulty is to design (or use an existing scheme) that reliably targets the most affected households while not creating perverse incentives. If, for example, only households below a certain minimum income level receive a

transfer, households close to this threshold might have an incentive to reduce their incomes in order to obtain the transfer. On the other hand, if – in order to avoid such effects – the scheme becomes too complicated[69], less-affluent households in particular might be less able to participate.

- **Reducing other regressive taxes**, such as VAT, or increasing allowances for labour taxes, might compensate low-income households for the regressive effects of climate policies. But changing taxes might also change incentives. If, for example, VAT on electricity is reduced, it might incentivise higher consumption.
- **Using income for low-carbon investment that primarily benefits less-wealthy households** (see section 3.3).
- **Facilitate the transition towards new jobs**. The transitional issue related to climate change is not very different to the challenges from globalisation or technological change, so the solution could be the same: if a change in the demand for skills is quick, there is a role to play for authorities to ensure that the workforce (and in particular displaced workers with low skills) can be retrained successfully and quickly. Claeys and Sapir (2018) and Tagliapietra (2017) proposed to broaden the scope of the European Globabilisation Adjustment Fund to put in place active labour market policies in the EU to help workers who have lost their jobs as a result of the implementation of climate policies.

One additional issue is that the aforementioned compensation policies are already a very crowded policy space. It is thus difficult to attribute individual compensation measures to individual regressive policies – whose regressive nature might also change over time.

Given the real-world complexities of getting compensation schemes right so that they exactly offsets the regressive effect for each household in a way that does not distort incentives and does not

---

[69] For example, if households need to submit proof of income, assets and costs going back many years.

over-extend fiscal budgets is impossible. So policymakers will be faced with a trade-off. This might be best addressed by a combination of measures and continued monitoring of the actual regressive effects of climate polices and an evaluation of the compensation schemes.

In the long-term, another issue will arise. After a certain point in time emissions, will likely fall faster than carbon prices will increase. Government revenues from carbon taxes will then start to fall, shrinking the space for recycling of revenues[70].

5.2 Design less-regressive policies

A second approach would be to design policies in a way that their burden is proportionate to the income of the affected households. In many cases, addressing distributional effects in the design of policies will have some impact on the effectiveness and efficiency of the climate policies.

Focus on less-regressive sectors first. We described how climate policies for different products/services have different distributional impacts. In order to reduce the regressive effects, climate policymakers might prioritise the least regressive elements. For example, putting high prices on carbon in transport, especially aviation, will have less dramatic distributional consequences than a similar price for heating or electricity.

Focus on less-regressive policy tools. A sector can be decarbonised using different policy instruments. And some policy instruments are more regressive than others. Policy choices should therefore not only be concerned by effectiveness and efficiency considerations, but should also take account of distributional aspects. In the discussion on taxes versus technology standards, distributional concerns typically provide an additional argument for the former.

---

[70] Assuming a back-stop technology such as CCS becomes competitive with the carbon tax (eg, at €100/tonne) the money spent by consumers on removing emissions using such technologies will not be available as tax income that can be used for recycling.

Renewable support schemes. As discussed in section 3.1, renewable support schemes that are financed through a levy on the electricity price are regressive. If industrial consumers are exempted and only higher-income households can benefit from support schemes, this effect is exacerbated. A number of design elements can reduce the regressive effects. If some of the renewables support can be financed from taxes or levies on a basis that is more correlated with income (eg electricity consumption above a certain per-capita allowance), it could significantly reduce the regressive nature of the support. Making systems more efficient and competitive (eg through auctioning approaches) can reduce the excess profit potential for higher-income households and reduce the cost for lower-income households. Finally, by including industrial consumers in the schemes, the cost could be spread much more widely – reducing the burden on lower-income households. Any reform has to deal with the complexity and path dependency of renewables support schemes[71] and the difficult political trade-offs (support for industry versus support for low-income households). It might therefore be more important to spend political capital to come up with as-fair-as-possible future schemes, than to reform less-fair existing schemes, which are being (and should be) phased-out.

The EU ETS puts a price on carbon that might have to rise substantially if the EU wants to meet its decarbonisation ambition. As discussed in section 3.2, the ETS is designed in a very regressive way by exempting/compensating industrial users and passing through the cost to households. Some of the compensation (free allowances) is supposed to be phased out over time – but interest groups are trying to prevent this. One way to reduce the regressive nature would be to give a certain share of free allowances to households on a per-capita basis (ie a lump sum that is indexed to the carbon price). Alternatively, protection against carbon leakage could be organised

---

[71] The German main renewables support scheme law (Erneuerbaren Energien Gesetz) text currently has 134 pages and has undergone major reforms every three or four years since the year 2000.

through some form of border adjustment[72] so that all allowances can be auctioned. This, however, would be highly complex.

Climate diplomacy to mitigate the competitiveness versus equality trade-off. One recurring theme when discussing distributional effects is the efficiency-equity trade-off, or the choice between having a larger cake or a more equally-shared cake. In particular, when faced with international competitors that conduct less-aggressive climate policies, putting the costs of decarbonisation onto capital and skilled labour might encourage those crucial production factors to leave. Putting the cost onto those economic actors that find it more difficult to leave – consumers – allows for more aggressive climate policies. This even holds for compensation, because the corresponding resources need to be generated through distorting taxation. We would argue that – if more attention were paid on this – it would be possible to design policies with less distributional effects. But at some point, the efficiency-equity trade-off will kick in. Thus, it is the role of climate diplomacy to ensure that global climate policies are somewhat synchronised to avoid this trade-off.

5.3 Allow the benefits of climate policies to go to the least wealthy

Section 2 showed that subsidies for private investments in low-carbon assets (eg electric vehicles or solar panels) are highly regressive. On the other hand, public low-carbon investment that primarily benefits low-income households could reduce inequality. Examples include public programmes to increase the energy efficiency of public housing or to improve public transport. The same can hold for investment support programmes targeted at low-income households, such as the US Department of Energy's Weatherization Assistance Program,

[72] Many proposals imply taxing the imported carbon content of products and exempting the exported carbon content from the ETS.

which deploys energy efficiency improvements for low income households[73].

Another approach is to ensure that regulation and market design choices properly remunerate the value low-income households might provide to the heat and electricity system in terms of flexibility. Low-income households might prefer to subscribe to lower heat and electricity tariffs, in return for accepting a slightly lower degree of supply security. In current schemes, there is however the risk that the value of these load-shaving services might be captured by the suppliers or other intermediaries. Hence, regulation should ensure that suppliers have to return the full value of such flexibility to households, and not just the small amount at which a sufficient number of low-income households are indifferent between a flexible and an inflexible scheme. It is the role of policymakers and regulators to provide consumers with some degree of market power in this newly developing market segment.

[73] Several corresponding programmes are discussed at https://epatee.eu/case-studies, but typically the distributional impacts are not evaluated.

6 CONCLUSION

In order to avoid potentially disastrous consequences from climate change, greenhouse gas emissions need to be reduced drastically in the coming decades. To achieve this objective, a suite of intrusive polices is needed, most notably putting a meaningful price on emissions but also fostering public support for the deployment of low-carbon technologies and bans on inefficient technologies. These and other climate policies can have substantial distributional side effects. Such distributional effects will depend on the targeted sectors/products, the specific economic circumstances of each country and the policy design.

While several 'pure' climate policies can be regressive, the costs and impacts of climate change are also likely to fall disproportionately on low-income households. Furthermore, many adverse distributional effects of climate policies can be avoided by appropriate policy design or remedied by using fiscal revenues linked to these policies to compensate low-income households.

Based on our analysis we make five recommendations:

1) Invest more in research

Overall, we find that – despite excellent work on individual instruments – the issue of the distributional effects of climate policies has been under-explored in research and policymaking. In particular, the large-scale modelling exercises that underpin many long-term climate strategies do not address this issue. Thus, we recommend investing more in collecting data and researching this issue. Including different household types with different consumption patterns, capital stocks and discount rates into the models could provide valuable insights into this complex question. This can ultimately enable policymakers to make better choices in terms of designing a suite of climate policies that is simultaneously effective in mitigating emissions, efficient in minimising overall costs, and socially just.

2) Making policies less regressive

We already know that decarbonising certain sectors, such as aviation, has less adverse distributional effects, that certain policies are less regressive than others (eg taxes compared to standards) and that certain design elements make policies less regressive (eg auctioning emissions permits instead of grandfathering them to polluters). Policymakers should factor such distributional consequences more prominently into their policy choices.

3) Actively develop climate policies that benefit low-income households

There are climate polices – such as support for energy-efficiency investment targeted at low-income households – that can bring benefits to low-income households. Policymakers should become more creative in developing such measures, not least to increase public acceptance of climate policies.

Furthermore, countries that conduct active climate policies can seek to accommodate low-carbon technology sectors. This should include policies to facilitate the reallocation of workers and avoid skill shortages: priority should be given to improving science, technology, engineering and maths skills, while retraining the workforce, especially in the construction sector.

4) Compensation is feasible – but needs to be done

To achieve their ambitious decarbonisation targets, developed countries will have to resort to regressive carbon taxes on basic needs (eg heating fuel) to some degree. But recycling the revenues from such schemes – for example, through lump-sum transfers – will allow distributional concerns to be mitigated to a great extent, and should be forcefully implemented.

5) An international approach can make domestic climate policies fairer

Policymakers should continue to fight for a globally synchronised decarbonisation effort. This will create space for less-regressive national policies by assuaging the competitiveness concerns of domestic industry, which currently excuse instruments that benefit high-income households at the cost of low-income households.

REFERENCES

Bajari, P., J.C. Fruehwirth, K.I. Kim, and C. Timmins (2012) 'A Rational Expectations Approach to Hedonic Price Regressions with Time-Varying Unobserved Product Attributes: The Price of Pollution', American Economic Review 102 (5): 1898-1926

Bartoli, A., D. Cavicchioli, D. Kremmydas, S. Rozakis, and A. Olper (2016) 'The impact of different energy policy options on feedstock price and land demand for maize silage: The case of biogas in Lombardy', Energy Policy 96: 351-363

Blanco Foncesca, M., A. Burrell, S.H. Gay, M. Henseler, A. Kavallari, R. M'Barek, I. Pérez Domínguez, and A. Tonini (2010) 'Impacts of the EU Biofuel Target on Agricultural Markets and Land Use: A Comparative Modelling Assessment', JRC Reference Reports, Luxembourg: Publications Office of the European Union

Borusyak, K., and X. Jaravel (2018) 'The Distributional Effects of Trade: Theory and Evidence from the United States', [Internet], Working Paper

BPIE (2011) Europe's buildings under the microscope: A country-by-country review of the energy performance of buildings

Brännlund, R., and J. Nordström (2004) 'Carbon tax simulations using a household demand model', European Economic Review 48 (1): 211-233

Bundesministerium für Wirtschaft und Energie (2017) EEG in Zahlen: Vergütungen, Differenzkosten und EEG-Umlage 2000 bis 2018

Burtraw, D., R. Sweeney, and M. Walls (2009) 'The Incidence of U.S. Climate Policy: Alternative Uses of Revenues from a Cap-and-Trade Auction', National Tax Journal 62 (3): 497–518

Calderón, C., and L. Servén (2004) 'The effects of infrastructure development on growth and income distribution', Policy Research Working Paper No. 3400, World Bank

Cambridge Econometrics (2013) Employment Effects of selected scenarios from the Energy roadmap 2050, Final report for the European Commission (DG Energy)

Cames, M., J. Graichen, A. Siemons, and V. Cook (2015) Emission Reduction Targets for International Aviation and Shipping, Brussels: European Parliament

Capros, P., A. De Vita, N. Tasios, P. Siskos, M. Kannavou, A. Petropoulos, S. Evangelopoulou, M. Zampara, D. Papadopoulos, C. Nakos, and L. Paroussos (2016) EU Reference Scenario 2016 - Energy, transport and GHG emissions Trends to 2050, Brussels: European Commission

Carrosio, G. (2013) ‘Energy production from biogas in the Italian countryside: Policies and organizational models’, Energy Policy 63: 3-9

Center for Climate and Energy Solutions (2018) ‘Global Emissions’, retrieved from https://www.c2es.org/content/international-emissions/

Chatterjee, S., and S.J. Turnovsky (2012) ‘Infrastructure and Inequality’, European Economic Review 56 (8): 1730-1745

Chiarazzo, V., P. Coppola, L. Dell’Olio, A. Ibeas, and M. Ottomanelli (2014) ‘The Effects of Environmental Quality on Residential Choice Location’, Procedia - Social and Behavioral Sciences 162: 178-187

Civil Aviation Authority (2016) CAA Passenger Survey Report 2016

Claeys, G., and A. Sapir (2018) ‘The European Globalisation Adjustment Fund: Easing the pain from trade?’, Bruegel Policy Contribution Issue n˚05, March 2018

Cludius, J.M. (2015) ‘Distributional effects of energy and climate policy’, PhD thesis, Doctor of Philosophy, UNSW Business School, UNSW Australia

Cramton, P.C., D.J.C. MacKay, A. Ockenfels, and S. Stoft (Eds.) (2017) Global Carbon Pricing: The Path to Climate Cooperation, Cambridge, Massachusetts: The MIT Press

Davis, L.W., and C.R. Knittel (2016) ‘Are fuel economy standards regressive?’, NBER Working Papers No. 22925, National Bureau of Economic Research, Inc

Davis, S.J., and K. Caldeira (2010) ‘Consumption-based accounting of CO2 emissions’, Proceedings of the National Academy of Sciences of the United States of America 107 (12): 5687-592

De Bruyn, S., E. Schep, and S. Cherif (2016) Calculation of additional profits of sectors and firms from the EU ETS, CE Delft

De Bruyn, S., R. Vergeer, E. Schep, M.‘t. Hoen, M. Korteland, J. Cludius, K. Schumacher, C. Zell-Ziegler, and S. Healy (2015) Ex-post investigation of cost pass-through in the EU ETS: An analysis for six sectors, European Commission

De Ferranti, D., G.E. Perry, F.H. Ferreira, and M. Walton (2004) Inequality in Latin America: Breaking with history?, World Bank Latin American and Caribbean Studies, Washington, D.C.: World Bank

Delarue, E.D., P.J. Luickx, and W.D. D’haeseleer (2009) ‘The actual effect of wind power on overall electricity generation costs and CO2 emissions’, Energy Conversion and Management 50 (6): 1450-1456

Dercon, S. (2014) 'Is Green Growth Good for the Poor?', Policy Research Working Papers No. 6936, Washington, D.C.: World Bank

Desjardins, R.L., D.E. Worth, X.P. Vergé, D. Maxime, J. Dyer, and D. Cerkowniak (2012) 'Carbon Footprint of Beef Cattle', Sustainability 4: 3279-3301

Direct Energy (n.d.) 'What is the difference between Direct Energy and my local utility company?', retrieved from https://www.directenergy.com/faqs/global/signing-up/general-information/difference-between-direct-energy-local-utility-company

Dluhosch, B. (2018) 'Trade, inequality, and subjective well-being: Getting at the roots of the backlash against globalization', LIS Working Paper Series No. 741, LIS Cross-National Data Center in Luxembourg

DOE (2014) 'Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnace Fans', Federal Register, Volume 79, No. 128, p.38132–33, Tables I.3–I.4, retrieved from https://www.federalregister.gov/documents/2014/07/03/2014-15387/energy-conservation-program-for-consumer-products-energy-conservation-standards-for-residential

Dumagan, J.C., and T.D. Mount (1992) 'Measuring the consumer welfare effects of carbon penalties: Theory and applications to household energy demand', Energy Economics 14 (2): 82–93

European Commission (2011) 'A Roadmap for moving to a competitive low carbon economy in 2050', Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2011) 112 final

European Foundation for the Improvement of Living and Working Conditions (2012) 'Greening of Industries in the EU: Anticipating and Managing the Effects on Quantity and Quality of Jobs'

Evans, A., V. Strezov, and T.J. Evans (2009) 'Assessment of sustainability indicators for renewable energy technologies', Renewable and Sustainable Energy Reviews 13 (5): 1082-1088

Fajgelbaum, P.D., and A.K. Khandelwal (2016) 'Measuring the unequal gains from trade', The Quarterly Journal of Economics 131 (3): 1113-1180

Fan, S., and X. Zhang (2004) 'Infrastructure and regional economic development in rural China', China Economic Review 15 (2): 203-214

FAOSTAT (n.d.), retrieved from http://www.fao.org/faostat/en/#data

Milne, R. (2017) ‘Reality of subsidies drives Norway’s electric car dream’, Financial Times, retrieved from https://www.ft.com/content/84e54440-3bc4-11e7-821a-6027b8a20f23

Flues, F., and A. Thomas (2015) ‘The distributional effects of energy taxes’, OECD Taxation Working Papers No. 23, Paris: OECD Publishing

Förster, H., S. Healy, C. Loreck, F. Matthes, M. Fischedick, S. Samadi, and J. Venjakob (2012a) ‘Information for Policy Makers 1: Decarbonisation Scenarios leading to the EU Energy Roadmap 2050’, SEFEP Working Paper 2012

Förster, H., S. Healy, C. Loreck, F. Matthes, M. Fischedick, S. Samadi, and J. Venjakob (2012b) ‘Information for Policy Makers 2: Analysis of the EU’s Energy Roadmap 2050 Scenarios’, SEFEP Working Paper 2012

Fragkos P., L. Paroussos, P. Capros, S. Boeve, and T. Sach. (2017) ‘Job creation related to Renewables’

Fragkos, P., and L. Paroussos (2018) ‘Employment creation in EU related to renewables expansion’, Applied Energy 230: 935-945

Fraunhofer Institute for Solar Energy Systems ISE (2018) ‘Monthly electricity spot market prices in Germany’, Datasource: EPEX, retrieved from https://www.energy-charts.de/price_avg.htm?price=nominal&period=monthly&year=all

FTSE Russell (2014) FTSE Developed ex Fossil Fuel Index Series, FTSE Russell. retrieved from https://www.ftse.com/products/downloads/FTSE_Stranded_Assets.pdf

Fullerton, D., and E. Muehlegger (2017) ‘Who Bears the Economic Costs of Environmental Regulations?’, National Bureau of Economic Research No. w23677

Fullerton, D., G. Heutel, and G.E. Metcalf (2012) Does the Indexing of Government Transfers Make Carbon Pricing Progressive?, American Journal of Agricultural Economics 94 (2): 347–353

Furceri, D., and B.G. Li (2017) ‘The macroeconomic (and distributional) effects of public investment in developing economies’, IMF Working Papers Working Paper No. 17/217

Government of the United Kingdom (2018) Family Food 2016/17 survey, retrieved from National Statistics of the United Kingdom https://www.gov.uk/government/statistics/family-food-201617

Graff Zivin, J., and M.J. Neidell (2014) ‘Temperature and the allocation of time: Implications for climate change’, Journal of Labor Economics 32 (1): 1-26

Grösche, P., and C. Schröder (2014) 'On the redistributive effects of Germany's feed-in tariff', Empirical Economics 46 (4): 1339–1383

Hallegatte, S., M. Bangalore, L. Bonzanigo, M. Fay, T. Kane, U. Narloch, J. Rozenberg, D. Treguer, and A. Vogt-Schilb (2016) 'Shock waves: Managing the impacts of climate change on poverty', Climate Change and Development, Washington, DC: World Bank

Hamerschlag, K., and K. Venkat (2011) 'Meat Eaters Guide: Methodology 2011', Environmental Working Group

Hanigan, I.C., C.D. Butler, P.N. Kokic, and M.F. Hutchinson (2012) 'Suicide and drought in New South Wales, Australia, 1970–2007', PNAS 109 (35): 13950–13955

Harrison, G.W., M.I. Lau, and M.B. Williams (2002) 'Estimating individual discount rates in Denmark: A field experiment', American Economic Review 92 (5): 1606-1617

Hassett, K., A. Mathur, and G.E. Metcalf (2009) 'The Incidence of a U.S. Carbon Tax: A Lifetime and Regional Analysis', Energy Journal 30 (2): 155–177

Heidjann J. (2018) Strompreis – Atlas, retrieved from: https://www.stromauskunft.de/strompreise/strompreis-atlas/

Heindl, P., and A. Löschel (2014) 'Addressing the social implications of green growth: Session 1, Energy Sector Reform and its Impact on Households, Green Growth and Sustainable Growth Forum', OECD

International Energy Agency (2017a) World Energy Outlook 2017, OECD/IEA

International Energy Agency (2017b) Technology Roadmap Delivering Sustainable Bioenergy, OECD/IEA

International Energy Agency (2018) Global Energy & CO2 Status Report – 2017, OECD/IEA

International Maritime Organization (2018) 'UN Body adopts climate change strategy for shipping', retrieved from http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx

IPCC (2014) 'Fifth Assessment Report. Climate Change 2014: Impacts, Adaptation and Vulnerability', Cambridge University Press

Italian National Institute of Statistics (2017) Household Budget Survey of the Italian National Institute of Statistics

Islam, S.N., and J. Winkel (2017) ‘Climate change and social Inequality’, UN Department of Economic & Social Affairs (DESA) Working Paper No. 152

Jacobsen, M.R. (2013) ‘Evaluating US fuel economy standards in a model with producer and household heterogeneity’, American Economic Journal: Economic Policy 5 (2): 148–187

Jones, F. (2007) ‘The effects of taxes and benefits on household incomes, 2005/06’, United Kingdom Office for National Statistics

Kalcik, R., and G. Zachmann (2018) ‘Export and patent specialization in low carbon technologies’, Global Innovation Index 2018, co-published by Cornell University, INSEAD, and the World Intellectual Property Organization (WIPO)

Khandker, S., and G. Koolwal (2007) ‘Are pro-growth policies pro-poor? Evidence from Bangladesh’, Mimeo, The World Bank

Kollamthodi, S., A. Pueyo, G. Gibson, R. Narkeviciute, A. Hawkes, S. Cesbron, R. Milnes, J. Harries, T. Zamparutti, G. Hernandez, S. Kaltsouni, S. Vancauwenbergh, G. Goldenman, C. Pålsson, N. Bengtsson, T. Rydbergh, L. Nilsson, A. Krantz, K. Weber, T. Scarbrough, C. Whall, C. Green, J. Hill, J. Lee, R. Noden, B. Grebot, and H. Lindstad (2013) ‘Support for the impact assessment of a proposal to address maritime transport greenhouse gas emissions’, Ricardo-AEA

Lauterbach, K.W., M. Lüngen, B. Stollenwerk, A. Gerber, and G. Klever-Deichert (2006) ‘Zum Zusammenhang zwischen Einkommen und Lebenserwartung’, retrieved from: http://www.sozialpolitik-aktuell.de/tl_files/sozialpolitik-aktuell/_Kontrovers/Rente67/Zusammenhang-Einkommen-Lebenserwartung.pdf abgerufen

Leicester, A., and C. O'Dea (2008) ‘Aviation taxes’, in R. Chote, C. Emmerson, A. Shaw, and D. Miles (Eds.), IFS Green Budget 2008 (The Institute for Fiscal Studies)

Leichenko, R., and J.A. Silva (2014) ‘Climate change and poverty: Vulnerability, impacts, and alleviation strategies’, WIREs Climate Change 5: 539-556

Levinson, A. (2016) ‘Energy efficiency standards are more regressive than energy taxes: Theory and evidence’, NBER Working Paper No. w22956

Marcu, A., E. Alberola, J.-Y. Caneill, M. Mazzoni, S. Schleicher, W. Stoefs, C. Vailles, and D. Vangenechten (2018) 2018 State of the EU ETS Report, I4CE, ICTSD/ERCST, the University of Graz, Nomisma Energia and Ecoact

Markandya, A., I. Arto, M. González-Eguino, and M.V. Román (2016) ‘Towards a green energy economy? Tracking the employment effects of low-carbon technologies in the European Union’, Applied Energy 179: 1342-1350

McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken, and K.S. White (2001) Climate change 2001: Impacts, Adaptation, and Vulnerability, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, published for the IPCC by the University of Cambridge

McInnes, G. (2017) ‘Understanding the distributional and household effects of the low-carbon transition in G20 countries’, OECD

Miller, S.E. (2015) ‘One Discount Rate Fits All? The Regressive Effects of DOE’s Energy Efficiency Rule’, Policy Perspectives 22

Munksgaard, J., and P.E. Morthorst (2008) ‘Wind power in the Danish liberalised power market - Policy measures, price impact and investor incentives’, Energy Policy 36 (10): 3940-3947

Mutter, J.C. (2015) The disaster profiteers: How natural disasters make the rich richer and the poor even poorer, New York: St. Martin’s Press

Nonhebel, S. (2005) ‘Renewable energy and food supply: will there be enough land?’, Renewable and Sustainable Energy Reviews 9 (2): 191-201

OECD (2017) Investing in Climate, Investing in Growth, Paris: OECD editions, retrieved from https://doi.org/10.1787/9789264273528-en

Opio, C., P. Gerber, A. Mottet, A. Falcucci, G. Tempio, M. MacLeod, T. Vellinga, B. Henderson, and H. Steinfeld (2013) Greenhouse gas emissions from ruminant supply chains – A global life cycle assessment, Food and Agriculture Organization of the United Nations (FAO)

Peters, G.P., S.J. Davis, and R.M. Andrew (2012) ‘A synthesis of carbon in international trade’, Biogeosciences Discussions 9 (3): 3949-4023

Rausch, S., G.E. Metcalf, and J.M. Reilly (2011) ‘Distributional impacts of carbon pricing: A general equilibrium approach with micro-data for households’, Energy Economics 33 (S1): 20-33

Ray, S., J. Munksgaard, P.E. Morthorst, and A.-F. Sinner (2010) ‘Wind Energy and Electricity Prices: Exploring the 'merit order effect'’, European Wind Energy Association

Robinson, L.A., J.K. Hammitt, and R. Zeckhauser (2014) ‘The Role of Distribution in Regulatory Analysis and Decision Making’, M-RCBG Regulatory Policy Program Working Paper Series 2014-02

Sensfuß, F., R. Mario, and M. Genoese (2007) ‘Merit Order Effect: A Detailed Analysis of the Price Effect of Renewable Electricity Generation on Spot Prices in Germany’, Energy Policy 36: 3086-3094

Shapiro, J.S. (2016) ‘Trade Costs, CO2, and the Environment’, American Economic Journal: Economic Policy 8 (4): 220-254

Statista (2018) ’Marktkapitalisierung der börsennotierten Unternehmen in Deutschland von 1980 bis 2017 (in Milliarden US-Dollar)’, retrieved from https://de.statista.com/statistik/daten/studie/6989/umfrage/marktkapitalisierung-deutscher-unternehmen-von-1980-bis-2007/ abgerufen

Stölzel, T., and K. Fischer (2018), ‘Der Preis Deutschlands beträgt 5.453.700.000.000 Euro’ retrieved from WiWo https://www.wiwo.de/finanzen/immobilien/exklusive-rechnung-der-preis-deutschlands-betraegt-5-453-700-000-000-euro/23233944.html abgerufen

Tagliapietra, S. (2017) ‘Beyond coal: facilitating the transition in Europe’, Bruegel Policy Brief Issue 5 November 2017

Tagliapietra, S., and G. Zachmann (2018) ‘Addressing Europe's failure to clean up the transport sector’, Bruegel Policy Brief, retrieved from http://bruegel.org/2018/04/addressing-europes-failure-to-clean-up-the-transport-sector/

Terna (2017) ‘Monthly Report on the Electricity System. Various Issues’, retrieved from

www.terna.it/en-gb/sistemaelettrico/dispacciamento/datiesercizio/rapportomensile.aspx

Tiezzi, S. (2005) ‘The welfare effects and the distributive impact of carbon taxation on Italian households’, Energy Policy 33 (12): 1597-1612

Tovar Reaños, M.A., and K. Sommerfeld (2018) ’Fuel for inequality: Distributional effects of environmental reforms on private transport’ Resource and Energy Economics 51: 28-43

Tovar Reaños, M.A., and N.M Wölfing (2018) ’Household energy prices and inequality: Evidence from German microdata based on the EASI demand system’, Energy Economics 70: 84–97

UNCTAD (2009) The Biofuels Market: Current Situation and Alternative Scenarios, Geneva: UNCTAD

UNCTAD (2017) Review of maritime transport 2017, Geneva: UNCTAD

United Kingdom Office for National Statistics (2018) ‘Household disposable income and inequality’, retrieved from United Kingdom Office for National Statistics https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/datasets/householddisposableincomeandinequality

United Nations Framework Convention on Climate Change (2015) 'Adoption of the Paris Agreement', 21st Conference of the Parties, Paris: United Nations

Vyn, R.J. (2018) 'Property Value Impacts of Wind Turbines and the Influence of Attitudes toward Wind Energy', Land Economics 94 (4): 496-516

Weigt, H. (2008) 'Germany's Wind Energy: The Potential for Fossil Capacity Replacement and Cost Saving', Applied Energy 86: 1857-1863

West, S.E. (2004) 'Distributional effects of alternative vehicle pollution control policies', Journal of Public Economics 88 (3): 735–757

West, S.E., and R.C. Williams III (2004) 'Estimates from a consumer demand system: Implications for the incidence of environmental taxes', Journal of Environmental Economics and Management 47 (3): 535–558

Williams III, R.C., H. Gordon, D. Burtraw, J.C. Carbone, and R.D. Morgenstern (2015) 'The Initial Incidence of a Carbon Tax across Income Groups', National Tax Journal 68 (1): 195–214

ANNEX

Table A: Categories used for summary table in section 2.2

<table>
<tr><th>Category name in our report</th><th>Category name in Eurostat (which sourced from EEA)</th><th>Italian National Institute of Statistics category name</th><th>Engel curve slope category name in Fajgelbaum and Khandelwal (2016)</th></tr>
<tr><td>Air transport</td><td>Fuel combustion in domestic aviation + International aviation</td><td>Passenger transport by air</td><td>Air transport</td></tr>
<tr><td>Road fuel</td><td>Fuel combustion in cars</td><td>Fuels and lubricants for personal transport equipment</td><td>Inland transport</td></tr>
<tr><td>Agriculture</td><td>Agriculture</td><td>Food</td><td>Food, beverages, and tobacco</td></tr>
<tr><td>Electricity</td><td rowspan="2">Fuel combustion in public electricity and heat production</td><td>Electricity</td><td>Electricity, gas, and water supply</td></tr>
<tr><td>Heating</td><td>Heat energy + Liquid fuels + Solid fuels + Gas</td><td>-</td></tr>
</table>

Table B: Name of the food items used in the analysis in the various data sources

Name in the analysis	Name in the Family Food 2016/17 survey of the Government of the United Kingdom (2018)	Name in FAOSTAT	Name in Hamerschlag and Venkat (2011)
Rice	Rice	Rice, paddy	-
Beef and veal	Beef and veal	Meat, cattle	-
Milk	Liquid wholemilk	Milk, whole fresh cow	-
Chicken	Chicken, uncooked - whole chicken or chicken pieces + Other poultry, uncooked (including frozen) + Chicken and turkey, cooked	Meat, chicken	-
Eggs	Eggs	Eggs, hen, in shell	-
Natural cheese	Natural cheese	-	Natural cheese
Lamb	Mutton and lamb	-	Lamb
Salmon	Salmon, fresh, chilled or frozen	-	Salmon
Pork	Pork + Bacon and ham, uncooked + Bacon and ham, cooked	Meat, pig	-
Fruits and vegetables	Fresh and processed fruit and vegetables, including potatoes	-	-

Source: Bruegel.

Table C: Food item categories sourced from UN Comtrade

Name in the analysis	Code on UN Comtrade
Beef and veal	20110
	20120
	20210
	20220
Pork	20311
	20312
	20319
	20321
	20322
	20329
Lamb	20410
	20421
	20422
	20423
	20430
	20441
	20442
	20443
Chicken	20711
	20712
	20713
	20714
	20732
	20733
	20735
	20736
Salmon	30212
	30311
	30319
	30322
	30541
Milk	40120
	40130
Natural cheese	40610
	40620
	40640
	40690
Eggs	40700
Rice	100610

Name in the analysis	Code on UN Comtrade
Fruits and vegetables	701
	702
	703
	704
	705
	706
	707
	708
	709
	710
	711
	712
	713
	714
	801
	802
	803
	804
	805
	806
	807
	808
	809
	810
	811
	812
	813
	814

Source: UN Comtrade.

DISTRIBUTIONAL EFFECTS OF CLIMATE POLICIES

Bruegel, Rue de la Charité 33, B-1210 Brussels
(+32) 2 227 4210
info@bruegel.org
www.bruegel.org

€20