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The Poverty and Distributional Impacts of Carbon Pricing: Channels and Policy Implications

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The Poverty and Distributional Impacts of Carbon Pricing: Channels and Policy Implications[1]

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Abstract

Addressing the poverty and distributional impacts of carbon pricing reforms is critical for the success of ambitious actions in the fight against climate change. This paper uses a simple framework to systematically review the channels through which carbon pricing can potentially affect poverty and inequality. It finds that the channels differ in important ways along several dimensions. The paper also identifies several key gaps in the current literature and discusses some considerations on how policy designs could take into account the attributes of the channels in mitigating the impacts of carbon pricing reforms on households.

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Keywords: carbon pricing; poverty; inequality; redistributive effects

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[1] Carbon pricing typically refers to market instruments that put a price on carbon emissions, such as a carbon tax or an emissions trading system. According to the UNFCCC, carbon pricing curbs greenhouse gas emissions by placing a fee on emitting and/or offering an incentive for emitting less. While the focus of this paper is on carbon pricing, many of the channels discussed in the paper may also apply to the poverty and inequality impacts from the regulatory approach.

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I. INTRODUCTION

The 2015 Paris climate agreement marked a milestone in response to climate risks by the international community, with the key objective of limiting future global warming to between 1.5 and 2˚C above pre-industrial levels (UNFCCC, 2016 and 2018). The progress on climate mitigation, however, has been slow (World Bank, 2020). The average price of emissions worldwide is currently only about US$2 per ton of CO_2, well below what is needed to reach country emission pledges—which represent about one third of the emissions reduction needed to achieve under 2˚C—and the 2˚C goal (Parry, 2019).[3] Among the main barriers to ambitious carbon pricing reforms, concerns about their impacts on poverty and inequality and the associated political ramifications have been well documented in the literature (Metcalf, 2009; Rentschler and Bazilian, 2017; Coady and others, 2018; Klenert and others, 2018; Hallegatte, 2019; Carattini and others, 2019; WEO, 2020).[4]

Therefore, effective and efficient policy designs to mitigate the effects of carbon pricing on households are needed, not only to facilitate the advancement of carbon pricing reforms, but also to protect the most vulnerable and improve social welfare. Designing such policies requires a full understanding of how carbon pricing affects households and workers as well as their communities. Many policy analyses often only focus on the direct impact of carbon pricing on the prices of energy products and indirectly on the prices of other consumption goods and services that use energy products as inputs, with simplifying assumptions on pass-throughs of energy prices and demand responses by consumers. There is, however, a growing literature which, in addition to further examining the consumption channel (e.g., how demand responses by consumers may differ by household income and other household characteristics), assesses how the effects of carbon pricing on employment and income as well as health outcomes differ by population groups (Rausch and others, 2011; Beck and others, 2015; Moshiri and Santillan, 2018; Marin and Vona, 2019; Hille and Möbius, 2019; Tessum and others, 2019; Goulder and others, 2019; Ganapati and others, 2020).

This paper uses a simple framework to systematically review the channels through which carbon pricing may affect poverty and inequality. The paper identifies four major channels: the consumption channel, the income channel, the health channel, and the revenue recycling channel. For the channels that have been extensively studied in the literature, the review focuses on the methodologies and the empirical estimates. For the channels that have been largely overlooked, the review focuses on relevant theoretical and empirical analyses that could help better understand and quantify their impacts. The review finds that incorporating the evidence from the literature on the channels—such as firm and consumer responses and

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[3] The carbon taxes that are needed to meet country emission pledges vary by country, reflecting differences not only in the stringency of pledges, but also in the responsiveness of emissions to taxes. For example, a carbon tax of US$35 per ton would exceed the level needed to meet mitigation pledges in such countries as China, India, and South Africa, and it would be about right to meet pledges in Indonesia, the Islamic Republic of Iran, Pakistan, the United Kingdom, and the United States. But even a carbon tax as high as US$70 per ton would fall short of what is needed in countries like Australia and Canada (Parry, 2019).

[4] Here the poverty impact refers to the decline in the level of consumption/income of vulnerable households even if the decline is uniform across all households, and the inequality/distributional impact refers to the decline in the consumption/income of vulnerable households relative to that of other households. Most studies in the literature have focused on the inequality/distributional impact, with few studies on the poverty impact.

structural changes in factor income—would tend to lower the poverty and inequality impacts of carbon pricing, relative to the case with simplifying assumptions of unity pass-through, no behavioral responses by firms and households, a closed economy with carbon pricing applying to all sectors, and no income effect.

Another focus of the paper is to analyze the differences among the channels along several dimensions, including timing, place, nature, heterogeneity and uncertainty of their poverty and inequality impacts. For example, the effects from many of the channels are subject to large uncertainties, tend to be heterogenous, or would only materialize over the medium and long term. This highlights the importance that while not incorporating all the channels may misinform policy designs, not carefully considering their differences may also come to misleading conclusions. For example, policy designs based on the average equilibrium effects ignore the timing and heterogeneity of the impacts and could result in inadequate support upfront for certain low-income households and workers.

Finally, the paper identifies several key gaps in the current literature and discusses some considerations on how to best utilize existing knowledge—particularly on the attributes of the different channels—in designing effective and efficient policies to mitigate the impacts of carbon pricing on households, from both the political economy perspective and the social welfare perspective. The paper proposes that policy designs should focus on the channels that are most relevant for the given country or region, that have near-term impacts, and that are better understood with their impacts less uncertain. In addition, policy designs should go beyond the averages and provide support to the specific groups that are particularly affected. This suggests that it is likely a reasonable starting point to base the analysis of the poverty and distributional impacts on the simplifying assumptions of unity pass-through, no behavioral responses by firms and households, a closed economy with carbon pricing applying to all sectors, and no income effect, while assisting workers that would be severely affected by carbon pricing such as those in the fossil-fuel sectors. The paper also summarizes the designs of carbon pricing schemes in seven countries/regions (British Columbia, China, Colombia, France, Singapore, South African, and Sweden) and draws some useful lessons.

The rest of the paper is organized as follows. Section II discusses some considerations in defining the baseline; Sections III-V take up the three main issues in turn; and Section VI concludes with a summary of the main messages.

II. THE BASELINE

A clearly defined baseline helps identify the drivers of the poverty and distributional impacts under reform scenarios and compare results across studies. The baseline is typically defined in two ways in the literature. Some studies use what actually happened in the recent past—typically the year when the most recent household survey was completed—as the baseline and estimate the poverty and distributional impacts had a carbon pricing scheme been introduced (Rausch and others, 2011; Dorband and others, 2019). Another line of studies build an explicit baseline, using the latest household survey and projecting into the future (Fiscal Monitor, 2019; Goulder and others, 2019). The latter is more realistic and policy relevant as a forward-looking exercise but requires assumptions on the trends of key factors related to consumption and production, particularly those discussed below.

In addition, the interactions between certain baseline characteristics and carbon pricing mean that the baseline itself also plays a role in the poverty and distributional impacts of carbon pricing, particularly related to:

- *Access to energy*. Studies find that carbon pricing tends to be progressive in developing economies, which is largely driven by the fact that the poor have limited access to energy, particularly electricity (Dorband and others, 2019; Fiscal Monitor, 2019; Pizer and Sexton, 2019). This, however, will likely change as these countries develop. In fact, universal access to energy is one of the United Nation's Sustainable Development Goals (SDGs), and governments in developing economies and the international community have been taking steps in achieving them. It would thus be reasonable to reflect improving access to energy by the poor in the baseline, which would likely worsen the poverty and distributional impacts of carbon pricing relative to the baseline.

- *Carbon intensity of consumption goods and services*. The development and deployment of low-carbon technologies and fuel switching by firms would lead to less increases in the prices of consumption goods and services from carbon pricing and smaller poverty and distributional impacts. Carbon intensity of consumption goods and services has declined substantially over the past decades, though the literature finds that only a small share may be attributed to the introduction of carbon pricing schemes such as the European Union Emissions Trading System (EU ETS).[5] Having explicit assumptions on the carbon intensity of goods and services in the baseline is thus essential to fully take into account the declining trend in carbon intensity.

III. THE POVERTY AND DISTRIBUTIONAL IMPACTS OF CARBON PRICING

Carbon pricing reforms can have broad effects on the economy, including consumption, investment, structure of the economy, health outcomes, and ultimately the welfare of households. This section reviews both theoretical and empirical studies to identify the channels through which carbon pricing affects poverty and inequality. A simple utility maximization model can help facilitate the discussions of the channels: households maximize their utility, which is a function of consumption (C) and health (H), and health is in turn a function of consumption including medical care and the environment (E):

$$Max\ U(C, H(C, E))$$

Subject to the budget constraint:

$$PC=Y+G$$

Furthermore, P can be written as:

$$P=P_0 + (1+\tau)\ R\theta\omega T$$

Here P is a price vector corresponding to the vector of consumption goods and services C; Y denotes market income and G denotes net government transfers (transfers minus taxes); T denotes carbon prices (for example, US dollars per ton of CO_2), ω denotes the carbon

[5] This is discussed in more details in Section III.

intensity of consumption goods and services (carbon emissions in producing one unit of goods or services), θ denotes the pass-through of carbon price (the share of carbon price that is passed forward to the prices of consumption goods and services), R is a vector indicating to what extent consumption goods and services are subject to the carbon pricing (for most goods and services, $R = 1$ so the full carbon price would apply; R may be less than 1 for goods and services that are imported in the absence of border carbon adjustments or that are from sectors where carbon pricing does not apply or is reduced along the supply chain). The effects of carbon pricing may be further amplified by the existence of a consumption tax (τ), which is often levied on top of other taxes such as an excise tax. A subscript zero denotes values under the baseline.

The impact of carbon pricing through the left side of the budget constraint, PC, is the consumption channel (also called use-side effect); through the Y component from the right side of the budget constraint is the income channel and the G component the revenue recycling channel (also called source-side effect); and through E in the utility function is the health channel.

Many policy analyses only focus on the consumption channel and make the simplifying assumptions of unity pass-through, no behavioral responses by firms and households, and a closed economy with carbon pricing applying to all sectors ($C=C_0$, $\theta=1$, $\omega=\omega_0$ and $R=1$). The methodology is easy to understand and implement. After the carbon intensity of each energy product is determined, an input-output table can be used to trace the carbon intensity of other goods and services. Then it is straightforward to calculate the final prices of all consumption goods and services with carbon pricing, assuming unity pass-through.[6] The overall poverty and distributional impacts also depend on the budget shares of consumption goods and services for any given household. However, a growing literature suggests that the simplistic approach ignores important channels and may come to incorrect conclusions on the poverty and distributional impacts of carbon pricing. Next the paper systematically reviews the channels and available evidence.

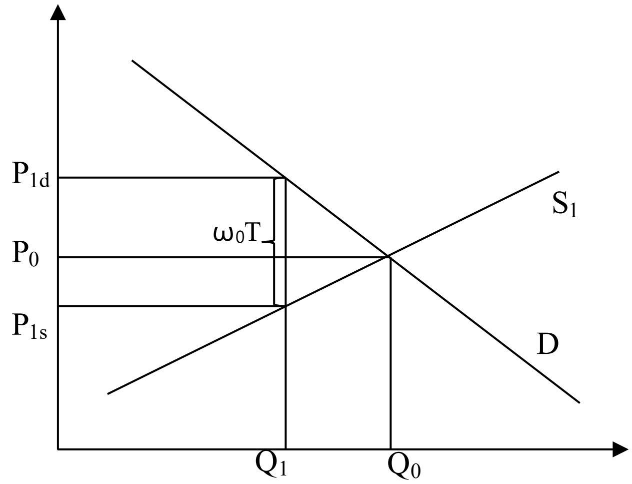
A. The Consumption Channel

Pass-throughs (θ may differ from 1)

As illustrated in Figure 1, for a product market characterized by supply curve (S_1) and demand curve (D), the initial equilibrium occurs at price P_0 and quantity Q_0. With carbon price T (per ton of CO_2), the new quantity is Q_1 with consumer price P_{1d} and producer price P_{1s}, while production technologies and carbon intensity of the product remain unchanged from the baseline (ω_0). Here the pass-through (θ) is defined as $(P_{1d}-P_0)/(\omega_0 T)$, the share of the carbon price that is passed to consumers. In this case, partial pass-through of carbon pricing to consumer prices leads to lower consumer prices, from $(P_0+\omega_0 T)$—under the simplistic assumption of unity pass-through—to P_{1d}.

[6] Alternatively, carbon pricing would increase the cost of living for households directly through an increase in fossil-fuel energy prices and indirectly through higher prices for other goods and services. The increases in energy prices would depend on the carbon intensity of each energy product. An input-output table can be used to trace the effects of higher energy prices on the prices of other goods and services, assuming full pass-through (Coady and others, 2006).

Figure 1. Pass-Throughs of Carbon Pricing to Consumer Prices: An Illustration



Source: author's formulation.

Thus, pass-through of carbon pricing to consumer prices may not be unity. Not all the burden of carbon pricing may be passed forward in higher prices for households, as some may be passed backward in lower prices for firms. As a result, some of the burden may be borne by owners of capital and workers in these firms. There may also be instances where the pass-through is larger than one, as the result of imperfectly competitive product markets with very convex demand (Weyl and Fabinger, 2013; Ganapati and others, 2020).[7] In such a case, the benefit from over pass-through would also have poverty and distributional implications through the income channel.

This is an area where empirical evidence is till emerging, and the findings thus far have been mixed, ranging from below unity to above unity. Kotchen (2021) finds an average pass-through of 0.85 for coal, natural gas, gasoline, and diesel, based on demand and supply elasticities. Many studies use firm- or industry-level data to estimate pass-throughs:

- Ganapati el al. (2020) find that, on average, around 70 percent of energy price-driven changes in input costs get passed through to consumers over the short to medium term. There are, however, large heterogeneities across sectors with pass-through ranging from 0.36 (gasoline) to 1.87 (cement).

- Fabra and Reguant (2014) find that costs imposed by the EU ETS are almost fully passed through to consumers in the form of higher electricity prices due to high correlation of cost shocks among firms, inelastic demand, and the absence of relevant price rigidities. Stolper (2016) finds that, while the average pass-through is around unity in Spanish retail automotive fuel market, pass-through varies substantially by local market conditions such as brand concentration and spatial isolation, ranging from 70 percent to 115 percent. In particular, the paper finds pass-through rises

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[7] Please see Weyl and Fabinger (2013) for detailed discussions on the conditions under which pass-through is larger than one: in a general symmetric model of oligopoly, for pass-through to exceed unity it is sufficient that marginal costs are constant, firms exercise market power, and demand is log-convex.

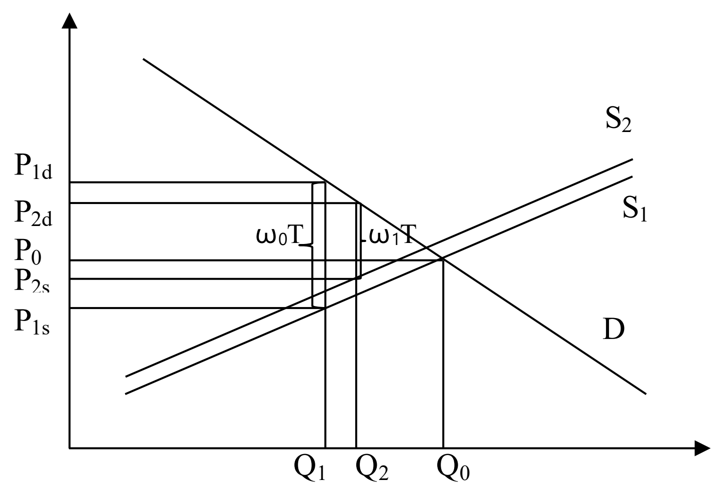
monotonically with area-average house prices, which could have important implications on the poverty and distributional impacts of carbon pricing.

- Marion and Muehlegger (2011) find at least full, and potentially more than full, pass-through of both federal and state diesel and gasoline taxes to consumers and that the pass-through depends on factors such as refinery capacity constraints. Based on six manufacturing sectors in the United States, Miller and others (2017) find evidence that the pass-through in the cement industry exceeds one.

Production responses by firms ($\omega<\omega_0$)

Conceptually carbon pricing would also incentivize firms to improve energy efficiency and switch to less carbon-intensive energy (Pearce, 1991; Jaffe and others, 2002; Acemoglu and others, 2012; Parry and others, 2014). As a result, this can help mitigate the effect of carbon pricing on production costs and consumer prices (Figure 2). As firms respond to carbon pricing by improving energy efficiency and switching to less carbon-intensive energy, the supply curve shifts to the left (S_2), as production cost increases. This also leads to lower carbon intensity of the product ($\omega_1<\omega_0$) and thus lower carbon price per unit of output ($\omega_1 T$). At equilibrium, the quantity is Q_2 with consumer price P_{2d}, producer price P_{2s}. In this case, production responses by firms further lower consumer prices, from P_{1d} to P_{2d}. In addition, production responses by firms could potentially alter factor prices for labor and capital and have poverty and distributional implications through the income channel as well.

Figure 2. Production Responses by Firms: An Illustration



Source: author's formulation.

Here energy efficiency is defined as energy services provided per unit of energy input (Jaffe and others, 2004).[8] For energy-consuming firms, improving energy efficiency typically involves trading off upfront investment in energy-saving measures and technologies—such as improving the insulation of buildings and replacing incandescent light bulbs with LED

[8] For example, energy-efficient LED light bulbs are able to produce the same amount of light as incandescent light bulbs by using 75 to 80 percent less electricity.

light bulbs—against lower energy consumption and cost in the long run. Essentially this is a substitution of non-energy input for energy input to lower production costs, as carbon pricing raises the cost of energy. This can be achieved through both more widespread adoption of existing technologies and the development of new ones, which could substantially reduce the long-run cost of carbon abatement.

The literature, including case studies and expert interviews, indicates that firms have been employing new machinery/equipment and making behavioral/process changes with some of which might simply not have been economically viable in the absence of carbon pricing schemes such as the EU ETS (Petsonk and Cozijnsen, 2007; Hoffmann, 2007; Tomás and others, 2010; Martin and others, 2011; Anderson and others, 2011). Non-price barriers, including inadequate information, high uncertainty, principal-agent problems, and constrained capital financing, have also been identified as important factors in determining the diffusion of low-carbon technologies. This suggests that policies to address the associated market failures can complement carbon pricing reforms and help accelerate the diffusion process (Jaffe and others, 2002).

Studies also find evidence on low-carbon technological innovation from existing ETS schemes (e.g., the EU ETS and China ETS pilots), but their overall impact appears to be limited (Calel and Dechezleprêtre; 2016; Zhu and others, 2019a; Lilliestam and others, 2021). For example, Calel and Dechezleprêtre (2016) find that the EU ETS in the first five years of its existence has increased low-carbon innovation among regulated firms by as much as 10%, while not crowding out patenting for other technologies and not affecting patenting beyond the set of regulated companies. Because regulated firms only account for a small share of all patients, the EU ETS contributes to less than 1 percent of the increase in European low-carbon patenting compared to a counterfactual scenario, suggesting that the EU ETS has had at best a very limited impact on the overall pace and direction of low-carbon technological advancement. On the other hand, the effect of carbon taxes on low-carbon innovation is found to be significant, when inferred from energy price changes or pollution taxes (Aghion and others, 2016). The different findings may reflect low coverage, excessive allowance allocation, and low carbon prices of the existing ETS schemes (Calel and Dechezleprêtre; 2016; Lilliestam and others, 2021).

In addition to improving energy efficiency, carbon pricing can also provide incentives for firms to switch toward less carbon-intensive energy, such as from coal to natural gas or renewables in electricity production. The literature has documented fuel switching, particularly by energy firms, and shows that it accounts for the majority of the carbon emissions reduction under the EU ETS (Anderson and others, 2011; Borghesi and others, 2015; Calel and Dechezleprêtre; 2016; Lilliestam and others, 2021; Gugler and others, 2021).

The production responses by firms could have large impact on production costs and consumer prices both in the short term and over the long term, which would benefit more the consumers whose consumption is more carbon intensive under the baseline. For example, the carbon intensity of the European chemical industry (carbon emissions per production unit) dropped by about 50 percent over a 15-year span, well above that of its counterpart in the United States, at least part of which may be attributed to the carbon pricing schemes in Europe (Tomás and others, 2010). Sager (2019) suggests that the substitution of intermediate inputs along global value chains and fuel switching, without taking into account the impact on energy-saving technological innovation and the substitution between energy and other inputs, can significantly mitigate the consumer price increases from carbon pricing.[9]

Leakages (R<1)

The discussions thus far have largely been based on a closed economy, and international trade can further reduce the impact of carbon pricing schemes on consumer prices, in the absence of some form of global carbon pricing—such as the establishment of an international carbon price floor—or border carbon adjustments. This would mean that imported intermediate inputs or final consumption goods and services would not be subject to carbon pricing and their prices would remain at the level prior to the introduction of carbon pricing. Furthermore, some foreign goods and services whose prices were not competitive previously may further replace domestic production.[10] Separately, ETS schemes often only cover large emitters and even carbon tax schemes sometimes provide exemptions for selected sectors. This would also lead to lower consumer prices.

Demand responses by consumers (C may differ from C_0)

In addition to behavioral responses by firms, behavioral responses by consumers to carbon pricing can further mitigate its impact on household welfare. Consumption level and composition would respond to changes in both price levels and relative prices as a result of carbon pricing. West and others (2004) find that ignoring demand responses could substantially overstate the impact on consumers and that the differences between equivalent variation and easier-to-implement consumer surplus measures are relatively small. Sager (2019) suggests that the emissions reduction from demand responses would likely be moderate. A carbon price of US$30 per ton of CO_2 would reduce carbon emissions by about 14 percent, and this reduction is mostly due to consumers substituting away from emissions-intensive goods, with only a small portion from across-the-board price increases. In addition, behavioral responses by consumers may vary across income groups (Muller and Yan, 2018; Moshiri and Santillan, 2018). However, empirical estimates of such effects appear to vary substantially across studies due to differences in methodologies and data (Zhu and others, 2019b).

The rebound effect has been extensively discussed in the context of energy efficiency and needs to be take into account in estimating consumer responses, in both the baseline and the carbon pricing scenario.[11] The effect appears significant with large variations across studies,

[9] The rebound effect associated with improved energy efficiency is discussed under demand responses by consumers.

[10] There is one line of research which examines the overall impact of carbon pricing on competitiveness (Ellis and others, 2019; Kpodar and others, 2019). However, few studies estimate the effect of international trade on domestic consumer prices. Sager (2019) may capture at least some of the effect through its modeling of the global value chain under the scenario of EU ETS without border carbon adjustments. However, no results are reported in this regard.

[11] The rebound effect refers to the phenomenon that improved energy efficiency can lead to an increase in energy use because the cost of energy service declines. One example of the rebound effect is a household that upgrades their washing machine to a more efficient model. Because the new model is more efficient and thus cheaper to operate, the household may end up running the washing machine more often, which therefore offsets some of the energy savings associated with upgrading to the more efficient model.

depending on sector and type of efficiency improvement (Frondel and others, 2012; Gillingham and others, 2013; Dimitropoulos and others, 2018). For example, Dimitropoulos and others (2018) find that, for road transport, the short-run rebound effect is, on average, about 10–12 percent, whereas the long-run effect about 26–29 percent.

B. The Income Channel

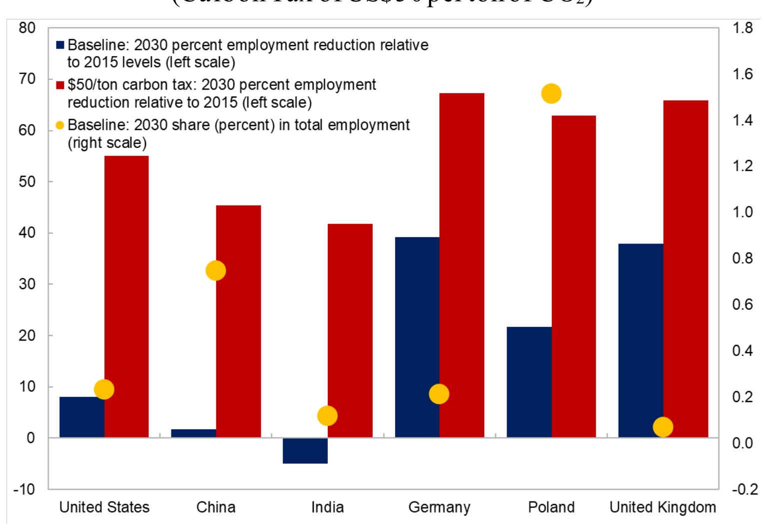
Destruction of brown jobs

Substantive carbon prices could have large negative impacts on certain groups of workers and regions engaged in carbon intensive activities, fossil-fuel sectors in particular, including through trade. For example, a carbon tax could lead to substantial job losses in the coal sector (Morris, 2016; Fiscal Monitor, 2019). Typically, coal- (or fossil fuel-) related jobs are highly geographically concentrated, accounting for a large share of local employment. Winding down production in these regions could lastingly reduce output and employment prospects for local communities. In addition, extractive activities may cause scarred local landscapes and impaired waterways, reducing prospects for attracting new industries (Morris, 2016).

For illustrative purposes, a gradual increase of carbon tax to $50 per ton by 2030 could substantially accelerate this process—the already declining coal production and coal-related employment—and increase job losses in the coal sector relative to the 2015 levels. For example, the decline in coal-related jobs would increase from 8 to 55 percent in the United States; coal-related jobs in China would decline by 45-percent, instead of very small losses; and in India, the carbon tax would turn coal-related jobs from a 5-percent growth to a 42-percent decline. These job losses would amount to 0.3–0.9 percent of economywide employment in China and Poland and less than 0.2 percent in other countries (Figure 3).

Figure 3. Impact of Carbon Pricing on Employment in the Coal Sector

(Carbon Tax of US$50 per ton of CO_2)



Source: Fiscal Monitor, 2019.

On a larger scale, global action on climate could have substantial economy-wide impact on countries that heavily rely on oil income for their economic growth and fiscal revenues (through for example, royalties and corporate income tax), including many low-income developing economies. Both oil demand and oil prices are likely to drop substantially under such a scenario, which would lead to a sharp decline in revenues in these economies (IEA, 2018; Fiscal Monitor, 2019; Mirzoev and others, 2020). Fiscal Monitor (2019) estimates that under a 2°C climate change scenario, revenues could decline between 7 and 9 percent of GDP by 2040 for a group of oil exporting countries, with considerable variation across countries. The biggest economic impact would be felt in countries most dependent on fossil fuel revenues (for example, Kuwait, Saudi Arabia, Timor-Leste). This loss in revenues would need to be compensated either though tax increases or expenditure tightening, resulting in a reduction in total income of their populations. The exact poverty and distributional impacts would also depend on the designs of the fiscal adjustment measures.

Creation of green jobs

On the other hand, carbon pricing may lead to increases in employment in other sectors, due to, for example, investments in less-carbon intensive energy such as renewables. With carbon pricing, renewables would become more economically viable, and both investments and employment would likely increase in the sector (Yamazaki, 2017; Hille and Möbius, 2019; Fiscal Monitor, 2019; Tavares, forthcoming). Yamazaki (2017) finds modest positive impact on employment of the British Columbia carbon tax. While aggregate impact is small, the paper finds significant job shifting from carbon intensive to non-carbon intensive sectors.

Income gain due to climate improvements

In addition, to the extent that carbon pricing can help reduce the frequency and severity of damaging climate events such as floods, droughts, and tropical cyclones, the poor could potentially benefit more from such improvements for a number of reasons. First, areas that the poor live may be more prone to climate related damage. However, empirical evidence appears mixed on whether exposure to adverse climate changes is greater for poorer populations; second, marginal damages from climate changes tend to be larger for poorer populations for climate changes of similar magnitudes because, for example, they may have less access to credit or technology and thus are less capable to insure themselves or build resiliency against adverse climate events; and third, poorer populations may derive a greater proportion of their income from sectors that are most vulnerable to climate changes, such as agriculture, forestry, and fisheries (World Bank, 2004; Hsiang and others, 2019).

Structural changes in factor income and demand for skills

More broadly, carbon pricing can affect economic activities and induce structural changes in employment and factor income. However, both theoretical and empirical literature is still emerging in this area. While large-scale computable general equilibrium models tend to suggest some modest negative impact of carbon pricing on economic growth, empirical studies of existing carbon pricing schemes have found little evidence of such adverse effect (Goulder and Hafstead, 2017; Goulder and others, 2019; Metcalf, 2019; Metcalf and Stock, 2020; Dussaux, 2020).

Studies suggest that low-carbon structural changes from carbon pricing may also have direct distributional implications. First, carbon pricing may alter the demand for workers with different skill levels (Marin and Vona, 2019; WEO, 2020). Marin and Vona (2019) find that the skill bias of climate policies mostly consists of a substitution of technical and, to a lesser extent, professional workers for manual workers. Second, to the extent that the pass-through from carbon pricing is not unity, the burden/benefit sharing may differ by capital and labor (Rausch and others, 2011). In the case of self-employed, particularly agricultural households for which fertilizers are a major input in food production, partial pass-through would result in lower income. This could be especially concerning for low-income developing economies where poverty rates among agricultural households tend to be high. Little research, however, has been done on the poverty and distributional impacts of carbon pricing on this group. Third, if carbon-intensive industries are also capital-intensive, and carbon can be more easily substituted by labor than by capital, returns to capital would decline more than wages, and as such, households with greater income shares derived from capital would suffer more. This suggests that the composition of income (from labor, capital, and government transfers) by income level is an important determinant of the distributional impact of carbon pricing reforms (Fullerton and Heutel, 2010; Rausch and others, 2010; Dissou and Siddiqui, 2014; Beck and others, 2015; Goulder and others, 2019).

A number of studies use general equilibrium models to explore the distributional implication of the factor income channel. One main takeaway from this literature is that the factor income channel could be important and in some cases appears sufficient to reverse the overall distributional impact of carbon pricing reform from being regressive to progressive; however, it should be noted that this is partially driven by the assumption on government transfers,[12] which are counted as part of household income (Rausch and others, 2010; Rausch and others, 2011; Dissou and Siddiqui, 2014; Beck and others, 2015; and da Silva Freitas and others, 2016; Goulder and others, 2019). Another takeaway is that the results tend to be sensitive to parameter value assumptions, for example, on factor intensities and factor substitution rates (Fullerton and Heutel, 2010; Cao and others, 2020).

C. The Health Channel

In addition to helping achieve the global objective of carbon emissions reduction, carbon pricing can also generate important health co-benefits. According to the World Health Organization (WHO), 4.2 million deaths every year occur as a result of exposure to ambient (outdoor) air pollution, and carbon pricing can lead to substantial improvements in air quality and help reduce such deaths (Coady and others, 2017; Karlsson and others, 2020; Parry and others, 2020). For example, Parry and others (2020) estimate that a carbon tax gradually rising to US$70 per ton of CO_2 by 2030 in China could reduce annual deaths from fossil-fuel air pollution by one third in 2030.

There is some indicative evidence that the health co-benefits may vary by population groups. For example, empirical studies have documented that low-income and vulnerable households

[12] In some of these models, along with slowing economic activities with the introduction of carbon pricing, both wages and returns to capital fall. However, government transfers (under the baseline and not as part of carbon revenue recycling) are assumed to remain unchanged in real terms.

disproportionately live in areas with higher exposure to air pollution (Boyce and Pastor, 2013; Zwickl and others, 2014; EEA, 2018; Hsiang and others, 2019). Tessum and others (2019) show that, in the United States, PM2.5 exposure is disproportionately caused by the consumption of goods and services by the non-Hispanic white majority, but disproportionately inhaled by black and Hispanic minorities. However, Cushing and others (2018) find that in the first three years of California's Cap & Trade program, environmental disparities in industrial air pollution exposure were not reduced.

Additionally, carbon pricing is expected to and has been found to reduce traffic-related injuries and fatalities (Grabowski and Morrisey, 2004; Parry and others, 2007; Burke and Nishitateno, 2015). However. There is little research on its distributional impact, which is likely complex as it involves multiple parties related to both the physical harm and the associated medical treatment and compensation including through insurance.

D. The Revenue Recycling Channel

Revenue recycling is an essential part of a carbon pricing reform package. Its design needs to balance between the efficiency/growth impacts and the poverty/inequality impacts of carbon pricing. A typical carbon pricing reform package consists of elements to improve efficiency and support growth (e.g., tax cuts and public investment) and elements to reduce poverty and inequality (e.g., transfers to households). Intended or not, all these elements could have significant poverty and distributional implications (Klenert and others, 2018; Fiscal Monitor, 2019; Metcalf, 2019). Below summarizes the poverty and distributional impacts of the main revenue recycling measures included in major carbon pricing reform packages and early reforms.[13]

Lowering personal income tax (PIT). Its distributional impact depends on the exact design of the PIT cut. The PIT cut could be at the top bracket or at the bottom bracket. Lowering PIT rate at the top bracket would reduce PIT progressivity and at the bottom bracket improve PIT progressivity. The existence of exemptions and deductions complicates the assessment of PIT progressivity (Gerber and others, 2020). To the extent that low-income households do not pay much income tax, it would be difficult for low-income households to benefit from a PIT cut.

Lowering corporate income tax (CIT). The economic literature tends to agree that the CIT burden is shared between labor and capital, but there is still substantial disagreement over how much of the burden is shifted to workers and ultimately the incidence of a CIT cut (Fuest and others, 2018; Nallareddy and others, 2018). Nallareddy and others (2018) provide evidence that CIT cuts lead to increases in income inequality in the United States, as the gains to capital income for top earners exceed the gains to total income for bottom earners, in

[13] Another option to use carbon revenues that is also mentioned in the literature is public debt reduction. On the surface, it does not appear to have any direct poverty and distributional impacts. However, if public debt reduction is a policy priority, in the absence of carbon pricing, revenues would need to be raised through some taxes or some expenditures would need to be cut. Thus, the poverty and distributional impacts of debt reduction depend on the tax or expenditure measures that would have been taken. So again, this eventually comes down to the poverty and distributional impacts of taxes and expenditures.

part, because high income individuals shift their compensation to reduce taxes. It also appears that the passing of CIT changes to wages may be gradual (Fuest and others, 2018).

Increasing public spending on education and healthcare. The distributional impact depends on how the public spending increase is targeted. If it is used to expand access to education and healthcare by low-income households or to improve public schools and healthcare facilities in less developed regions and poorer communities, it will reduce inequality (Coady and Dizioli, 2018). On the other hand, if the spending increase concentrates on further improving public schools and healthcare facilities in urban areas and well-off neighborhoods, it will exacerbate inequality.

Increasing public investment in infrastructure, including green investment. The distributional impact of public investment depends on many factors, including whether the investment is in less developed regions, whether workers in the sectors that benefit most from public investment have higher initial wages, and the extent of spillover effect from the sectors involved. There have been very few empirical analyses on the distributional impact of public investment, and there is some evidence that public investment tends to lower income inequality in developing economies (Furceri and Li, 2017). Green investment could potentially lower income inequality if it can help lower energy prices when carbon intensity of consumption is higher for low-income households. On the other hand, investment in electric car charging stations is more likely to benefit the rich, as they are more likely to own electric cars.

Strengthening social safety nets or making universal transfers. Both targeted transfers through social safety nets and universal transfers can help mitigate the impact of carbon pricing on the most vulnerable and lower inequality. However, targeted transfers can provide more generous benefits for the most affected for a given fiscal envelop or can protect the most affected with lower fiscal cost. On the other hand, social safety nets may have coverage gaps, particularly in developing economies with limited administrative capacity, and targeted transfers also provide disincentives to work (Coady and Le, 2020).

While it is important to understand the poverty and distributional impacts of each tax or expenditure measure, what matters in the end is the performance of a reform package as a whole, not any individual component of the package, in achieving the poverty and distributional objectives with the least efficiency cost. For example, a combination of public investment and targeted cash transfers may be preferred to universal cash transfers, for example, in a country with large public investment needs. Eventually the measures to recycle carbon revenues should be integrated into the broad tax-benefit systems to achieve optimal allocation of all public resources as a whole.

Table 1. Overview of the Channels and Findings in the Literature

Main channels	Sub-channels	Useful references	Key findings and remaining issues
The consumption channel	Pass-throughs	Ganapati and others, 2020; Kotchen, 2021	The literature finds large variations in the estimates of pass-throughs across sectors. The overall impact on consumer prices is still unclear.
	Production responses by firms	Jaffe and others, 2002; Calel and Dechezleprêtre, 2016; Aghion and others, 2016; Sager, 2019; Lilliestam and others, 2021	Carbon pricing could lead to large reduction in production costs and consumer prices, as firms adopt existing low-carbon technologies, develop new low-carbon innovations, and switch fuels toward those with low-carbon content. Quantitative estimate of the overall impact, however, is still lacking.
	Leakages, including through trade and incomplete coverage of carbon pricing schemes	Sager, 2019	Research quantifying this effect is still limited.
	Demand responses by consumers	West and others, 2004; Dimitropoulos and others, 2018; Muller and Yan, 2018; Zhu and others, 2019b	Demand responses can help mitigate the impact of carbon pricing on households. However, to what extent such responses differ by income and other household characteristics is still unclear.
The income channel	Destruction of brown jobs	Morris, 2016; Fiscal Monitor, 2019	The impact can be large for certain sectors, communities and even countries.
	Creation of green jobs	Hille and Möbius, 2019; Yamazaki, 2017	There is some evidence that carbon pricing can lead to a shift of employment from carbon intensive to non-carbon intensive sectors. The distributional implication of such a shift, however, is unclear.
	Income gain due to climate improvements	Hsiang and others, 2019	The poor likely can benefit more from climate improvements. However, further evidence is still needed.
	Structural changes in factor income and demand for skills	Fullerton and Heutel, 2010; Rausch and others, 2011; Beck and others, 2015; Marin and Vona, 2019; Goulder and others, 2019	Results from general equilibrium models suggest that the inequality effect from structural changes in factor income could be large. Part of the results are driven by the assumption on government transfers, which are part of household income. In addition, the results may be sensitive to parameter value assumptions. Research on the impact of carbon pricing on demand for skills is still scarce.
The health channel	Reduction in air pollution	Burke and Nishitateno, 2015; Hsiang and others, 2019; Parry and others, 2020	The health co-benefits from reduction in air pollution is found to be substantial, and there is indicative evidence that the poor and the disadvantaged may benefit more. However, little empirical evidence is available from existing carbon pricing schemes.
	Reduction in traffic-related injuries and fatalities	Burke and Nishitateno, 2015	There is little research on how the effect differ by population groups.
The revenue recycling channel	Tax cuts	Fuest and others, 2018; Nallareddy and others, 2018	The distributional impact of a PIT cut depends on the design; the distributional impact of a CIT cut is still being debated.
	Boosting public investment in human capital and infrastructure	Coady and Dizioli, 2018; Furceri and Li, 2017	The distributional impacts would highly depend on the design of the policies. Programs to expand access to education and healthcare are likely to be pro-poor. There is still limited evidence on the distributional impact of infrastructure investment, including green investment.
	Targeted or universal cash transfers	Coady and Le, 2019	Both targeted and universal transfers can help mitigate the poverty and distributional impacts of carbon pricing. There are, however, tradeoffs in terms of fiscal cost, coverage and work incentives. The appropriate measure would be country specific, depending also on administrative capacity.

Source: author's assessments.

IV. Attributes of the Channels and Gaps in the Literature

Carbon pricing can affect household poverty and inequality through many channels, some of which are better understood than others. Table 1 summarizes the main findings on the channels from the literature. Often when studies incorporate multiple channels in their analysis, there is a tendency to lump their effects together and make a blanket statement on whether carbon pricing is progressive or regressive. However, the channels differ from each other in important ways, and simply a conclusion on the overall progressivity of carbon pricing masks the differences in their welfare effect and could potentially lead to policy designs that may inadequately protect the most vulnerable and jeopardize political support for carbon pricing reforms. Specifically, the channels can be assessed from a number of dimensions:

Timing of impact. The impacts from some channels are almost immediate, including the pass-through of carbon pricing from firms to consumers, the leakages through trade and exemptions, and the revenue recycling measures such as tax cuts and cash transfers; the impacts from some channels may be more gradual and take time to materialize and would only have an economically meaningful impact over the long term, including the income gain from climate improvements; and some channels would have both short- and long-term impacts, including production responses by firms (e.g., fuel switching and the adoption of existing low-carbon technologies may take place relatively quickly, while it may take time for low-carbon innovations to emerge), destruction of brown jobs (this would happen naturally as high-cost producers go out of business first), creation of green jobs (carbon pricing would likely spur immediate investment and job creation in the sector, and the process will continue as economic structures evolve, structural changes in factor income and demand for skills (while the pass-back of carbon pricing to wages and returns to capital would be immediate, other structural changes could take time), and the health co-benefits from reduction in air pollution (this largely would follow the same path as that of carbon emissions reduction). This suggests that even if the combined distributional effect is progressive at steady state, it does not necessarily mean that the most vulnerable would not suffer more in the short run, and policy designs will need to explicitly take this into account.

Place of impact. Fossil-fuel industries are often geographically concentrated. As a result, sectoral job relocation could lead to variations in changes in net jobs by region at least in the short run, with some regions gaining jobs and others losing jobs, even if the net effect for a country or globally is small. For example, job losses from the coal industry already have and will continue to have severe impacts on the regions where coal mines are located. Major oil exporting countries will be hit hard if oil demand and prices fall because of global climate actions. These regions or countries, however, may not be able to attract green jobs immediately because, for example, their lack of skilled work force. There may also be constraints on labor mobility in the short run as well, so workers in the coal industry may not be able to take advantage of job opportunities elsewhere. Therefore, even if on average there is no net job loss, targeted policies to assist the particularly affected regions may still be needed to facilitate the transition of their local economies.

Nature of impact. Most of the channels affect either household income or household expenditure, so their aggregation is straightforward. However, some channels also affect health or education outcomes, such as the health channel and the revenue recycling channel (e.g., public investment in education and health). The challenge is thus how to translate the in-kind benefits into household welfare, given that their valuation may differ by population groups (Hsiang and others, 2019).

Heterogeneity of impact. Exclusively focusing on averages across income groups may obscure important with-group variations. Rausch and others (2011) find large variations within income groups by race and region, both on the use-side—particularly the consumption of electricity, coal, and natural gas—and on the source-side.[14] Just like many other reforms, carbon pricing creates winners and losers. As it reallocates jobs across sectors, the workers who lose jobs in negatively affected industries may not be the same workers who are hired in industries that increase hiring, especially in the short run. This calls for targeted policies to assist those who are negatively affected by the reform beyond what is suggested by group averages for which the groups are defined based on pre-reform income.

Uncertainty of impact. This may have two underlying causes. One is that some channels are inherently uncertain, such as the development of low-carbon technological innovations and the climate impact of carbon pricing (e.g., on the frequency of extreme weather events). The other is due to limited understanding of the channels by researchers and policymakers or imprecise estimates because of data limitations. For the latter, additional investment in R&D or prioritizing certain areas of research would be particularly important. The uncertainties create challenges in incorporating these channels in policy designs.

Table 2 provides an illustrative assessment of the key attributes of the main channels and highlights how the channels differ along the five dimensions and the need to carefully consider them in policy designs. Together with Table 1, it also helps identify gaps in the literature and some topics for future research. A few areas that are worth emphasizing include:

Firm responses. Existing evidence suggests that firm responses—including both pass-throughs and production responses by firms—could significantly reduce the impact of carbon pricing on consumers prices, and thus help limit the welfare loss by households and the size of mitigating measures, leaving more resources to address the efficiency cost of carbon pricing reforms. However, research in these areas has been limited, particularly in quantifying their impacts and understanding their transition path.

Structural changes in factor income. A number of studies based on general equilibrium models suggest that this is likely an important channel. However, it still appears very much a theoretical possibility, and the results are also sensitive to parameter value assumptions. Therefore, further research in the area is warranted, particularly on the empirical side to support the model parametrization and provide support from existing carbon pricing schemes. In addition, even if the effect from this channel is real, it may take time for its effect to materialize. Thus, research on the potential transition path would also be very valuable and should also take into account the evidence on real and nominal wage rigidity in the literature (Babecký and others, 2009; Elsby and Solon, 2019; Kaur, 2019). Particularly, Babecký and others (2009) find that both types of rigidity are positively corelated with the share of high-skilled white-collar workers in a firm.

[14] In this case, while the large variations are in baseline characteristics, the interactions between carbon pricing and baseline characteristics lead to large heterogeneity in the poverty and distributional impacts of carbon pricing.

Leakages. This is an area which has been largely overlooked in the literature. Given the challenge of coordinated global climate actions, the difficulties in implementing border carbon adjustments and the large exemptions in many existing designs of carbon pricing schemes, this channel could significantly reduce the burden on firms and households at the cost of carbon emissions reduction and co-benefits.

Table 2. Key Attributes of the Channels

Main channels	Sub-channels	Timing	Place	Nature	Heterogeneity	Uncertainty
The consumption channel	Pass-throughs	Short to medium term	All	Monetary	Small	High
	Production responses by firms	Short to long term	All	Monetary	Small	High
	Leakages, including through trade and incomplete coverage of carbon pricing schemes	Short term	All	Monetary	Small	Low
	Demand responses by consumers	Short to medium term	All	Monetary	Medium	High (with respect to how demand responses vary by different groups)
The income channel	Destruction of brown jobs	Short to long term	Areas where fossil-fuel industries are concentrated	Monetary	Large	Medium
	Creation of green jobs	Short to long term	Not necessarily in the same areas where brown jobs are lost	Monetary	Large	High
	Income gain due to climate improvements	Long term	Climate vulnerable areas	Monetary	Large	High
	Structural changes in factor income and demand for skills	Short to long term	All	Monetary	Medium	High
The health channel	Reduction in air pollution	Short to long term	Areas that are currently most affected (e.g., urban areas and adjacent areas to coal power plants)	In-kind	Large	Medium
	Reduction in traffic-related injuries and fatalities	Short to long term	All	In-kind	Large	Medium
The revenue recycling channel	Tax cuts	Short-term	All	Monetary	Small	Medium (with respect to CIT)
	Boosting public investment in human capital and infrastructure	Medium to long term	Targeted areas	Monetary/in-kind	Large	High
	Targeted or universal cash transfers	Short-term	All	Monetary	Small	Low

Source: author's assessments.
Note: the assessments here are illustrative, given that the evidence is still emerging, and the findings often vary significantly across studies.

V. IMPLICATIONS OF THE CHANNELS FOR POLICY DESIGNS AND LESSONS FROM COUNTRY EXPERIENCES

Climate actions are urgent, and many countries have introduced or are planning to unreal their carbon pricing schemes. Therefore, designs of climate policies cannot wait for the knowledge gaps to be closed and need to be based on existing evidence. Policy tools (e.g., cash transfers[15] and public investment in education and healthcare) are generally available to policymakers in mitigating the poverty and distributional impacts of carbon pricing, and here are some general considerations in designing such policies, based on available evidence on the different channels and their attributes:

First, the poverty and distributional impacts of carbon pricing are complex, involving many channels. It would thus be challenging to reflect and model all the channels in policy analysis. The relative importance of each channel also likely depends on country-specific conditions and the designs of carbon pricing schemes. One viable strategy is to focus on the key channels in the detailed policy analysis and in the design of policy measures for any given country or region, after a preliminary review of all the channels. However, it is important to recognize that the channels are often not independent of each other, and the modeling would need to take into account their linkages. For example, with partial pass-through, the portion that is passed backward in lower prices for firms would need to be distributed between capital and labor on the source-side. Also production responses by firms not only can help reduce consumer prices, but also can alter factor prices for labor and capital.

Second, in the absence of mitigating measures, a carbon pricing reform may initially worsen poverty and inequality as the immediate effects dominate (for example, through the consumption channel), and the impacts may gradually improve as the income channel starts to take effect. This suggests the need to initially focus on short- to medium-term effects in the designing of mitigating measures, which can help both garner political support for carbon pricing reforms and protect the wellbeing of the most vulnerable. Such measures could be gradually phased out over time.

Third, policy designs should go beyond the averages. There are large variations within income groups, and such variations may by associated with household characteristics such as race and region. Targeted measures, if administrative capacity allows, should be considered to assist specific populations that are particularly affected.

Fourth, the findings may also imply that the design of policy responses should start with the channels that are better understood with their impacts less uncertain. Gradually, the design could be adjusted as new evidence emerges including from reform experiences of other countries. The policy designs may also error on overcompensating rather than

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[15] Many countries have expanded their social protection programs, particularly cash transfer programs, in response to the COVID impact on households (https://documents.worldbank.org/en/publication/documents-reports/documentdetail/281531621024684216/social-protection-and-jobs-responses-to-covid-19-a-real-time-review-of-country-measures-may-14-2021; accessed May 19, 2021).

undercompensating the most vulnerable, given the uncertainties on the effects of some channels.

More specifically, policy designs would typically depend on policy objectives, available policy instruments, administrative capacity, and political environment.

Generally, cash transfers are the most effective tool to *protect the most vulnerable*:

- Targeted transfers based on means-testing are generally most cost-effective but require strong administrative capacity. For countries with strong social safety nets, the impacts through the consumption channel can help set the eligibility criteria and the benefit level for social safety nets under carbon pricing, while the income channel can help inform the number of beneficiaries and fiscal cost. The social safety nets can be gradually adjusted to take into account the timing of the impacts from different channels.

- For countries without strong social safety nets, as they build their administrative capacity, alternative targeting may be considered including categorical targeting and geographic targeting. In addition, these countries may also consider (quasi) universal cash transfers. Similarly, the different channels can help inform the designs of the transfer programs in terms of their coverage and benefit level.

- There may also be a need to make it easier for households to shift toward lower-carbon consumption, for example, by providing affordable public mass transport in regions with a high share of long-distance commuters or through government subsidies for certain appliances, such as more energy efficient cook stoves or less carbon-intensive heating systems.

Addressing inequality and garnering public support beyond protecting the most vulnerable. Political economy considerations may require compensating a large share of the population, at least in the short run. Again, the channels can help inform coverage and benefit level, including phasing if chosen. Below are two potential designs, and their efficiency and distributional impacts should be carefully evaluated:

- Universal cash transfers. This can help protect the poor, while also allowing some offset of the impact of carbon pricing on middle-income households and even high-income households.
- Reductions in taxes, such as labor taxes, coupled with targeted cash transfers for low- and possibly also middle-income households. Similarly, under such a design, most if not all households receive some compensation from carbon revenues.

Compensating some of those who are severely affected beyond social safety nets. Understanding the channels can help identify groups that would be heavily affected by carbon pricing and may also be politically vocal. For workers whose livelihoods depend on fossil fuels, assistance will likely be appropriate to help them transition to new jobs, and this can also help enhance the political viability of carbon pricing. While the exact design would depend on country circumstances, measures for displaced workers could center around extended unemployment benefits, training and re-employment services, and financial assistance related to job search, relocation, and healthcare.

Support to affected regions may also be considered. Closures of extractive industries often take a toll on communities with limited alternative employment opportunities, and declining home values make it difficult for people to move. Assistance for reclaiming abandoned mining and drilling sites and temporary budget support for local governments could help create jobs and bridge the transition for adversely affected communities. Additional investments or other geographically targeted policies may also be warranted to help the regions engage in economically viable and sustainable opportunities.

Many countries have introduced carbon pricing, some of which have taken effect for decades. Their experiences could provide useful lessons. Table 3 summarizes the reform experiences of seven carbon pricing schemes (British Columbia, China, Colombia, France, Singapore, South Africa, and Sweden).

- All schemes adopted a gradual approach to carbon pricing reforms, which allows firms and households time to adjust. Caron pricing of several recent schemes starts at very low levels, and this may reflect uncertainty about its impacts (e.g., China, Colombia, Singapore, and South Africa).[16] In South Africa, the effective rate is only US$0.3-1.20 per ton of CO_2 due to exemptions and offset allowances (World Bank, 2020).

- Nearly all schemes include some measures to soften the impact on firms. However, no scheme has implemented border carbon adjustments thus far. This includes tax cuts (British Columbia), exemptions (Colombia, France, South Africa), and low initial carbon tax rate (Singapore and Sweden). In the case of China, while no information is available on support to firms, the impact on firms could potentially be mitigated through the highly regulated electricity tariffs (Supponen and others, 2020). The support to firms would also have implications on poverty and inequality through the leakage channel.

- Only some countries introduced measures to support households. This may partially reflect the very low effective levels of carbon pricing in some cases (e.g., China, Colombia, and South Africa). In South Africa, the carbon tax scheme will not have any impact on electricity prices in the first phase, and in China, electricity tariffs are regulated.

- France's experience in suspending the increase in carbon tax in 2018 following a public backlash highlights the political sensitivity of carbon pricing reforms and the need to address their poverty and inequality implications.

[16] A review of the South African carbon tax scheme will be conducted before the second phase. Future changes to rates and tax-free thresholds in the carbon tax will follow after the review (https://www.iea.org/policies/3041-south-african-carbon-tax; accessed May 19, 2021). Singapore is currently reviewing its carbon tax level and will announce the outcome of the review in 2022.

Table 3. Country Experiences in Designing Carbon Pricing Schemes

Country	Reform description	Household support	Firm support	Revenue use
British Columbia (BC)	The carbon tax applies to the purchase and use of fossil fuels and covers around 70 percent of provincial greenhouse gas emissions. Introduced on July 1, 2008 at US$10 per ton of CO_2, raised to US$36 on April 1, 2021, and is scheduled to increase to US$40 on April 1, 2022.	Tax credit to offset the impact of the carbon taxes paid by low- and middle-income individuals and families; progressive PIT cuts; and tax credits and transfers targeted at various groups.	CIT cuts, particularly for small businesses; tax cuts and credits for targeted uses (e.g., training and scientific research)	The BC carbon tax is designed to be revenue neutral, in the sense that all revenues raised are to be recycled to households and businesses, largely in the form of tax cuts. In practice, there have been some deviations.
China	The China national ETS (to be launched in 2021) initially covers only the power sector. Its coverage is expected to be gradually expanded to other sectors.	No information available. However, electricity tariffs in China are highly regulated.	No information available on any support for power-sector firms. For other firms, electricity tariffs in China are highly regulated.	No revenue gain due to free allowance allocation
Colombia	An economy-wide carbon tax at US$5 per ton on all liquid and gaseous fossil fuels used for combustion introduced in 2017 and planned to be gradually increased to US$11 per ton.	No information available	Exemptions apply to natural gas consumers that are not in the petrochemical and refinery sectors, and fossil fuel consumers that are certified to be carbon neutral.	Revenue from the Colombia carbon tax is earmarked for the Colombia in Peace Fund, which supports activities such as watershed conservation, ecosystem protection, and coastal erosion management.
France	Carbon tax introduced on non-ETS emissions in 2014. Rates were initially set at US$8 per ton, and rose to US$36 per ton in 2017, and were on a trajectory to reach to US$97 per ton in 2022. Ramping up of tax suspended at around $50 per ton in 2018.	A compensation scheme was introduced in 2015 to provide financial assistance for low-income households on their energy bill.	Agriculture, taxis and trucks are exempted from the carbon tax to protect their competitiveness.	While in general France does not earmark revenues, the reform was accompanied by some support to energy transition, financial assistance to low-income households, and broad tax reductions.
Singapore	Carbon tax, applying to all large emitters and covering about 80 percent of total emissions, is set at US$4 per ton from 2019 to 2023, with plans to increase to around US$8-11 by 2030.	Improving energy efficiency of public housing; supporting low-income households in purchasing more energy efficient appliances; and ensuring that consumers are not over-charged by electricity retailers	Starting at a low level takes into account the potential impact on competitiveness.	Support initiatives to address climate change such as incentives for energy efficiency improvements in the industrial sector.
South Africa	With two phases: 2019-2022 and after 2022. The carbon tax rate was US$7 per ton in 2020 and will increase until 2022 by CPI plus two percent annually. After 2022, only inflation adjustments are envisioned. The tax applies to industry, power, buildings and transport sectors irrespective of the fossil fuel used.	The introduction of the carbon tax will not have any impact on the price of electricity for the first phase.	Exemptions and offset allowances vary by sector (e.g., trade-exposed companies receive additional allowances). Companies could receive tax-free allowances ranging 60-95 percent of their emissions, reducing the effective tax rate to US$0.3-1.20 per ton.	The tax will go to the general budget. There is indication that most carbon tax revenues will be used to prevent an increase in the price of electricity during the first phase of the carbon tax. Any leftover revenues will fund new energy efficiency initiatives via the budget process.
Sweden	Carbon tax on motor fuels and heating fuels introduced in 1991 at US$28 per ton (industries covered by the EU ETS are excluded) and increased to US$133 per ton by 2019. Lower rate for industry (at US$7 per ton in 1991) was phased out by 2018.	Social transfers and increased basic income tax reductions for low- and middle-income households were adopted to address undesirable distributional consequences of the carbon tax.	A lower initial rate for industry (at US$7 per ton) and the adjustments during following years take into account competitiveness concerns.	Carbon tax revenues go to the general budget. General budget funds may be used for specific purposes linked to the carbon tax, such as addressing undesirable distributional consequences of taxation or financing other climate-related measures, including cuts in income and labor taxes and investment in public transportation.

Sources: Fiscal Monitor, 2019; World Bank, 2020; author's assessments.
Note: EU ETS = European Union Emissions Trading System.

VI. Conclusion

Both the policymaking and the research communities alike have realized that policy designs to address the poverty and distributional impacts of carbon pricing should be an integral part of carbon pricing reform packages. This is important not only from a political economy perspective to ensure public support for carbon pricing reforms, but also from the perspective of protecting the wellbeing of the most vulnerable groups.

Numerous studies have emerged over recent years on the issue, and it is not surprising that there are different views on whether carbon pricing is progressive or regressive. While some disagreements reflect healthy debates over the issue, at least part of the disagreements may be due to the fact that different studies often focus on different subsets of the many channels.

This paper uses a simple framework to systemically review the channels through which carbon pricing may affect poverty and inequality, with the hope to assist both the policymaking and the research communities to better understand current state of the literature and to best utilize existing knowledge in designing effective and efficient policies. The framework includes four main channels: the consumption channel, the income channel, the health channel, and the revenue recycling channel, with sub-channels embedded within the main channels. The review indicates that despite the rapid development in the literature, there are still significant gaps, particularly related to firm responses to carbon pricing, structural changes in factor income, and leakages through trade and exemptions. Furthermore, the paper finds that the channels differ in important ways, including the timing, place, nature, heterogeneity, and uncertainty of their impacts. As such, a blanket assessment on whether carbon pricing is progressive or regressive lumps together the effects from channels with different attributes, could be misleading, and is not informative in designing effective and efficient policy responses.

As countries continue to roll out their carbon pricing schemes to meet their Nationally Determined Contributions (NDCs) under the Paris climate agreement, the analysis of the channels offers several considerations in addressing the poverty and inequality impacts of carbon pricing: (i) focusing on the channels that are most relevant given country-specific conditions as it would be challenging to consider all the channels; (ii) focusing initially on the channels that have short- to medium-term effects; (iii) policy designs should go beyond the averages due to large variations within income groups; and (iv) the findings may also imply that the design of policy responses should start with the impacts that are better understood and less uncertain.

While many countries are taking steps to introduce carbon pricing schemes, the levels of carbon pricing have tended to be very low. This may partly reflect policymakers' concerns over the uncertain impacts of carbon pricing schemes, particularly on households and firms, as a number of countries have taken a review-and-reevaluate approach. Climate actions are urgent, and countries need to take more ambitious steps in the fight against climate change. To do so, the policymaking and the research communities need to work closely together, to exchange information, close the knowledge gaps, and use existing knowledge to the fullest extent in policy designs.

REFERENCES

Acemoglu, Daron, Philippe Aghion, Leonardo Bursztyn, and David Hemous, 2012, "The Environment and Directed Technical Change," American Economic Review, 102(1): 131–166.

Aghion, Philippe, Antoine Dechezlepretre, David Hémous, Ralf Martin, and John Van Reenen, 2016, "Carbon Taxes, Path Dependency, and Directed Technical Change: Evidence from the Auto Industry," Journal of Political Economy, 124(1):1–51.

Anderson, Barry, Frank Convery, and Corrado Di Maria, 2011, "Technological Change and the EU ETS: The Case of Ireland," IEFE working paper 43.

Babecký Jan, Philip Du Caju, Theodora Kosma, Martina Lawless, Julián Messina, and Tairi Rõõm, "Downward Nominal and Real Wage Rigidity: Survey Evidence from European Firms," Working Paper Series No. 1105, European Central Bank.

Beck, Marisa, Nicholas Rivers, Randall Wigle, and Hidemichi Yonezawa, 2015, "Carbon Tax and Revenue Recycling: Impacts on Households in British Columbia," Resource and Energy Economics, Vol. 41: 40–69.

Borghesi, Simone, Francesco Crespi, Alessio D'Amato, Massimiliano Mazzanti, and Francesco Silvestri, 2015, "Carbon Abatement, Sector Heterogeneity and Policy Responses: Evidence on Induced Eco Innovations in the EU," Environmental Science & Policy (54): 377–388.

Boyce, James, and Manuel Pastor, 2013, "Clearing the Air: Incorporating Air Quality and Environmental Justice into Climate Policy," Climatic change, 120 (4): 801–814.

Burke, Paul, and Shuhei Nishitateno, 2015, "Gasoline Prices and Road Fatalities: International Evidence," Economic Inquiry 53 (3): 1437–50

Calel, Raphael, and Antoine Dechezleprêtre, 2016, "Environmental Policy and Directed Technological Change: Evidence from the European Carbon Market," Review of Economics and Statistics, 98(1): 173–191.

Cao, Jing, Mun Ho, and Rong Ma, 2020, "Analyzing Carbon Pricing Policies Using a General Equilibrium Model with Production Parameters Estimated Using Firm Data," Energy Economics, 92.

Carattini, Stefano, Steffen Kallbekken, and Anton Orlov, 2019, "How to Win Public Support for a Global Carbon Tax," Nature 565, 289–291.

Coady, David, Moataz El-Said, Robert Gillingham, Kangni Kpodar, Paulo Medas, and David Newhouse, 2006, "The Magnitude and Distribution of Fuel Subsidies: Evidence from Bolivia, Ghana, Jordan, Mali, and Sri Lanka," IMF Working Paper WP/06/247, International Monetary Fund.

Coady, David, Ian Parry, Louis Sears and Baoping Shang, 2017, “How Large Are Global Fossil Fuel Subsidies?” World Development, 91: 11–27.

Coady, David, Ian Parry, and Baoping Shang, 2018, “Energy Price Reform: Lessons for Policymakers,” Review of Environmental Economics and Policy, Vol. 12, Issue 2: 197–219.

Coady, David, and Allan Dizioli, 2018, “Income Inequality and Education Revisited: Persistence, Endogeneity and Heterogeneity,” Applied Economics, Volume 50, Issue 25: 2747–2761.

Coady, David, and Nghia-Piotr Le, 2020, “Designing Fiscal Redistribution: The Role of Universal and Targeted Transfers,” Working Paper No. 20/105, International Monetary Fund.

Cushing, Lara, Dan Blaustein-Rejto, Madeline Wander, Manuel Pastor, James Sadd, Allen Zhu, and Rachel Morello-Frosch, 2018, “Carbon Trading, Co-Pollutants, and Environmental Equity: Evidence from California’s Cap and Trade Program (2011–2015),” PLoS medicine, 15(7).

da Silva Freitas, Lucio Flavio, Luiz Carlos de Santana Ribeiro, Kênia Barreiro de Souza, and Geoffrey John Dennis Hewings, 2016, "The Distributional Effects of Emissions Taxation in Brazil and Their Implications for Climate Policy," Energy Economics, Vol. 59(C): 37–44.

Dimitropoulos, Alexandros, Walid Oueslati, and Christina Sintek, 2018 “The Rebound Effect in Road Transport: A Meta-Analysis of Empirical Studies,” Energy Economics 75: 163–79.

Dissou, Yazid, and Muhammad Shahid Siddiqui, 2014, “Can Carbon Taxes Be Progressive?” Energy Economics 42 (2014) 88–100.

Dorband, Ira Irina, Michael Jakob, Matthias Kalkuhl, and Jan Christoph Steckel, 2019, “Poverty and Distributional Effects of Carbon Pricing in Low- and Middle-Income Countries—A Global Comparative Analysis,” World Development 115: 246–257.

Dussaux, Damien, 2020, “The Joint Effects of Energy Prices and Carbon Taxes on Environmental and Economic Performance: Evidence from the French Manufacturing Sector,” OECD Environment Working Papers, No. 154.

EEA, 2018, “Unequal Exposure and Unequal Impacts: Social Vulnerability to Air pollution, Noise and Extreme Temperatures in Europe,” European Environmental Agency Report No 22/2018.

Ellis, Jane, Daniel Nachtigall, and Frank Venmans, 2019, “Carbon Pricing and Competitiveness: Are they at Odds?” Environment Working Paper No. 152, OECD.

Elsby, Michael, and Gary Solon, 2019, "How Prevalent Is Downward Rigidity in Nominal Wages? International Evidence from Payroll Records and Pay Slips." Journal of Economic Perspectives, 33 (3): 185-201.

Fabra, Natalia, and Mar Reguant, 2014, "Pass-Through of Emissions Costs in Electricity Markets," American Economic Review 104(9), 2872–2899.

Fiscal Monitor, 2019, "How to Mitigate Climate Change," International Monetary Fund (Washington D.C.).

Frondel, Manuel, Nolan Ritter, and Colin Vance, 2012, "Heterogeneity in the Rebound Effect: Further Evidence for Germany," Energy Economics, Volume 34, Issue 2: 461–467.

Fullerton, Don, and Garth Heutel, 2010, "Analytical General Equilibrium Effects of Energy Policy on Output and Factor Prices," The B.E. Journal of Economic Analysis & Policy, Volume 10, Issue 2 (Symposium), Article15.

Fuest, Clemens, Andreas Peichl, and Sebastian Siegloch, 2018, "Do Higher Corporate Taxes Reduce Wages? Micro Evidence from Germany," American Economic Review, Volume 108, No. 2: 393–418.

Furceri, Davide, and Bin Grace Li, 2017, "The Macroeconomic (and Distributional) Effects of Public Investment in Developing Economies," IMF Working Paper WP/17/217, International Monetary Fund (Washington D.C.).

Ganapati, Sharat, Joseph Shapiro, and Reed Walker, 2020, "Energy Cost Pass-Through in US Manufacturing: Estimates and Implications for Carbon Taxes," American Economic Journal: Applied Economics, 12(2): 303–342.

Gerber, Claudia, Alexander Klemm, Li Liu, and Victor Mylonas, 2020, "Income Tax Progressivity: Trends and Implications," Oxford Bulletin of Economics and Statistics, Volume 82, Issue 2: 365–386.

Gillingham, Kenneth, Matthew Kotchen, David Rapson, and Gernot Wagner, 2013, "The Rebound Effect is Overplayed," Nature 493, 475–476.

Goulder, Lawrence, and Marc Hafstead, 2017, *Confronting the Climate Challenge*, New York: Columbia University Press.

Goulder, Lawrence, Marc Hafstead, GyuRim Kim, and Xianling Long, 2019, "Impacts of a Carbon Tax across US Household Income Groups: What Are the Equity-Efficiency Trade-Offs? Journal of Public Economics 175 (2019) 44–64.

Grabowski, David, and Michael Morrisey, 2004, "Gasoline Prices and Motor Vehicle Fatalities," Journal of Policy Analysis and Management 23(3):575–593.

Gugler, Klaus, Adhurim Haxhimusa, and Mario Liebensteiner, 2021, “Effectiveness of Climate Policies: Carbon Pricing vs. Subsidizing Renewables.” Journal of Environmental Economics and Management 106.

Hallegatte, Stéphane, 2019, “Listening to the Streets: The Political Economy of Climate Policy,” World Bank blog, 5 December.

Hille, Erik, and Patrick Möbius, 2019, “Do Energy Prices Affect Employment? Decomposed International Evidence,” Journal of Environmental Economics and Management, Vol. 96:1–21.

Hsiang, Solomon, Paulina Oliva, and Reed Walker, 2019, “The Distribution of Environmental Damages,” Review of Environmental Economics and Policy, Vol. 13, Issue 1: 83–103.

Hoffmann, Volker, 2007, “EU ETS and Investment Decisions: The Case of the German Electricity Industry,” European Management Journal 25: 464–474.

International Energy Agency (IEA), 2018, “World Energy Outlook,” International Energy Agency.

Jaffe, Adam, Richard Newell, and Robert Stavins, 2002, “Environmental Policy and Technological Change,” Environmental and Resource Economics, Volume 22: 41–70.

Jaffe, Adam, Richard Newell, and Robert Stavins, 2004, “Economics of Energy Efficiency,” Encyclopedia of Energy, Volume 2: 41–70.

Karlsson, Mikael, Eva Alfredsson, and Nils Westling, 2020, “Climate Policy Co-Benefits: A Review,” Climate Policy, Volume 20, Issue 3: 292–316.

Kaur, Supreet, 2019, "Nominal Wage Rigidity in Village Labor Markets." American Economic Review, 109 (10): 3585-3616.

Klenert, David, Linus Mattauch, Emmanuel Combet, Ottmar Edenhofer, Cameron Hepburn, Ryan Rafaty and Nicholas Stern, 2018, “Making Carbon Pricing Work for Citizens,” Nature Climate Change 8: 669–677.

Kotchen, Matthew, 2021, “The Producer Benefits of Implicit Fossil Fuel Subsidies in the United States,” Proceedings of the National Academy of Sciences, 118 (14).

Kpodar, Roland, Stefania Fabrizio, and Kodjovi Eklou, 2019, "Export Competitiveness - Fuel Price Nexus in Developing Countries: Real or False Concern?" IMF Working Papers 2019/025, International Monetary Fund.

Lilliestam, Johan, Anthony Patt, and Germán Bersalli, 2021, “The Effect of Carbon Pricing on Technological Change for Full Energy Decarbonization: A Review of Empirical Ex-Post Evidence,” WIREs Climate Change, Volume12, Issue1.

Marin, Giovanni, and Francesco Vona, 2019, “Climate Policies and Skill-Biased Employment Dynamics: Evidence from EU Countries,” Journal of Environmental Economics and Management, Vol. 98.

Marion, Justin, and Erich Muehlegger, 2011, “Fuel Tax Incidence and Supply Conditions,” Journal of Public Economics, Volume 95, Issues 9–10, October 2011, Pages 1202–1212.

Martin, Ralf, Mirabelle Muûls, and Ulrich Wagner, 2011, “Climate Change, Investment and Carbon Markets and Prices: Evidence from Manager Interviews,” Climate Strategies, Carbon Pricing for Low-Carbon Investment Project.

Metcalf, Gilbert, 2009, “Designing a Carbon Tax to Reduce U.S. Greenhouse Gas Emissions,” Review of Environmental Economics and Policy, Vol. 3, Issue 1: 63–83.

Metcalf, Gilbert, 2019, "On the Economics of a Carbon Tax for the United States," Brookings Papers on Economic Activity, (Spring): 405–458.

Metcalf, Gilbert, and James Stock, 2020, “The Macroeconomic Impact of Europe’s Carbon Taxes,” NBER Working Paper 27488, National Bureau of Economic Research.

Miller, Nathan, Matthew Osborne, and Gloria Sheu, 2017, “Pass-Through in a Concentrated Industry: Empirical Evidence and Regulatory Implications,” The RAND Journal of Economics, 48 (1): 69–93.

Mirzoev, Tokhir, Ling Zhu, Yang Yang, Tian Zhang, Erik Roos, Andrea Pescatori, and Akito Matsumoto, 2020, “The Future of Oil and Fiscal Sustainability in the GCC Region,” Departmental Paper No. 2020/001, International Monetary Fund.

Morris, Adele, 2016, “Build a Better Future for Coal Workers and Their Communities,” Brookings Institution, Washington, D.C.

Moshiria, Saeed, and Miguel Alfonso Martinez Santillan, 2018, “The Welfare Effects of Energy Price Changes Due to Energy Market Reform in Mexico,” Energy Policy, Vol. 113: 663–672.

Muller, Christophe, and Huijie Yan, 2018, “Household Fuel Use in Developing Countries: Review of Theory and Evidence,” Energy Economics, Vol. 70: 429–439.

Nallareddy, Suresh, Ethan Rouen, and Juan Carlos Suárez Serrato, 2018, "Do Corporate Tax Cuts Increase Income Inequality?" NBER Working Papers 24598, National Bureau of Economic Research.

Parry, Ian, Margaret Walls, and Winston Harrington, 2007, “Automobile Externalities and Policies,” Journal of Economic Literature, 45 (2): 373–399.

Parry, Ian, Dirk Heine, Eliza Lis, and Shanjun Li, 2014, *Getting Energy Prices Right: From Principle to Practice*, International Monetary Fund (Washington D.C.).

Parry, Ian, 2019, "Putting a Price on Pollution," Finance & Development 56(4): 16–19.

Parry, Ian, Baoping Shang, Philippe Wingender, and Nate Vernon, 2020, "Evaluating Policies to Implement the Paris Agreement: A Toolkit with Application to China," *Handbook on the Economics of Climate Change*, Graciela Chichilnisky and Armon Rezai, editors, Edward Elgar Press.

Pearce, David, 1991, "The Role of Carbon Taxes in Adjusting to Global Warming," The Economic Journal, 101(407), 938–948.

Petsonk, Annie, and Jos Cozijnsen, 2007, "Harvesting the Low-Carbon Cornucopia: How the European Union Emissions Trading System (EU-ETS) Is Spurring Innovation and Scoring Results," Environmental Defense Fund.

Pizer, William, and Steven Sexton, 2019, "The Distributional Impacts of Energy Taxes," Review of Environmental Economics and Policy, Vol. 13, issue 1: 83–103.

Rausch, Sebastian, Gilbert Metcalf, John Reilly, and Sergey Paltsev, 2010, "Distributional Implications of Alternative U.S. Greenhouse Gas Control Measures," B.E. Journal of Economic Analysis & Policy, Volume 10, Issue 2 (Symposium), Article1.

Rausch, Sebastian, Gilbert Metcalf, and John Reilly, 2011, "Distributional Impacts of Carbon Pricing: A General Equilibrium Approach with Micro-Data for Households," Energy Economics, Vol. 33, Supplement 1: S20-S33.

Rentschler, Jun, and Morgan Bazilian, 2017, "Policy Monitor—Principles for Designing Effective Fossil Fuel Subsidy Reforms," Review of Environmental Economics and Policy, Vol. 11, Issue 1: 138–155.

Sager, Lutz, 2019, "The Global Consumer Incidence of Carbon Pricing: Evidence from Trade," Grantham Research Institute on Climate Change and the Environment Working Paper No. 320.

Stolper, Samuel, 2016, "Who Bears the Burden of Energy Taxes? The Critical Role of Pass-Through," Harvard Environmental Economics Program Discussion Paper 16–7.

Supponen, Matti, Qing Xia, Qixin Chen, and Nan Jiang, 2020, "Electricity Markets and Systems in the EU and China," EU-China Energy Cooperation Platform (ECECP).

Tavares, Marina, forthcoming, "Carbon Pricing Winners and Losers: Workers, Consumers, and Policy Options," IMF Working Paper, International Monetary Fund.

Tessum, Christopher, Joshua Apte, Andrew Goodkind, Nicholas Muller, Kimberley Mullins, David Paolella, Stephen Polasky, Nathaniel Springer, Sumil Thakrar, Julian Marshall, and Jason Hill, 2019, "Inequity in Consumption of Goods and Services

Adds to Racial-Ethnic Disparities in Air Pollution Exposure," Proceedings of the National Academy of Sciences, 116 (13): 6001–6006.

Tomás, Rogério, Ramoa Ribeiro, V.M.S. Santos, João Bordado, and Joao Bordado, 2010, "Assessment of the Impact of the EuropeanCO2 Emissions Trading Scheme on the Portuguese Chemical Industry," Energy Policy 38: 626–632.

UNFCCC, 2016, Paris Agreement, United Nations Framework Convention on Climate Change (New York City, NY).

UNFCCC, 2018, Nationally Determined Contributions (NDCs). United Nations Framework Convention on Climate Change (New York City, NY).

West, Sarah, and Roberton Williams III, 2004, "Estimates from a Consumer Demand System: Implications for the Incidence of Environmental Taxes," Journal of Environmental Economics and Management, Volume 47, Issue 3, Pages 535–558.

Weyl, Glen, and Michal Fabinger, 2013, "Pass-Through as an Economic Tool: Principles of Incidence under Imperfect Competition," Journal of Political Economy 121(2), 528–583.

World Bank, 2004, "Sustaining Forests: A Development Strategy," World Bank, Washington DC.

World Bank, 2020, State and Trends of Carbon Pricing 2020 (Washington, DC: World Bank).

World Economic Outlook, 2020, "Mitigating Climate Change—Growth- and Distribution-Friendly Strategies," International Monetary Fund (Washington D.C.).

Yamazaki, Akio, 2017, "Jobs and Climate Policy: Evidence from British Columbia's Revenue-Neutral Carbon Tax." Journal of Environmental Economics and Management (83): 197–216.

Zhu, Junming, Yichun Fan, Xinghua Deng, and Lan Xue, 2019a, "Low-Carbon Innovation Induced by Emissions Trading in China," Nature Communications, 10(1): 1–8.

Zhu, Xing, Lanlan Li, Kaile Zhou, Xiaoling Zhang, and Shanlin Yang, 2019b, "A Meta-Analysis on the Price Elasticity and Income Elasticity of Residential Electricity Demand," Journal of Cleaner Production, Vol. 201: 169–177.

Zwickl, Klara, Michael Ash, and James Boyce, 2014, "Regional Variation in Environmental Inequality: Industrial Air Toxics Exposure in US Cities," Ecological Economics 107: 494–509.