

The Distributional Impacts of Carbon Pricing on Households: A Literature Review

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Abstract. Assessing macroeconomic impacts is essential to the design of cost-effective market-based environmental policies. As carbon pricing instruments (CPIs) take the center of the stage for emission abatement, their regressive nature gains attention and becomes a potential political obstacle to their implementation. Numerous studies analyze the distributional impacts of CPIs in individual jurisdictions and obtain various results, but there lacks an integrated view of patterns and variations of the results. By reviewing existing literature, this study finds that CPIs are generally regressive in developed countries with a few exceptions. For developing countries, no unanimous outcome is reached, but the results could be generalized into predictable patterns given the economic structures of the jurisdictions and designs of CPIs.

Keywords: Carbon pricing; emission reduction; distributional impacts; environmental policies.

1. Introduction

The IPCC Sixth Assessment Report [1] estimates that the net anthropogenic greenhouse gas (GHG) emissions have caused an increase in global temperature of 1.1°C above the pre-industrial level. Average GHG emissions during the last decade hit the highest historical record [2], and the global temperature increase is expected to exceed 2.1°C by 2100 even if all current mitigation pledges are achieved [3]. Thus, following the goal of 2015 Paris Agreement to restrain temperature increase within 1.5°C, global GHG emissions should be slashed by 43% with drastic policy progress [4]. Jurisdictions across the globe are taking steps forward to implement various emission reduction policies, among which the most cost-effective ones are carbon pricing policies.

Carbon pricing is a market-based approach that “puts a price on carbon emissions”, which gives firms and households involved in carbon-related transactions an economic incentive to reduce carbon emission by limiting demand or investing more in research and development for energy-efficient technologies. CPIs include direct CPIs, carbon taxations and emissions trading systems (ETS), as well as indirect CPIs, energy taxes (such as a general fuel tax and gasoline tax), which are not directly proportional to the carbon contents of output yet still able to increase the cost of emission. Currently, there are 68 CPIs implemented worldwide, covering 23% of total GHG emissions [3]. David Gordon Wilson was the forerunner to propose the approach of a carbon tax in 1973 [5]. However, earnest debates over the use of CPIs only started in 1990 when Finland first began to tax GHG emissions. Unanimous agreements on carbon pricing’s effectiveness in emission reduction are reached among scholars, followed by numerous studies studying the macroeconomic impacts. However, the redistribution effects of carbon pricing vary across jurisdictions with various economic structures and population stratification. Early studies [6,7] mostly settle on the regressivity of carbon pricing, whereas progressive and distributional results emerge as CPIs start to prevail across the world. Ohlendorf et al. [8] draw from a meta-analysis the greater likelihood of progressivity for low-income countries and the transportation sector. Wang et al. [9] review the literature on redistribution effects of the carbon tax across both households and industries but leaving out the impacts of ETS and fuel tax which are more commonly used in low income countries. Therefore, there still lacked an integrated view linking the distributional impacts with characteristics of jurisdictions. This paper reviews existing literature studying the distributional effects of CPIs, attempting to shed light on the general trends of impacts on countries with similar economic structures and expenditure patterns, examining cases of outliers, and exploring reasons for the patterns and variations.

The rest of the paper is structured as follows. Section 2 elaborates on the mechanisms and status quo of three main types of CPIs. Section 3 presents an integrated view on distributional impacts of CPIs across households in jurisdictions across the world. Section 4 identifies loopholes in current studies. Section 5 concludes the study, discusses policy implications, and offers suggestions for future research.

2. An Overview of Carbon Pricing Instruments

2.1 Carbon tax

A carbon tax is a fee charged on the combustion of fossil fuels during production to lower GHG emissions. It is a Pigouvian tax to correct market failures when there is a difference, the external cost, between the marginal social and private cost [10]. In the case of carbon emission, market failure occurs because of an externality (detrimental effects of global warming) incurred on the third party not involved in the transaction. There is an external cost because the marginal social cost of combusting fossil fuel is larger than the private cost; energy-intensive goods are thus overproduced. A carbon tax raises the cost of emission and internalizes the detrimental effect on the environment. As the price is higher, emissions would be lowered, restoring the emission back to the socially optimal level. The carbon tax also acts as an economic incentive for firms to switch to cleaner energy and to develop less carbon-intensive production technologies. On top of eliminating the external cost of carbon, the design of the environmental tax also considers the use of tax revenue. If the revenue is recycled in the form of lowered payroll tax, lump sum payments to households [11], or lowered food tax, the redistribution of revenue could largely moderate or even reverse the regressivity of carbon tax. The carbon tax is collected “upstream,” i.e., at stages of extraction or import of fuels. Currently, 37 jurisdictions have implemented carbon taxes, ranging from 135 USD per tonne in Uruguay to 0.08 USD per tonne in Poland [3].

2.2 Emissions trading system

Emissions trading, also known as “cap-and-trade”, mitigates emissions by putting a market-determined price on carbon emissions. The government caps the maximum volume of GHG emissions of the economy or industrial sectors by distributing the tradable allowances free or auctioning them to entities covered. Attached with scarcity, emissions thus become valuable, and a market-determined price is charged on carbon emissions. To minimize costs, emitting firms that could cut back on emissions with a cost lower than the allowance price choose to sell the surplus allowances, while those with a higher cost choose to purchase emission allowances. The price of allowances thus reflects the marginal cost of emission compliant with the maximum emission level [13]. Therefore, ETS is a flexible instrument that allows market forces to determine the emissions of each firm in an economically efficient manner. ETS contrasts with the command-and-control type of environmental policies, such as technological standards for pollution abatement and subsidies, which distort market signals more and are not necessarily consistent. Until April 2022, there are 34 ETSs in the EU and jurisdictions in North America and Asia [3].

2.3 Fuel tax

Fuel tax is an indirect CPI that raises the cost of GHG emissions in ways not proportional to the volume of carbon emissions. Examples of fuel taxes include general fuel excise tax, gasoline tax, and kerosene tax. These taxes also partially internalize the externalities of combusting fossil fuels, incentivizing lower consumption and abating carbon emissions in processes such as industrial combustion, private transportation, and home heating. Fuel taxes are more widely implemented in developing countries in Asia and South America than in developed countries. For most countries with fuel taxes, the primary reason for taxation is not to address environmental issues but to raise government revenue. However, fuel taxes are still found to significantly impact low-carbon transition processes [2].

3. Distributional Impacts Across Households

With the initiation of carbon taxes by Nordic countries in the early 1990s, carbon pricing started to gain the academia's attention. Early studies [14,15] focus on the effectiveness and economic efficiency of carbon tax, which generally suggest that carbon pricing tools are effective in emission reduction, with limited damage on economic growth. Later, Bovernburg and Goulder [16] empirically extend the previous literature in a general equilibrium setting, indicating that the environmental tax rate would be lower than optimal as suggested by the Pigouvian principle in the presence of other distortionary taxations. Around the same time, scholars shifted attention to the regressive nature of carbon pricing. Metcalf [17] uses both current and lifetime income with a 40-sector input-output model, showing that the regressive nature of environmental taxes is stark. However, the regressivity could be eliminated with a moderate progressive tax cut in the payroll tax or the personal income tax. Following Metcalf, studies assessing degrees of regressivity and determining measures of moderating its adverse impacts spring up.

To determine the distributional impacts of CPIs, the proportion of income accounted for by carbon tax, energy tax or increased product prices due to the ETS needs to be determined. If the proportion increases as the household's income increases, the carbon pricing scheme is progressive. If the proportion decreases with the household's income, the scheme is regressive. The proportion could stay constant as income rises or falls; in this case, the scheme is proportional. Carbon pricing burdens households through two channels: direct spending and indirect spending effect. The direct effect occurs when households' spending on fuels, such as coal, gasoline, and gas, rises directly because of the rising cost of upstream production. The indirect effect is due to an increment in the price of other products due to carbon pricing. These products include energy-intensive goods and services (e.g., electricity, heating, and public transportation) and all other goods.

3.1 Distributional impacts across households in developed countries are generally regressive

The academia mostly agree that carbon pricing has a regressive distributional impact on households in developed countries. Cramton and Kerr [18] conduct multiple assessments on various OECD countries. They conclude that regardless of economic structure, carbon pricing tools, and modeling techniques, carbon-related environmental policies consistently present a weak regressivity. The increases in energy and other goods prices due to carbon tax or cap-and-trade system hit low-income households more hardly, as the increase in price accounts for a larger fraction of their income. The consequent adverse effect on inequality further adds to the political obstacle to implementing CPIs, given that governments are already faced with oppositions from business actors [5].

The majority of the studies show regressive effects of CPIs in developed countries. Results in the Netherlands and Singapore present high degrees of regressivity [19]. For the United Kingdom, as estimated by Santos and Catchesides [21], low-income households and rural households are much more severely affected by an increase in the gasoline tax. The UK's carbon tax also has a high degree of regressivity. Based on the study of Feng et al. [22], the carbon tax payment accounts for 6% of the income of the lowest decile, while it only accounts for 2.4% for the highest decile. The intuitive explanation for the regressivity is that carbon-intensive goods such as electricity, heating, and transportation fuels are essential expenditures that constitute a greater fraction of poorer households' income or expenditure, compared to that of richer households who spend proportionally more on discretionary expenditures (such as luxuries, entertainment and vacations). An increase in the price of those carbon-intensive products thus burdens the poorer households more. On top of this universally applicable reason, Feng adds that the regressivity also arises from the heterogeneity of households in rural and urban areas in the UK. Rural households tend to travel a longer distance for commuting or to community facilities; they are also more densely dwelled in higher latitude areas of the UK where more heating is required in the winter. Thus, rural households, generally the poorer ones, spend more on carbon-intensive goods, even in absolute terms. Similarly, in America, the price impact of operating the ETS equals to about 5% of the lowest quintile households' income but less than 2% of the highest quintile households' income [23]. The poorer households bear a greater burden

of carbon pricing, but the carbon emission of their consumption only constitutes 20% of total emissions, while that of the highest quintile constitutes 50%. Mathur and Morris [24] also confirm the regressive effect of carbon pricing on US households' incomes; meanwhile, the regressivity is found abated using households' consumption data as a proxy for lifetime income. Most scholars [25-27] agree on the greater accuracy of using lifetime income in estimating the distributional effects, and the energy consumption is found to align with lifetime income. People tend to smooth spending across lifetimes through saving and borrowing; having low current incomes does not necessarily represent that they are poor. The elderly with low income could be well-off as they draw on their saving after retirement. Thus, assuming the observed consumer's behaviors obey such a permanent income hypothesis, expenditure could be a proxy for lifetime income.

However, there are a few outliers, such as progressive carbon pricing schemes in Denmark [28] and British Columbia [11]. Denmark has low inequality and an efficient public transportation system frequently used by poorer household groups. Moreover, the wealthier in Denmark live further from the workplace than the poorer. Thus, gasoline consumption takes up a greater proportion the richer households' income, and they are more severely affected by an increment in the gasoline tax. A plausible explanation for the progressive distributional result in British Columbia is that the heterogeneity in spending patterns of the richer and the poorer is small, i.e., there is no significant difference in the fraction of income they spend on energy-intensive goods. This is because hydro, instead of carbon, is the source of generating electricity in British Columbia.

3.2 Distributional impacts across households in developing countries do not exhibit a consistent pattern

The general regressive result cannot be replicated in developing countries because of different income sources and spending patterns of households and economic structures. The distributional impacts across households in developing countries vary depending on the specific settings of the country. Plus, as carbon taxation and cap-and-trade systems have only recently begun and have still not been extensively implemented in developing countries, the studies of distributional effects of those CPIs are still incipient. A definite conclusion on the regressivity of CPIs in developing countries cannot be drawn. Meanwhile, assessments on redistributive effects of indirect CPIs are sufficient, showing no unanimous result on the distributional issue. In Mexico, the gasoline tax in general is progressive across households, except within the highest decile [29]. The difference in vehicle ownership could explain this progressivity as opposed to previous regressive results in developed countries. Households who own vehicles in Mexico concentrate in the highest socioeconomic strata, so a gasoline tax burdens them more than the poorer households who commute by bike or public transportation. However, car ownership is more evenly distributed across households of all income groups in high-income countries. A gasoline tax thus shows regressivity in developed countries as the fraction of income that tax incidence accounts for decreases with income. Similarly, the fuel tax in India is found highly progressive [30], regardless of whether indirect effects are considered. The progressivity is eliminated when it comes to Costa Rica with a 10% hike in fuel price [31]. The fuel tax can be broken down into two components, the gasoline tax, and the diesel tax, with the former being progressive while the latter regressive. The distribution of vehicle ownership across the population could again explain this divergence. Gasoline tax burden the richer more, but diesel tax burdens the poorer more because buses that use diesel become more expensive, which are proportionally consumed more by the poorer. Combining the two opposite effects, the overall distributional impact of Costa Rica's fuel tax is proportional. Fuel tax is found to have a greater incidence on the poorer households in Pakistan [32] and display a U-shape relationship in Mali [33], such that it burdens the middle-income households the most.

Similar unanimous results of distributional impacts are drawn for carbon taxes in developing countries. The distributional effect of energy-related environmental tax in South Africa is regressive, with the carbon tax being more regressive than the fuel tax [3]. Nevertheless, when the tax revenue is recycled back to households in the form of reduced food tax, the entire scheme turns progressive

and effective in poverty reduction, because food consumption comprises a larger share of poorer households' income, and the progressivity of lowered food prices ultimately prevails. In Brazil, the carbon tax is also regressive, exacerbating the problem of inequality [20]. Opposing result is found in China that if a 42 USD per tonne's carbon tax were imposed, there will be a progressive effect across households such that the tax incidence accounts for 2.1% of the poorest income and 3.2% of the richest. This progressive effect would be further enhanced so that poverty could be reduced to as much as 20% under the sky trust system [12]. The sky trust system is a tax revenue recycling scheme rebating lump-sum to households; the equal payment entails a progressive distributional effect as its share decreases with income. It operates autonomously and independently from the government's budget due to its unique feature in asserting the common ownership of nature's wealth [23]. Jiang's study [15] on Shanghai (a municipality in China) contrasts with Brenner's highly progressive result on China as a whole [12]. In Shanghai, the direct effect of the carbon tax is slightly regressive, while the indirect effect presents a strong regressivity. These findings align with the distributional result of developed countries, which is plausible given that Shanghai is at the forefront of China's economic development. With car ownership being more prevalent than in the rest of China but not as prevalent as in other developed countries, the regressivity of direct effects of Shanghai's carbon tax lies between that of developed countries and China's overall level. While the expenditure structure is akin to developed countries, thus resulting in a similar degree of the regressivity of indirect effect. Moreover, Brenner estimates that the urban poor bear a greater tax burden than the urban rich despite the general progressivity. Policy makers should thus consider complementary policies to temper the adverse effect on the lower income quintile in urban areas. Therefore, the distributional impacts of CPIs could display significant variation within a jurisdiction; cautious and targeted assessments should be carried out for designing policies of revenue recycling or exemption schemes complementary to the carbon pricing tool.

To conclude, the distributional impacts of CPIs in developed countries are generally regressive, which holds for various carbon pricing mechanisms and methodologies and economic indicators used for analysis; the regressivity could be enhanced or partially offset by context-specific reasons or estimation methods. For example, using households' expenditure data as an estimation for lifetime income moderates the regressivity of the results. Meanwhile, outliers exist for peculiar settings of jurisdictions, such as the unique spending pattern in Denmark and the energy source of British Columbia. For developing countries, unanimous distributional impacts are not found, whereas the results could be generalized into predictable patterns given the economic structures of the jurisdictions and the spending patterns of the households. The distributional impacts could be inferred partially using indicators such as the distribution of car ownership, the change in the proportion of energy-intensive goods across income brackets, and the scheme of revenue recycling. These economic indicators are more homogenous among developed countries but vary to a greater extent among developing countries. Remarkably, they also show variations within a jurisdiction or even a population stratum.

4. Discussion of Deficiencies of Current Literature

4.1 The use of expenditure data as a proxy for lifetime income

There are a growing number of studies using lifetime income rather than current income when evaluating the distributional effects [12,13,27]. The reason for choosing lifetime income as a more accurate indicator for estimating tax incidence is that current income is subject to more variations and could move households to income groups not representative of their actual living standard [17]. Lifetime income is impossible to measure with current information, and thus studies tend to use current spending data as an estimation for lifetime income. However, Bull et al. find that current consumption and consumption of energy are, in fact, not smoothed over lifetime as the lifetime income theory assumed, but closely track a life-cycle pattern. As a result, many existing studies can possibly underestimate the regressivity as the approximation using expenditure is likely to be higher

than their actual lifetime income. Hasset [13] thus demonstrates a more accurate way of estimating the lifetime incidence instead of directly using expenditure as a proxy. They stratified the population into subsamples that may follow similar life-cycle patterns based on socioeconomic background; lifetime income is then estimated by each subsample. More accurate methods of estimation should be constructed following Hasset's example.

4.2 The narrow focus on the effects of increased product prices due to carbon pricing

Existing studies primarily focus on the direct distributional effect of carbon pricing resulting from higher prices of fuels and energy-intensive products. The distributional effect from changes in relative income of the rich and poor and the distribution of environmental benefits are often overlooked. However, these factors are significant dimensions of distributional impacts that differently burden or favor strata of populations of different socioeconomic backgrounds. For instance, CPIs can have much lower impacts on the incomes of the poorest households, because a significant share of their income is received from social transfers, which is indexed against inflation. Cost-push inflation caused by rising carbon prices disproportionately affects the poor by less, if only considering the relative changes of incomes. Thus, studies neglecting the relative effects on households' income can overstate the regressivity of carbon pricing.

5. Conclusion and Policy Suggestions

Though it has been more than three decades when European countries-imposed carbon taxes for emission mitigation, current CPIs are still insufficient in limiting global warming within the 1.5°C goal [4]. A large number of developing countries still only have indirect CPIs implemented, the primary purpose of which is not emission reduction; the minority of them (such as China, Botswana, and Malaysia) are scheduling the implementation of direct carbon pricing schemes. Even in countries with carbon taxes and ETS, the carbon prices are far less than the optimal price outlined by the world bank [3]. One of the primary reasons that hinders the implementation of CPIs is its potential regressivity that exacerbates inequality, negates the process of economic and human development, and puts the government in a politically unfavorable position. Thus, by reviewing existing literature, this study decomposes the distributional effects of carbon pricing and provides an integrated view of different determinants of distributional impacts, which could help to predict the direction of distributional impact based on the particular characteristics of the jurisdiction which is considering to implement CPIs. This literature review concludes that results on distributional effects of carbon pricing present a general regressivity in developed countries with a few exceptions, whereas the results in developing countries are not consistent. Fuel taxes varies from progressive to proportional and regressive, mainly depending on the distributions of car ownership and the designs of the tax schemes. Direct CPIs also display different degrees of progressivity or regressivity depending on economic structures and revenue recycling schemes. Nevertheless, a constraint of this study lies with the limitations of qualitative literature reviews. Thus, the suggestion for further research is to conduct quantitative literature reviews, such as meta-analyses. The systematic screening of literature and quantitative method of combining study results and determining the strength of different dimensions of distributional impacts would generate more robust conclusions.

Assessing the distributional effects alone is insufficient to consider welfare impacts during the policy-making process. Even when the carbon pricing scheme is progressive, the rising cost of carbon could result in general inflation and relative changes in returns on labor and capital [8], which may increase the risk of poverty for the lowest quintile. Assessments of effects on poverty in absolute terms should also be conducted. In sum, this literature review draws a picture of the distributional impacts of CPIs in various jurisdictions, undermining the common belief on the regressivity of carbon pricing. Therefore, regressivity is not a grounded obstacle to the implementation of CPIs. However, the distributional results are affected by various factors with varying strengths of impacts under

different scenarios. Cautious evaluation of carbon pricing policies and the complementary schemes should be made based on context-specific and finely stratified analysis.

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