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Energy Policy 180 (2023) 113672

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Assessing distributional effects of carbon pricing in Israel

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ARTICLE INFO

JEL classification:
D57
D63
Q52
Q54

Keywords:
Carbon pricing
Climate policy
Distributional effect
Inequality
Israel
Middle East and Northern Africa (MENA)

ABSTRACT

The government of Israel has announced its plan to introduce a national carbon price of ILS 130 (~USD 40) per ton of CO_2 in 2023. In this study, we analyse the subsequent distributional impacts on Israeli households. We build on the recent Household Budget Survey from 2018 compiled by the Israeli Central Bureau of Statistics and merge this data with sector-specific embedded carbon intensities derived from multi-regional input-output data. We find that without further measures a carbon price would have regressive effects on Israeli households. Using statistical analyses we show that rural households, Arab households or households that own (and use) a car would face additional costs above average. Redistributing revenues from carbon pricing could help to address socially unbalanced and unintended outcomes. We model various redistribution schemes after iterating with Israeli stakeholders. Compensating households with lump sum transfers or (partially) subsidizing electricity consumption could lead to progressive outcomes, while proposed policies to lower existing transport fuel taxes would exacerbate regressive distributional effects.

1. Introduction

The government of Israel seeks to introduce an economy-wide carbon price in 2023. According to the Israeli Ministry of Finance (2021), a tax of ILS 130 (~USD 40) per ton of CO_2 (tCO_2) will be levied on the consumption of various fossil fuels, including coal, liquid fuels, LPG and natural gas.

As such, carbon pricing constitutes a pivotal part of the Israeli policy mix to reduce national carbon emissions. According to Israel's nationally determined contributions, as ratified in the Paris Agreement (Ministry of Environmental Protection of Israel, 2021), the government strives to decrease greenhouse gas (GHG) emissions by 27% (85%) until 2030 (2050) in comparison to GHG emissions in 2015. In 2020, Israel emitted 62 $MtCO_2$ or 7.2 tCO_2 per capita compared to 4.6 tCO_2 per capita on global average (European Commission, 2021).

Imposing a price on carbon emissions can help to internalize social costs of fuel combustion, thereby altering relative prices of carbon-intensive compared to cleaner goods and providing incentives for low-carbon innovation, technology deployment and consumption. Therefore, carbon pricing is regarded as an economically efficient instrument to reduce carbon emissions (Cramton et al., 2017). Recent publications indicate carbon pricing schemes have likely contributed to reducing emissions (Leroutier, 2022; Best et al., 2020; Andersson, 2019). Several (sub-national) governments have implemented carbon pricing or take an implementation into consideration (World Bank 2022), just as the Israeli government.

Past proposals to implement carbon pricing reforms have often raised concerns about unequal distributional implications among the population, in particular, if poorer households were to bear relatively high economic costs (Maestre-Andrés et al., 2019). An unequally distributed tax burden can lower the aggregate public support for climate policies (Dechezleprêtre et al., 2022) and subsequently hinder effective policy implementation. Assessing the distribution of additional costs among different groups of society facilitates the design of complementing social policies that aim at cushioning adverse impacts on (vulnerable) segments of the population.

In this study we examine the distributional effects of an economy-wide carbon price among households in Israel. Through combining detailed household-level survey data with sectoral embedded carbon intensities derived from multi-regional input-output data we simulate

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https://doi.org/10.1016/j.enpol.2023.113672
Received 19 August 2022; Received in revised form 17 April 2023; Accepted 7 June 2023
Available online 26 June 2023

additional costs of carbon pricing and potential rectifying compensation measures, such as providing lump sum transfers, subsidizing electricity consumption or exempting transport fuels from taxation. Capitalizing on a rich set of socio-demographic data we use statistical analyses to examine impacts on distinct household profiles. To this end, we also integrate insights from iterations with Israeli stakeholders that helped to identify groups of the population that are important in the local public debate.

Detailed information on the characteristics of disproportionally affected households matters especially in the context of designing suitable compensation schemes. Many researchers recommend lump sum transfers that ease the burden on lower income households *on average* (e.g., Budolfson et al., 2021), but lump sum transfers might fall short of compensating households whose consumption is especially carbon-intensive – potentially entailing corresponding consequences for public acceptability and hence political feasibility. We therefore extend the assessment of distributional impacts of carbon pricing beyond the comparison of average costs among income quintiles and identify socio-demographic characteristics of Israeli households that are likely bearing disproportionally high additional costs by carbon pricing.

Evaluating impacts on different segments of the population is of special importance in a country that suffers from inequality across multiple dimensions, such as Israel (Chancel et al., 2022). For example, parts of the population live in communities that segregate from the majority, such as Jewish Orthodox or Israeli-Arabs (i.e., Palestinian citizens of Israel). Those households are also more likely unemployed, prone to poverty and have less access to public transport facilities (Bank of Israel, 2020; Machlica, 2020).

We find that a carbon price in Israel would entail regressive distributional outcomes: Poorer households would face relatively higher additional costs compared to richer households. Higher additional costs also link to living in rural areas, owning a car or being part of Arab communities. These households are likely to be disproportionately affected. Recycling revenues back to households on a per capita basis (i.e., lump sum) would lead to progressive results, as does a proposed subsidy on electricity prices. In contrast, reducing existing taxes on transport fuels has regressive implications. Beyond our findings, designing revenue recycling schemes requires attention to behavioural responses of consumers and firms. For instance, subsidizing (or investing in) public transport infrastructure might enable fair and inclusive transitions to a sustainable and low-carbon economy.

In the following chapter we link our study to the literature concerning distributional impacts of carbon pricing. In the third chapter, we will introduce data and method fuelling our microsimulation, present our results in the fourth chapter before we finally discuss our findings and conclude in the fifth chapter.

2. Related literature on distributional impacts of carbon pricing

Carbon pricing provides an economic incentive to reduce carbon emissions by shifting relative prices between more carbon-intensive and cleaner goods and services. In the short term, households may expect increasing commodity prices and such additional economic costs may distribute unevenly across heterogeneous households. The distributional impacts of tax reforms can lead to lower public support and limit their political feasibility. In the context of carbon pricing this became apparent against the background of recent endeavours to reform fossil fuel subsidies (e.g., in Ecuador, 2019; see also Schaffitzel et al. (2019)) or to increase existing carbon prices (e.g., in France, 2018; see also Douenne and Fabre (2022)). Here, proposals to reform environmental policies have led to protests and violence, which contributed to reversing such reforms.

Therefore, many researchers have presented studies on the distributional impacts of carbon pricing reforms, for example conducting ex-ante microsimulations in the context of the United States (Goulder et al., 2019; Mathur and Morris, 2014), countries of the European Union (Feindt et al., 2021), countries of South East Asia (Steckel et al., 2021), countries of Latin America (Vogt-Schilb et al., 2019) or in single-country studies, such as Ecuador (Schaffitzel et al., 2019) or Peru (Malerba et al., 2021). Other researchers use more dynamic approaches to include demand responses, for example for the case of Brazil (Garaffa et al., 2021), Mexico (Renner et al., 2018) or Germany (van der Ploeg et al., 2022). A meta-analysis (Ohlendorf et al., 2021) confirms findings from these studies that carbon pricing is often regressive, but more likely to be progressive in lower income countries and if applied exclusively to the transport sector.

In high-income countries (such as many OECD countries including Israel) carbon pricing is likely to be regressive on average (Dorband et al., 2019). Regressive distributional impacts result from poorer households spending more money (relative to total expenditures) on carbon-intensive goods (such as energy), which leads to poorer households bearing higher additional costs (relative to total expenditures) compared to richer households. In addition, research suggests that differences *within* income groups can be meaningful, possibly exceeding differences *between* income groups (Cronin et al., 2019; Fischer and Pizer, 2019), but few publications engage explicitly with household characteristics correlating with the tax incidence of carbon pricing beyond differences in income (e.g., Feindt et al., 2021; van der Ploeg et al., 2022).

Carbon pricing typically generates revenues that governments could use to compensate firms or households for additional costs. Compensating measures include removing existing (and potentially distorting) taxes, increasing green spending or implementing (targeted) transfer schemes (Klenert et al., 2018). The prospective use of revenues provides the potential to substantially influence the distributional impacts of carbon pricing reforms (Goulder, 1995). For example, lump sum transfers would usually lead to more progressive impacts (Budolfson et al., 2021). Subsidizing or removing existing taxes of widely used consumption goods (such as transport fuels, electricity or food products) may help to cushion the burden for households that spend a disproportionally large budget share on such goods.

Ex-ante assessments of distributional impacts of carbon pricing reforms can help identifying segments of the population that would bear relatively high additional costs and explore their potential channels. Simulating the effects of different compensation measures may support the implementation of more targeted revenue recycling schemes, thereby shielding poorer or more economically vulnerable households from excessive economic costs, increasing public acceptance and sustaining more equitable and just environmental policies. For the case of the novel carbon price in Israel such assessments have been lacking.

3. Methodology and data

In this study, we assess the distributional effects of carbon pricing in Israeli households by calculating the carbon emissions embedded in single households' consumption. We combine two datasets: First, trade and emissions data from the GTAP database from which we draw sectoral embedded carbon intensities. Second, highly disaggregated data on consumption expenditures. With this approach we closely follow the method described in Steckel et al. (2021). As an extension and novelty in the literature, we decompose drivers and characteristics of especially affected households with the help of multi-variate logit-regression and model various compensation schemes after iteration in a stakeholder process with Israeli governmental and non-governmental organizations.

3.1. Multi-regional input-output data

We draw on multi-regional input-output (MRIO) data from the GTAP 10 database (Aguiar et al., 2019) to calculate sector-specific embedded carbon intensities that we use to derive carbon emission footprints embedded in household consumption. We convert the GTAP 10 database, which includes trade and emissions data for the year 2014, into a multi-regional input-output table (Peters et al., 2011). GTAP 10 data cover 65 different sectors (see Table S1).

The MRIO data consist of an inter-industry flow matrix $Z \in \mathbb{R}^{(m \bullet n) \times (m \bullet n)}$ and a final demand vector $Y \in \mathbb{R}^{m \bullet n \times n}$ with n regions (reflected by the set R) and *m* sectors (reflected by the set S). Entries $z^{r_2,s_2}_{r_1,s_1}$ of Z represent the total monetary value (in USD) of flows from sector s_1 in region r_1 to sector s_2 in region r_2, with $r_1, r_2 \in R = \{1, \ldots, n\}$ and $s_1, s_2 \in S = \{1, \ldots, m\}$. Analogously, $y^{r_2}_{r_1,s_1}$ comprises the sum of all monetary flows from sector s_1 of region r_1 into final demand of region r_2. Let Y^{HH,r_1} denote the final consumption that is of households in region r_1.

All entries $z^{r_1,s_m}_{r_1,s_m}$ and $y^{r_1}_{r_1,s_m}$ enter the calculation of the total output vector o_{r_1,s_m}.

$$o_{r_1,s_1} = \sum_s \sum_r \left(z^{r,s}_{r_1,s_1} \right) + \sum_r y^r_{r_1,s_1} \tag{1}$$

By $A \in \mathbb{R}^{(m \bullet n) \times (m \bullet n)}$, we denote the technology matrix with entries

$$a^{r_2,s_2}_{r_1,s_1} = \frac{z^{r_2,s_2}_{r_1,s_1}}{o_{r_2,s_2}} \tag{2}$$

that describe the amount of each input from sector s_1 in region r_1 that is necessary to produce one unit of output from sector s_2 in region r_2. Subsequently, we derive the Leontief inverse L that accounts for all pre-products used at some stage during production; I denotes the identity matrix.

$$L = (I - A)^{-1} \tag{3}$$

Let then $E \in \mathbb{R}^{m \times n}$ denote the vector whose elements $E_{r,s}$ reflect total emissions (of industries) released by sector s in region r. As our analysis focuses on modelling a national carbon price, we consider national emissions only. Thus, all elements $E_{r's'}$ with $r' \neq r_{Israel}$ are set zero. Dividing E entry-wise by total sectoral outputs O yields a vector $ICI \in R^{(m \times n)}$, whose non-zero entries $ICI_{r_1 s_1}$ represent the industrial carbon emissions intensity of Israeli industries. The total indirect emissions $E^{indirect,HH}_{r_1,s_1}$ that are embedded in the consumption of households in region r_1 and sector s_1 result as

$$E^{indirect,HH}_{r_1,s_1} = \sum_{r'} \sum_{s'} \sum_{r} ICI_{r',s'} L^{r,s1}_{r',s'} y^{HH,r_1}_{r,s_1} \tag{4}$$

Vector $E^{direct,HH}$ with entries $E^{direct,HH}_{r_1,s_1}$ denotes the direct carbon emissions of households in region r_1 and sector s_1 that stem from the GTAP database. We next derive *total* carbon emissions embedded in household consumption as

$$E^{HH}_{r_1,s_1} = E^{indirect,HH}_{r_1,s_1} + E^{direct,HH}_{r_1,s_1} \tag{5}$$

and thus sectoral embedded carbon intensities CI_{r_1,s_1} by using total household expenditures on goods of sector s_1 in region r_1 from GTAP as a denominator:

$$CI_{r_1 s_1} = \frac{E^{HH}_{r_1,s_1}}{\sum_r y^{HH,r_1}_{r,s_1}} \tag{6}$$

We rely on sectoral embedded carbon intensities $CI_{r,s}$ for calculating carbon footprints and thus the carbon pricing incidence. Table S1 lists all values of $CI_{r,s}$ for Israel, that is, the amount of carbon emissions (in tCO_2) released in Israel embedded in household expenditures of USD 1 in each sector. $CI_{r,s}$ accounts for all inter-sectoral trade linkages of the Israeli economy. This approach enables us to assess embedded carbon emissions. For instance, emissions associated to wheat production include emissions originating from fuel and electricity consumed in the production process of wheat. Our modelling approach accounts for reimported emissions, that is, for emissions from goods that were initially produced in Israel, exported to a third country and finally reimported to Israel. As a robustness check, we include emissions coming from imported goods, which would be equivalent to a carbon border adjustment mechanism (see Figure S1 and Table S1).

3.2. Household data

The Israeli Household Budget Survey 2018 (Central Bureau of Statistics Israel, 2019) contains detailed data on 8,792 households. Data were collected with standardised surveys during face-to-face visits in single households. The selected sample is representative for 97% of the Israeli population. The survey lists information on socio-demographic household characteristics, such as age and education levels, ethnicity, location and asset ownership. Households give detailed report on expenditures for 1,102 single consumption items. Addressing outliers we replace expenditures with median expenditures at the item-level, if expenditures are larger than 99.9% of all non-zero item-level expenditures. Subsequently, we extrapolate weekly and monthly expenditures to derive annual total household expenditures. Households fill the survey throughout the entire year, which reduces risk of bias because of seasonal consumption patterns. We assign households to expenditure quintiles based on their total per capita expenditures. Table S2 indicates summary statistics for Israeli households.

Note that income data from household surveys are usually less valid, since households might not be willing to report openly, especially on income from capital, rents or informal labour (Moore et al., 2000). Therefore, we proxy household income by total household expenditures, which also resembles lifetime income more closely (Poterba, 2016) and use household expenditures and household income synonymously throughout the rest of this study.

We also trace information on household-level transfers from public institutions, such as pensions, child benefits, several allowances or social security schemes.

3.3. Incidence of carbon pricing

Next, we match sectoral carbon intensities and household consumption data to derive an embedded carbon footprint in households' consumption. First, we match the 1,102 disaggregated consumption items from the household budget survey to the 65 sectors from GTAP. We assign each item to one single sector and group expenditures for each household at the sector-level.

Next, we use the total yearly consumption of household *i* on goods and services ($Exp_{i,s}$) matched to sector *s* and expressed in USD. In contrast to total household consumption $y^{HH,r_1}_{s_1}$ that we use in equations (4) and (6) and that origins from GTAP, we deduct $Exp_{i,s}$ from household budget survey data. We use CI_{r_1}, which is a vector containing embedded carbon intensities $CI_{r_1,s}$ in tCO_2/USD for each sector *s* in Israel (r_1), to calculate the carbon footprint embedded in consumption of household *i* CF_i as follows:

$$CF_i = \sum_s Exp_{i,s} \bullet CI_{r_1,s} \tag{7}$$

Households that spend more money on more carbon-intensive sectors would thus obtain a higher carbon footprint CF_i than other households would.

Having derived a carbon footprint enables us to calculate a carbon pricing incidence CPI_i for each household *i* following a carbon price of *t* in USD/tCO_2. We express CPI_i as a share of total expenditures.

$$CPI_i = \frac{CF_i{*}t}{\sum_s Exp_{i,s}} \tag{8}$$

As discussed during stakeholder interaction processes (see below) and in line with final legislation, we set *t* to ILS 130 (~USD 40) per tCO_2. CPI_i, the variable of interest in this study, thus expresses the additional costs that household *i* would face, if it was to consume the same consumption basket that it was consuming prior to the introduction of a carbon price. We express CPI_i in percentage points. $CPI_i = 2\%$ would indicate that household i would have to spend additional 2% of its total annual consumption expenditures in order to sustain consumption, if additional costs from carbon pricing were fully passed to consumers. Households that obtain a greater CPI_i than others would face higher relative costs following a carbon price than others would. Throughout this study, we thus refer to CPI_i as the *distributional incidence* of household i, as it allows for the comparison of multiple households both, *within* as well as *across* expenditure quintiles.

3.4. Decomposition of distributional effects

Capitalizing on a logit regression model, we determine econometrically which household characteristics are associated with households' carbon pricing incidence by estimating

$$log\left(\frac{p_{i,p_1}}{1-p_{i,p_1}}\right) = \alpha + \beta' X_i' + \varepsilon_i \tag{9}$$

p_{i,p_1} equals 1, if the carbon price incidence in household i (CPI_i) is greater than the carbon price incidence of the least affected p_1% (CPI_{p_1}) of the Israeli population and 0 otherwise. X' is a vector of independent variables, including log-transformed total household expenditures per capita, location, car ownership, ethnicity, religion and household head's education. α is the intercept; ε_i is the error term. We next derive fitted probabilities $\widehat{p_{i,90\%}}$ for households with characteristics X_i', which express the probability of household i to be more affected than 90% of all households. We use $\widehat{p_{i,90\%}}$ to assess the financial burden of any household i *relative* to other households, allowing for comparing households with their peers (e.g., income groups or regions). We derive $\widehat{p_{i,90\%}}$ for a set of *typical* households that Israeli stakeholders (see below) mentioned to influence the public perception of energy policies and hence their feasibility.

3.5. Stakeholder interaction and modelling compensation schemes

Using revenues from carbon pricing to compensate households and firms can positively affect the feasibility and political acceptance of climate policies. Nevertheless, which segments of the population are especially vulnerable to economic consequences of carbon pricing and which channels could be used to recycle revenues depends on national circumstances. To better understand the architecture of climate policy in Israel and to assess research questions that are more relevant to policy practitioners we engaged in a science-based stakeholder process (Welp et al., 2006). We iterated with non-governmental organizations and policy-oriented think tanks (namely the Israel Public Policy Institute and the Heinrich Boell Foundation in Tel Aviv) on societal groups in Israel that are frequently present in public debates. In a workshop that took place at the Bank of Israel we discussed preliminary results with representatives of governmental and financial institutions at the national level. This helped to identify existing subsidies or social security schemes that are conceivable as compensation channel and enabled us to widen the scope of our analysis accordingly.

Table 1 lists several compensation schemes that we model to compare distributional implications. We also include policies, such as an implicit subsidy for electricity and transport fuel prices that are included in the final policy proposal presented by the Israeli government (Ministry of Finance Israel, 2021).

We model the distributional implications of a carbon price and different revenue distribution instruments rd, to which we refer as CPI_i^{rd}, by calculating revenues B_i^{rd} for each household i and instrument rd and subsequently

$$CPI_i^{rd} = \frac{CF_i * t - B_i^{rd}}{\sum_s Exp_{i,s}} \tag{10}$$

For full lump sum transfers we redistribute potential revenues equally per capita. In our analysis revenues of a whole-economy carbon price would amount to approximately 1.88 billion USD (see methodological note in Appendix for more information). This serves as a reference option. We also model the opportunity of a full public transport subsidy, whereby each household receives a compensation B_i equalling its expenditures on public transportation. Moreover, the Israeli government caps the price of some basic food products, such as bread, butter, milk and cheese; low-income households dedicate a larger expenditure share on food. We therefore model a lower price cap on such basic goods (for instance by removing value added tax), since this policy would likely be leading to more progressive effects and could be implemented with comparably little effort.

We also model an implicit subsidy of electricity, which is in line with the proposal of the Israeli government to curb increases in electricity prices at 5% compared to pre-tax levels. In our approach, all additional expenditures on electricity consumption exceeding pre-tax payments by 5% are recycled back to households. In a similar fashion, we incorporate the envisaged policy of exempting transport fuels from taxation in our simulation.

Table 1
Redistribution scenarios in this study.

Instrument	Value	Share of Revenues
Full lump sum transfer	ILS 795 (~USD 245) per capita per year	100%
Full public transport subsidy	100% of expenditures on public transportation	24%
VAT removal on basic products	100% VAT expenditures on basic goods	19%
Electricity subsidy	Limiting electricity price increase to 5%	23%
Transport fuel subsidy	Additional costs on transport fuels	26%

3.6. Limitations

In our study, we investigate in detail the impacts of a carbon price and related compensation measures (such as an implicit subsidy on electricity prices or exempting transport fuels) to identify segments of the Israeli population that are likely to face disproportionally high additional costs. The inclusion of sociodemographic criteria in our econometric analysis draws on information from iterative stakeholder dialogues, which helps to increase the relevance of our findings for policy implementation. Nevertheless, our methodological approach rests on several assumptions that merit attention. First, all simulated impacts on post-tax consumption (including or excluding compensation) neglect general equilibrium effects and imply a completely inelastic demand of households. Thus, our variable of interest does not capture income or substitution effects. Instead, it represents an upper-bound first-order effect. Considering consumer responses to increasing prices usually leads to more progressive results (Ohlendorf et al., 2021). Second, we assume a complete pass-through of the carbon price along value chains, thereby ignoring within-industry differences in the technological ability to substitute fossil fuels. Third, we use household-level expenditure data to assess embedded carbon emissions, thereby assuming that embedded emissions are equivalent to expenditures. This ignores within-product differences in carbon intensity that we cannot capture with the level of data at hand. A detailed assessment of embodied emissions of all products through lifecycle assessments approaches is out of scope of this study. Instead, our analysis rests on differences between sectors and households. Fourth, household data represents consumption patterns in 2018. In general, our analysis does not capture recent international developments that may influence prices of fossil fuels, especially natural gas.

4. Results and discussion

The incidence of carbon pricing reflects each household's embodied carbon intensity of consumption. In this section, we present results on consumption expenditure shares and subsequent carbon pricing incidences. Furthermore, we exhibit heterogeneous impacts on different groups of the Israeli population and discuss how different revenue recycling mechanisms could help to compensate those households that would be most affected by carbon pricing.

4.1. Distributional effects of carbon pricing

Distributional effects of carbon pricing reflect differences in households' consumption patterns. In Israel, richer households allocate larger shares of expenditures to the consumption of goods and services (see panel a) in Fig. 1). Poorer households spend more money on food and energy compared to total household expenditures. This finding is consistent with consumption patterns in many industrialized economies (Dorband et al., 2019; Kaus, 2013).

The consumption of energy services, such as electricity, transportation and cooking fuels, is usually more carbon-intensive than the consumption of food, goods and services. In Israel, energy expenditure shares decline with rising income (see panel a) and b) in Fig. 1), which indicates that households with lower incomes spend relatively more money on more carbon-intensive energy services (see also Table S 2).

The carbon footprint embedded in households' consumption is arguably lower for poorer households (panel c) in Fig. 1, see also Table S 2) with average carbon footprints of the richest 20% of households

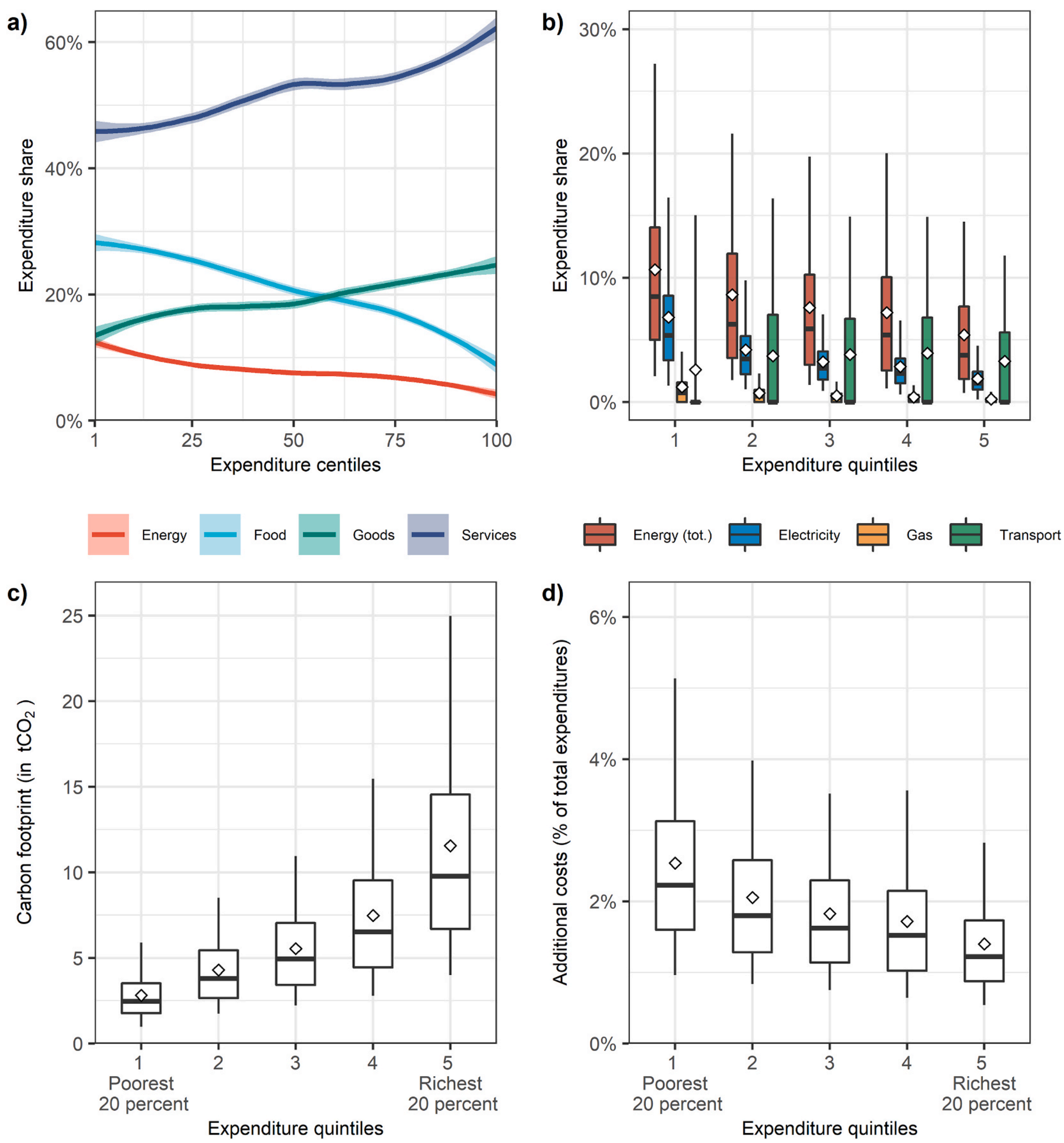

Fig. 1. a) Engel curves, b) energy expenditure share over expenditure quintiles, c) carbon footprints per capita over expenditure quintiles, d) carbon pricing incidence over expenditure quintiles. Panel a) displays expenditure shares for energy, food, goods and services (y-axis) over expenditure centiles (x-axis) for Israeli households. Smoothed curves show median shares within each centile. Panel b) shows the share of expenditures on energy items in percent of total consumption expenditures (y-axis) over expenditure quintiles (x-axis). Gas refers to *gas in containers* (LPG) or *central gas* consumed directly by households. Panel c) displays carbon footprints per capita embedded in household consumption (in tCO_2, y-axis) over expenditure quintiles (x-axis). Panel d) shows additional costs to households induced by a carbon price of ILS 130 (~USD 40) per tCO_2 in relation to total household expenditures (y-axis) over expenditure quintiles (x-axis). 1% additional cost indicates that a household would require an additional 1% of its reported expenditure budget in order to buy the same amount of goods and services that they bought prior to the price increase. In panels b), c) and d), rhombuses represent the mean. Whiskers indicate the 5^{th} and 95^{th} percentile respectively. See also Table S 4. Data: Household Budget Survey 2018 (Central Bureau of Statistics Israel, 2019), GTAP 10 (Aguiar et al., 2019)

(11.55 tCO_2) quadrupling the one among the poorest 20% of households (2.81 tCO_2). Imposing a carbon price of USD 40/tCO_2 would consequently induce higher *absolute* overnight costs to richer households (USD 462 on average) compared to poorer households (USD 113 on average, see also Table S 3).

Nevertheless, in comparison to total household expenditures, poorer households would bear higher *relative* costs, as displayed in panel d) in Fig. 1. Introducing carbon pricing in Israel is therefore likely to encompass regressive results. To acquire the same amount of goods and services households in the poorest quintile would on average require additional 2.5% of their current total expenditures. In comparison, households from the richest quintile would on average require additional 1.4% of total expenditures. At the median, households from the poorest quintile would require additional 2.2% of total expenditures compared to 1.2% for households from the richest quintile.

In addition, we document substantial heterogeneity of additional costs *within* income groups. The difference in additional costs between the 25th and 75th (5th and 95th) percentile among the poorest quintile amounts to 1.5% (4.2%) compared to 0.9% (2.3%) in the richest quintile, respectively (see also differences in standard deviations in Table S 4). This indicates larger inequality in carbon pricing incidence among poorer households compared to richer households. It is therefore reasonable to forecast that, first, carbon pricing in Israel would be regressive *on average* and, second, the households that bear the highest costs relative to total expenditures are more likely to be relatively poor. Both features raise concerns on the equity and perceived fairness (Maestre-Andrés et al., 2019) of such price-based climate policies, but could facilitate the design of socially just compensation schemes, if revenues from carbon pricing were to be recycled.

4.2. Differences across the Israeli population

Research interested in the distributional effects of carbon pricing often compares expected levels of carbon incidence across income groups, thereby addressing concerns on fairness and justice. Nevertheless, this often neglects other socio-demographic factors beyond income that are associated to the incidence of carbon pricing. Identifying such factors could enable the design of compensation schemes to cushion adverse effects on segments of the population that are likely to bear high additional costs.

We decompose household characteristics that relate to higher levels of additional costs in comparison to both, all Israeli households and households within the same expenditure quintile. Table S 5 exhibits estimates from equation (9) expressing correlation between household characteristics and the log-odds of facing higher additional costs than 90% of Israeli households. Lower expenditures (also within quintiles), living in rural areas or smaller cities, owning cars and being part of the Arab community is positively associated with high additional costs from carbon pricing, compared to the whole population. Fig. S 2 to Fig. S 6 visualize these findings.

Our results suggests that expenditures on transport fuels are likely to explain why households would face exceptional high additional costs from carbon pricing, since households that live in densely populated areas such as Tel Aviv and the Gush Dan area are less likely to commute by car. Consumption in Jewish Orthodox households is likely to be less energy-intensive than in Jewish secular households, including a lower probability to own (and use) cars. In contrast, we document households from the Arab community to dedicate higher expenditure shares on liquid transportation fuels (see Fig. S 7). It is unlikely that underreporting of fuel expenditures helps to explain this finding, since we do not observe differences in reporting non-zero expenditures on liquid fuels despite car ownership among Jewish orthodox and Arab households. Note that some households, however, receive fuels through benefits from employment, which might help to explain missing expenditures for many households.

We next derive the expected probability of facing higher costs than 90% of the Israeli population for different iconic household profiles that Israeli stakeholders identified to be meaningful in national discourses on climate policy in Israel. At average expenditure levels (see red vertical line in Fig. 2), Jewish secular households from densely-populated Tel Aviv are 2% likely to bear higher costs than 90% of the Israeli population. To the contrary, households from the Arab community that live in rural areas and own one car, are 24% more likely ($\widehat{p_{i,90\%}} = 26\%$) to be more heavily affected by carbon pricing. Differences exacerbate at lower levels of income ($\widehat{p_{i,90\%}} = 53\%$) for Arab households from rural areas with one car compared to Jewish secular households from Tel Aviv without a car ($\widehat{p_{i,90\%}} = 5\%$), at average expenditure levels of the poorest expenditure quintile).

These results can facilitate the design of tailored compensation schemes to dampen unintended adverse impacts for particular parts of the Israeli society. In addition, identifying segments of the population that are likely to face exceptionally high costs might help to design effective forms of communication around climate and social policies (Coady et al., 2018).

4.3. Compensation schemes

Governments could use (part of) carbon pricing revenues to compensate households, e.g., by lowering existing, possibly distortionary taxes or by providing targeted subsidies. In turn, recycling revenues to households could increase public acceptance for carbon pricing. In Fig. 3, we display changes to household budgets following different compensation schemes. Fig. S 8 displays fitted probabilities for different household profiles including revenues from different recycling schemes.

Recycling all revenues lump sum to households would fully compensate 93% of the poorest expenditure quintile. In comparison, the incidence of carbon pricing among the richest households would decrease to 0.7% of total expenditures compared to 1.4% of total expenditures without revenue recycling. Compensating households with lump sum transfers would therefore render the distributional effects of carbon pricing highly progressive on average.

The Israeli government proposes to limit resulting electricity price increases in response to carbon pricing to 5% compared to pre-tax prices, thereby effectively subsidizing electricity or removing existing taxes. Since poorer households spend a larger share of expenditures on electricity (see panel b) in Fig. 1), this policy is likely to cushion regressive impacts in the population with households from the lowest expenditure quintile expecting additional costs of 1.5% on average compared to 1.1% in the richest expenditure quintile. Despite reducing inequality between expenditure quintiles, results would remain regressive on aggregate.

In addition, the Israeli government has announced that carbon pricing will not affect prices of transport fuels, thereby partially removing existing gasoline and diesel taxes. This policy would effectively be regressive, since the poorest households spend less on transport fuels (see panel b) in Fig. 1). Our simulation confirms this intuition: On average, households from the poorest quintile would face additional costs of 2.2% of total expenditures compared to 0.9% in the richest quintile, thereby aggravating the regressive character of an uncompensated carbon price. Exempting transport fuels from taxation would however decrease differences within expenditure quintiles because expenditures on transport fuels are unevenly distributed among households (see panel b) in Fig. 1 also Fig. S 7).

Contrarily, lowering the VAT on basic, price-capped consumption goods would dampen regressive effects, since poorer households dedicate a larger share of expenditures to such goods. This also holds for a subsidy of public transport, albeit our simulation ignores behavioural responses to such subsidies.

It is important to note that compensation measures for households may reduce unintended economic consequences for many households,

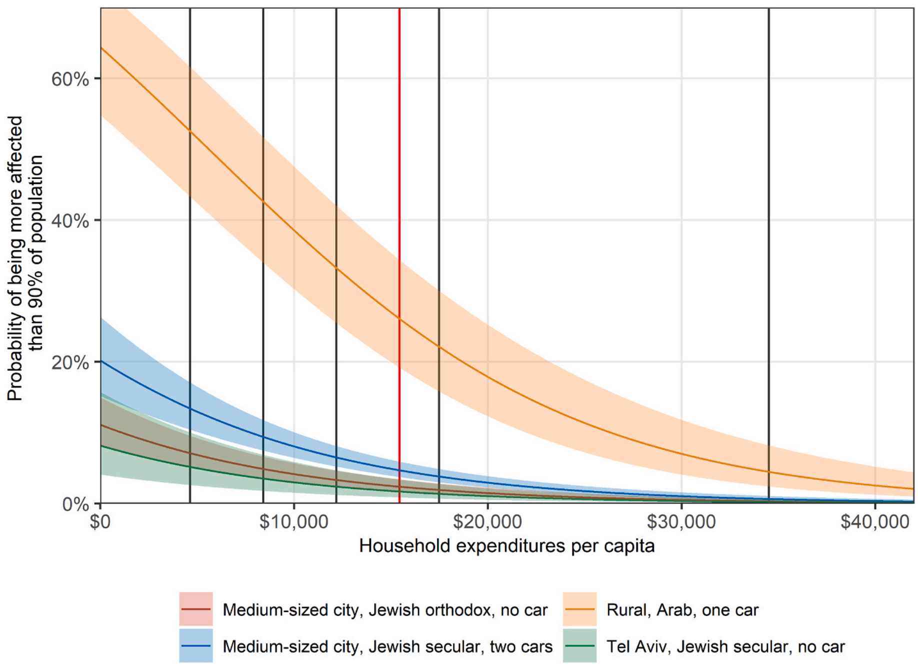

Fig. 2. Estimated probability of being more affected than 90% of Israelis for different household profiles.
Estimated probability of expecting higher costs by a national carbon price of ILS 130 (~USD 40) per tCO_2 than 90% of all Israeli households (y-axis) over total household expenditures per capita (x-axis) for different household profiles. Black vertical lines indicate average total household expenditures per capita for each expenditure quintile. The red vertical line indicates average total household expenditures per capita for all Israeli households. We display confidence intervals (95%) for each household profile. 'Medium-sized city' refers to cities with 50,000 to 200,000 inhabitants. We cluster households located in places with up to 10,000 inhabitants as 'Rural'. 'Jewish secular' is differentiated from 'Jewish orthodox'. Nevertheless, 'Jewish secular' includes households that reported to live a 'traditional' lifestyle. 'Arab' comprises Druze as well as Muslim Arabs. Data: Household Budget Survey 2018 (Central Bureau of Statistics Israel, 2019), GTAP 10 (Aguiar et al., 2019).

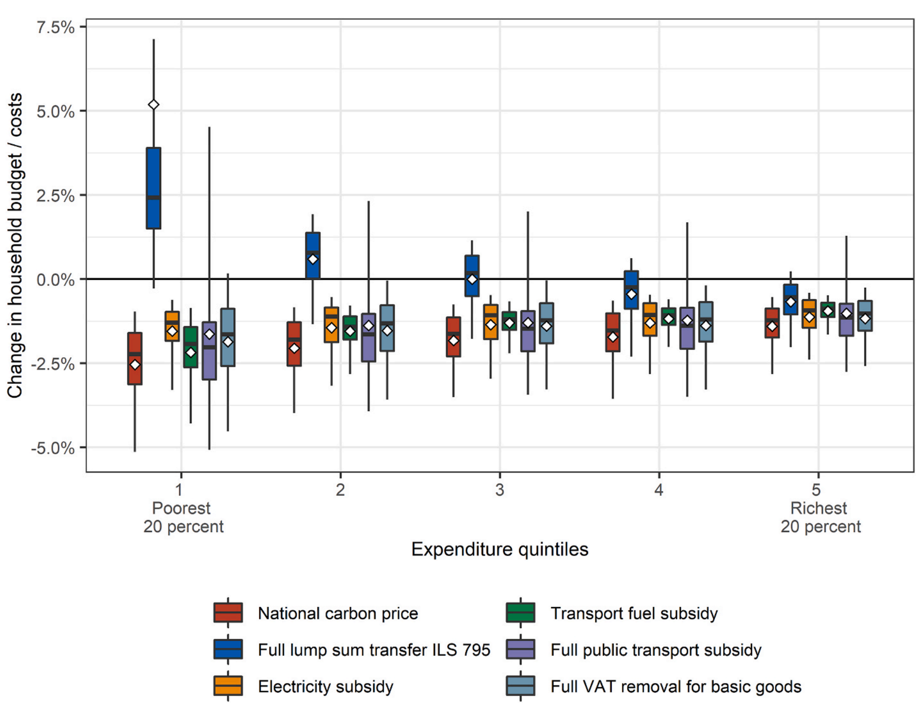

Fig. 3. Change in household budget/costs over expenditure quintiles for different compensation schemes. Changes in household budget / costs as a share of total expenditures (y-axis) over expenditure quintiles (x-axis). The first quintile includes those 20 % of households with the least total expenditures per capita. The fifth quintile includes those 20 % of households with highest total expenditures per capita. Positive values refer to additional budget gains (in % of household expenditure) available for consumption. Negative values refer to additional expenditures that a household would require in order to buy the same amount of goods they bought prior to the price increase. We add a lump sum transfer to national carbon price incidences ('Full lump sum transfer ILS 795'). 'Electricity subsidy' refers to limiting electricity price increases by 5% compared to pre-carbon tax levels. 'Transport fuel subsidy' refers to a compensation according to the additional costs by carbon pricing for the consumption of transport fuels. 'Full public transport subsidy' refers to compensating households for their expenditures on public transportation. 'Full VAT removal for basic goods' refers to removing the VAT of basic goods, such as bread, milk and cheese. Rhombuses represent the mean. Whiskers indicate the 5^{th} and 95^{th} percentile respectively. Data: Household Budget Survey 2018 (Central Bureau of Statistics Israel, 2019), GTAP 10 (Aguiar et al., 2019)

but may also reduce the incentive for households to lower the consumption of carbon-intensive products. For example, positive income shocks as stipulated by potential lump sum transfers may lead to increasing emissions, if households use income from transfers for relatively carbon-intensive consumption (Sager, 2019). Nevertheless, carbon pricing would shift relative prices, thereby providing economic incentives for producers and consumers to reduce carbon emissions.

5. Conclusion and policy implications

Starting in 2023, the Israeli government will introduce a carbon price of ILS 130 (~USD 40) in order to facilitate compliance with its climate targets. We show that this policy is likely to be regressive, i.e., poorer households will face higher additional costs as a share of total expenditures compared to richer households. This finding results from poorer households dedicating a larger share of their expenditures to energy services, such as electricity, cooking or transport fuels that are more carbon-intensive than other goods and services. We also document that additional costs within poorer parts of the population are more heterogeneous than within richer parts.

In addition, we provide evidence on other socio-demographic characteristics (beyond income) that relate to expected additional costs. We identify households that live in rural areas, own (and use) cars or identify with the Israeli-Arab community to be more likely to expect high costs, in comparison to the entire Israeli population. Drawing on insights from iterative discussions and a workshop with Israeli stakeholders, our analytical framework enables an opportunity to examine overnight effects of carbon pricing on different segments of the population. This might fuel the design of complementing policies to facilitate just and socially balanced sustainability transitions. In general, engaging with stakeholders over the course of ex-ante evaluations of policy reforms can help to yield insights that are more relevant to political decision makers.

Upon decision by the Israeli government, the introduction of a carbon price will go hand in hand with recycling revenues through lowering transport fuel taxes and subsidizing electricity prices (Ministry of Finance Israel, 2021). Accordingly, carbon prices will partially replace existing excise taxes on gasoline and diesel, while the government aims at limiting plausibly occurring electricity price increases to 5% compared to recent prices. In addition, the government will set up a fund to facilitate low-carbon transition in vulnerable population groups, but which currently lacks further details.

We show that recycling revenues through lowering excise taxes on transport fuels exacerbates regressive outcomes, since many poorer households rarely spend money on such fuels. In addition, effectively exempting transport fuels from carbon pricing is unlikely to additionally induce short-term switches in transport technology and subsequent decarbonisation of the Israeli transport sector.

Contrarily, using revenues from carbon pricing to limit envisaged increases of electricity prices has comparatively progressive implications, since poorer households spend a larger share of total expenditures on electricity than richer households do. On the supply-side, a carbon price in Israel would provide incentives to shift electricity generation from coal-fired power plants, which accounted for 28% of Israeli electricity generation in 2020 (IEA, 2021), to gas-fired turbines (65%, respectively) or to low-carbon electricity generation technology, such as solar power, for which Israel has ample potential (Navon et al., 2020; Halász and Malachi, 2014). Nevertheless, capping electricity prices on the supply-side, i.e., in firms and households, does not induce an economic stimulus for strengthening energy efficiency of consumption. Capping increases of electricity prices, as the Israeli government announced, is therefore suspicious of depriving carbon pricing policies of one of its fundamental strengths, that is, providing incentives for both, technological and behavioural adjustments on the demand or supply side (such as increased investments in electricity storage capacity or in electricity grids to facilitate the integration of volatile renewable energy sources).

As an alternative, distributing revenues from carbon pricing to the Israeli population through lump sum transfers reveals to render distributional impacts strictly progressive. This could potentially increase the public acceptability of the carbon pricing reform, especially among poorer households. In principle, governments could use existing social security programs, such as pensions or several allowances, to compensate the Israeli population at low administrative cost. Since our data shows that 23% of Israeli households do not currently have access to governmental transfer schemes (Table S 2), distributing revenues from carbon pricing through lump sum transfers would nevertheless require the expansion of existing or the setup of new transfer schemes. This might be critical for maintaining public support, especially, since some of those households that do not have access to public transfer schemes are among those that are like to face exceptionally high additional costs.

Examining the impact on several segments of the Israeli population including several compensation schemes offers insights into which parts of the population might require targeted support, e.g., households from the Israeli-Arab community. In addition, revenues could facilitate (infrastructure) investments in rural, less densely populated areas, where many households are prone to facing high additional costs. Those investments might comprise the development of public transport infrastructure, thereby encouraging low-carbon transformation in the transport sector.

Carbon pricing is as effective in curbing carbon emissions, as its implementation is delicate for governments, since additional costs for carbon-intensive goods and services might lower public acceptance of such reforms and hence political feasibility. Complementary compensation policies that alleviate a large economic burden on vulnerable households can be a cornerstone of fair and inclusive carbon pricing reforms. Nevertheless, the design of optimal compensation policies depends on country-specific circumstances – for which the envisaged carbon pricing reform Israel proves to be a prime example.

CRediT authorship contribution statement

Leonard Missbach: Conceptualization, Methodology, Formal analysis, Visualization, Software, Writing – original draft. **Jan Christoph Steckel:** Conceptualization, Project administration, Methodology, Writing – original draft. **Hauke Ward:** Methodology, Software, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data from GTAP 10 is subject to fees. Data from the Israeli Household Budget Survey is available upon request from the Central Bureau of Statistics in Israel. Code is available upon request from the authors.

Acknowledgements

We thank Mareike Blum, Polina Garaev (IPPI) and Oz Aruch (HBS Tel Aviv) for helpful comments and suggestions. We are also grateful to all participants of the workshop "Leaving No One Behind. Carbon Pricing in Israel & Germany", which was held in November 2020 at the Bank of Israel and which was organized by IPPI and HBS Tel Aviv. Leonard Missbach acknowledges financial support through the German Federal Environmental Foundation (DBU). Jan Steckel acknowledges support by the Horizon Europe Programme within the AdJust project (grant agreement number 101069880).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.enpol.2023.113672.

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