Distributional Effects of Environmental Trade Measures

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I investigate the distributional effects of environmental trade measures. Distributional effects are assigned to two channels: 'Use-side' effects describe which consumers bear the burden of changing prices, while 'source-side' effects describe shifts in income between sectors, factors of production and different groups of workers. I present simple statistics to characterize the distributional tendencies of climate policies in each of these channels. I then apply these statistics to assess the distributional effects of two types of policy instruments: Border Carbon Adjustments and Green Industrial Policy. I conclude with a more detailed case study investigating the distributional effects of introducing Border Carbon Adjustments to complement an EU-wide carbon price. The analysis highlights the importance of modeling the effects of environmental trade policy at different scales, capturing shifts between countries, as well as shifts between sectors and income groups within them.

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1. Introduction

Trade policy can support and reinforce climate policy, as long as it is properly designed. Besides assessing the feasibility and effectiveness of trade measures, it is important to understand how their costs and benefits are distributed. Distributional considerations can inform the design of equitable policies that gather public support. This paper draws out general insights about the distributional effects of environmental trade measures, using Border Carbon Adjustments and Green Industrial Policy as guiding examples.

International trade linkages can complicate environmental policy-making. A government considering to introduce, say, a price on carbon emissions, cannot merely look at the domestic economy in isolation. Instead, it has to consider whether the policy may lead to carbon leakage and harm the competitiveness of domestic industries, especially of those industries that are energy-intensive and trade-exposed. A number of measures have been applied, and more have been proposed, to achieve climate objectives while protecting domestic industries. Some are trade-specific, such as Border Carbon Adjustments that directly affect the final prices of traded goods via carbon-based import tariffs and export rebates (Markusen 1975; Felder and Rutherford 1993; Hoel 1996). Other policies affect trade only indirectly, but in important ways nevertheless, such as Green Industrial Policy that shifts the sectoral composition of the economy towards greener sectors, and consequently affects trade patterns as well as the allocation of production factors (Hallegatte, Fay, and Vogt-Schilb 2013; Altenburg and Assmann 2017).

I explore the distributional effects of environmental trade measures aimed at curbing greenhouse gas emissions. It draws on the framework developed in my previous work (Sager 2019a), in which I estimate the distributional effect of carbon pricing across consumers worldwide, taking into account the role of international trade and the global value chains. I distinguish between two primary channels for distributional effects:

(1) changes in consumer prices, sometimes called the ‘use-side’ effect, and

(2) changes in factor incomes flowing to labor and capital, called the ‘source-side’ effect.

For each of these two channels, I present a simple statistic to determine whether a policy will tend to burden (1) poor or rich consumers via the ‘use-side’, and whether it will (2) benefit workers or the owners of capital via the ‘source-side’. These statistics can be calculated from available data to provide an initial assessment of the likely distributional effects of environmental trade measures, similar to the ‘sufficient statistics’ approach used in public finance (Chetty 2009). Helpfully, the statistics can also be compared across policy options. The paper concludes with a case study that demonstrates the likely distributional effects of complementing an EU-wide carbon price with Border Carbon Adjustments. While the results generally agree with the simple statistics, they rely on the more complete structural model developed in Sager (2019a). The case study highlights the importance of modeling the effects of environmental trade policy at different scales, capturing shifts between countries (Whalley and Wigle 1991; Shah and Larsen 1992; Copeland and Taylor 1994), as well as shifts between sectors and income groups within them (Poterba 1991; Fullerton 2011; Goulder et al. 2019).

2. Environmental Trade Measures and Distributional Effects

To describe the distributional effects of environmental trade measures, we distinguish between two channels. Effects on the 'use-side' describe changes in final prices as they fall on consumers with different income levels. Effects on the 'source-side' describe changes in incomes, usually by shifting the returns to capital and labor, or the demand for different types of workers. This distinction is somewhat artificial, because policies tend to operate through both channels. Price changes induced by, say, a carbon price, will affect demand for various products and, as a result, affect the output and profitability of various sectors and the resulting income flowing to capital and labor. And policies that affect incomes will have repercussions on the demand side. Still, the distinction can be useful to better understand distributional effects.

We will look at distributional effects on the 'use-side' and the 'source-side' in turn. For each channel, I will propose a simple statistic to quantify the likely magnitude and direction of the distributional forces at play. I will apply these statistics to two trade-related climate policy instruments. First, we look at Border Carbon Adjustments as an example of policies that directly target the prices of traded goods. The most immediate effect is on final prices and thus the 'use-side', which I focus on. Second, we look at Green Industrial Policy as an example of policies that shape the sectoral composition of the domestic economy, which primarily affects the 'source-side'.

Border Carbon Adjustments (BCA) are generally proposed as trade policy instruments to complement unilateral carbon pricing. Their main objective is to safeguard the competitiveness of domestic industries when foreign competitors are not subject to a carbon price, and thus to mitigate carbon leakage (Markusen 1975; Felder and Rutherford 1993; Hoel 1996). BCA usually feature a combination of carbon tariffs levied on the emissions embodied in goods imported from countries with less stringent climate policy, and rebates for domestic goods that are exported[1]. Modeling suggests that BCA could be effective at protecting domestic firms and reducing leakage (Elliott et al. 2010; Böhringer, Balistreri, and Rutherford 2012; Jakob, Steckel, and Edenhofer 2014). Understandably then, BCA tend to be supported by industry groups and feature

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[1] Current import tariffs and non-tariff trade barriers that are actually lower for CO_2-intensive goods (Shapiro 2020).

prominently in major carbon pricing proposals, including those by the Climate Leadership Council for the United States[2] and the European Union's Green Deal[3].

Less is known about the distributional effects of Border Carbon Adjustments. In recent work I set out to better understand the distributional effects of BCA to complement an EU-wide carbon price (Sager 2019a). These distributional effects can be important in at least two ways. First, BCA will raise prices for energy-intensive imports that are not subject to an equivalent carbon price at home. Similarly, BCA will lower the all-inclusive cost of exports consumed abroad vie export rebates. Consumers with high and low incomes likely consume these goods in varying proportions, which means that they face unequal burdens from the resulting price changes. That's the 'use-side' effect of BCA.

Second, the change in relative prices following the introduction of BCA will shift the demand for both final goods and intermediates. Domestic demand for imports from countries that do not have their own carbon price will likely fall as they become subject to additional tariffs. In turn, demand abroad for exports from the country or region introducing BCA will rise, as these benefit from export rebates. This will shift the burden of emission abatement between countries, usually increasing the burden for those countries that did not implement their own carbon price and are thus subject to higher tariffs (Elliott et al. 2010; Böhringer, Balistreri, and Rutherford 2012; Larch and Wanner 2017). And it will lead to sectoral shifts within the economy introducing the BCA—carbon-intensive and trade exposed domestic sectors will likely benefit the most from the introduction of BCA, relative to a scenario with a domestic carbon price but without BCA. This may affect the returns to capital and compensation of different types of labor. That's the 'source-side' effect.

The consequences of BCA will vary by context. In Section 3, I derive stylized results that describe the likely distributional effects on the 'use-side' when introducing a generic form of BCA in many countries. In Section 5, I complement this with a more detailed case study of BCA to accompany an EU-wide carbon price. That case study is adopted from my previous work (Sager 2019a) and extended to include 'source-side' effects.

The second policy measure that we will investigate is Green Industrial Policy. Industrial Policy describes a range of policy measures aimed at changing the structure of an economy. The

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[2] The Four Pillars of our Carbon Dividends Plan, https://clcouncil.org/our-plan/

[3] EU Green Deal - Roadmap and key actions, https://ec.europa.eu/info/files/annex-roadmap-and-key-actions_en

objectives can vary greatly. For example, Industrial Policy may aim to strengthen the competitiveness of export-oriented sectors (Eaton and Grossman 1986) or it may aim to reduce market power and diversify the sectoral composition of an economy (Rodrik 2004). Industrial Policy is 'green' when the objective is to reduce an economy's environmental footprint—by cleaning up existing activities or by shifting the economic mix in favor or cleaner activities (Hallegatte, Fay, and Vogt-Schilb 2013; Rodrik 2014; Altenburg and Assmann 2017). In the context of climate policy, this translates into measures aimed at (1) reducing the carbon intensity of individual sectors (such as renewable energy subsidies and portfolio standards), and those measures aimed at (2) shifting the balance of the economy in favor or less carbon-intensive sectors. I focus on the latter, broadly defining Green Industrial Policy (GIP) as those policies that change the sectoral mix of an economy in ways that make it 'greener'.

Green Industrial Policy too can have important distributional effects. In this case, the most immediate effects are on the 'source-side'. Shifting the sectoral composition within an economy towards green sectors, and away from brown sectors, will also shift the composition of trade flows and income patterns. Labor demand will rise in green sectors but fall in others. Depending on the relative labor intensity of sectors, the aggregate labor demand could go in either direction. The effect could differ across workers, for example if the growing green service industries employ different workers from those in shrinking energy-intensive manufacturing. Equally, we may see shifts in the relative share of output falling to owners of capital and workers. In Section 4, I derive stylized results that describe the likely distributional effects on the 'source-side' of a generic version of GIP, and compare those across countries.

3. The ‘Use-side’: Welfare Cost of Price Changes

The work analyzing the distributional effects of climate policy, and carbon pricing in particular, usually takes one of two approaches. One approach attempts a relatively complete assessment of the specific policy at hand, including modeling of dynamic adjustment and general equilibrium effects. Such analyses—often carried out using computational models—can capture both ‘use-side’ and ‘source-side’ effects together (Hafstead and Williams 2018). In Section 5, I will use a computational framework developed in previous work (Sager 2019a) to simulate the distributional effects for an EU Border Carbon Adjustment, taking into account adjustments on both the supply and the demand sides of the economy.

Complex computational models come at the cost of reduced transparency, more demanding assumptions, and a loss of comparability across policy settings. That is why other, simpler approaches are sometimes helpful to understand the distributional forces at play. On the ‘use-side’, this usually involves looking at the ‘initial incidence’ to describe how the cost of the first dollar of a carbon price is distributed across consumers at different income levels (Grainger and Kolstad 2010; Williams et al. 2015; Dorband et al. 2019). In this static approach, welfare effects are based on observed expenditure patterns, readily available form household surveys. Importantly, the relative patterns of distributional incidence—a policy is either regressive or progressive across income groups[4]—tend to be similar under both approaches. Below I extend this second approach to a trade setting and show that we can summarize the ‘initial incidence’ of environmental trade measures using a simple statistic.

We begin with a model of consumer behavior. Let us assume that we can reasonably approximate consumer demand using the Almost Ideal Demand System (AIDS) proposed by Deaton and Muellbauer (1980), and that there are no savings. Total expenditure is equal to income. In this demand system, expenditure shares are log-linear in income[5]. Specifically, household h devotes the following share of her total budget x_h to good j:

$$s_j(\mathbf{p}, x_h) = \frac{x_{jh}}{x_h} = \alpha_j + \sum_{k=1}^{J} \gamma_{jk} \log(p_k) + \beta_j \log\left(\frac{x_h}{\mathrm{a}(\mathbf{p})}\right)$$

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[4] This ignores the ‘horizontal equity’ dimension due to differences between consumers with similar incomes.

[5] Engel curves may not be log-linear as assumed by AIDS, giving rise to non-monotonic incidence patterns. In such cases, statistic (1) could vary over different income levels.

Expenditure of household h on good j depends on preferences for good j (α_j), the prices of all goods k (p_k) and the logarithm of household h's income (x_h), normalized by the price level (a($\mathbf{p}$)). Price effects are captured through cross-price elasticities between goods j and k (γ_{jk}) and income effects through income (semi-)elasticities for each good j (β_j).[6] Goods with positive income elasticities ($\beta_j > 0$) are luxury goods—richer households devote larger budget shares to these. Conversely, a good is a necessity if $\beta_j < 0$. Income elasticities determine the relative expenditure shares of poor and rich consumers, and are thus the main driver of distributional effects.

In this model, individual consumer expenditures are easily aggregated. To describe the economy-wide average expenditure share devoted to good j, we simply replace the individual household expenditure (x_h) with an inequality-adjusted average ($\tilde{x}$), so that $S_j = s_j(\mathbf{p}, \tilde{x})$.[7] Using this aggregation property, we can rewrite individual expenditure shares $s_j(\mathbf{p}, x_h)$ as a combination of average expenditure shares, S_j, and a household-specific term:

$$s_j = S_j + \beta_j \log\left(\frac{x_h}{\tilde{x}}\right)$$

The second term represents the difference in household h's expenditure share devoted to good j to the average across all consumers[8]. These expenditure shares drive the welfare effect that consumers experience when prices change. The marginal welfare effect of a small change in (log) prices, $\hat{p}_j = \text{dlog}(p_j)$ on consumer h consuming goods j is:

$$\widehat{\omega}_h = \sum_{j=1}^{J}(-\hat{p}_j)S_j + \left(\sum_{j=1}^{J}\beta_j(-\hat{p}_j)\right)\log\left(\frac{x_h}{\tilde{x}}\right) = \widehat{W} + \widehat{\Psi}_h$$

This is the Hicksian equivalent variation—the maximum amount of income that a consumer would give up for a price increase not to occur—of a set of small price changes. Differences across income groups are captured by the consumer-specific element $\widehat{\Psi}_h$, which depends on a consumer's budget (x_h) and income semi-elasticities of goods j (β_j).

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[6] Parameters are restricted to $\sum_j \alpha_j = 1, \sum_j \beta_j = 0, \sum_k \gamma_{jk} = 0$ and $\gamma_{jk} = \gamma_{kj}$ for all j,k.

[7] Inequality-adjusted mean expenditure $\tilde{x} = \bar{x}e^{\xi}$ where $\xi = \sum_h \left[\frac{x_h}{\bar{x}} \log\left(\frac{x_h}{\bar{x}}\right)\right]$ is the Theil index of income inequality.

[8] This decomposition is adopted from Fajgelbaum and Khandelwal (2016), as presented in Sager (2019a).

The final step is to model price changes induced by climate policy. Let’s assume that a carbon tax results in price changes that are proportional to the tax rate τ_j (in \$ per ton of CO_2) multiplied by the emission intensity e_j of each good (in tons of CO_2 per \$ of final output). Prices rise to $p_j^{new} = (1 + \tau_j e_j)p_j$ and the price increase of good j is: $\hat{p}_j = \log(1 + \tau_j e_j) \approx \tau_j e_j$. For simplicity, the full carbon price is passed on to consumers.

Substituting price changes policy into our welfare effect derived above, we obtain a first-order approximation to the initial welfare loss from carbon prices τ_j (\$ per t of CO_2) for goods with carbon contents e_j (t of CO_2 per \$), as experienced by consumer h with income x_h:

$$-\widehat{\omega}_h \approx \sum_{j=1}^{J}(\tau_j e_j)S_j + \left(\sum_{j=1}^{J}\beta_j \tau_j e_j\right)\log\left(\frac{x_h}{\tilde{x}}\right) \tag{1}$$

This statistic summarizes the welfare effects of climate policy on the ‘use-side’. The first term is common to all consumers. Besides pricing elements τ_j and e_j, it is entirely determined by aggregate expenditure shares on j goods, S_j. Distributional effects are captured by the second term, which depends on consumer budgets (x_h), policy-induced price changes of goods j ($\tau_j e_j$) and income semi-elasticities of those goods (β_j).

The distributional character of climate policy is summarized by the term $(\sum_{j=1}^{J}\beta_j \tau_j e_j)$. This statistic describes the additional welfare loss of consumers for each log point increase in income. If it is positive, the policy is progressive—consumers with higher incomes experience larger losses relative to their incomes. If the statistic is negative, the policy is regressive.

Climate policy tends to increase the prices of carbon-intensive goods (larger e_j). This will be regressive if these goods are also necessity goods (negative β_j). Poorer households spend larger shares of their incomes on carbon-intensive necessities, and thus experience a relatively larger decrease in effective spending power when the prices of these goods rise. In equation (1), this can be summarized as a positive correlation between income elasticities and emission intensities, $\mathrm{cov}(\beta_j, e_j) < 0$.[9] Similarly, a carbon price is progressive if carbon-intensive goods tend to be luxury goods, i.e. $\mathrm{cov}(\beta_j, e_j) > 0$.

This relationship between income elasticities and emission intensities is at the heart of distributional analysis on the ‘use-side’. Considering all goods, domestic and imported, there is

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[9] This is based on the combination of $\left(\sum_{j=1}^{J}\beta_j \tau e_j\right) > 0$ and the AIDS model restriction that $\sum_{j=1}^{J}\beta_j = 0$.

usually a negative relationship, $\operatorname{cov}(\beta_j, e_j) < 0$. Poor consumers spend larger shares of their incomes on carbon-intensive goods such as heating fuel, electricity and gasoline, at least in rich countries like the United States (Sager 2019b). As a result, they tend to be more exposed to climate policy rendering these goods more expensive (Grainger and Kolstad 2010).

In previous work (Sager 2019a), I extended this approach to incorporate trade-specific effects. The key is to model price changes that differ not only by type of goods, but also by their origin. Consider a Border Carbon Adjustment introduced by the United States. American consumers purchase both Chinese and European electronics, which differ in carbon-intensity and will experience different price changes. This has distributional effects if poor consumers spend more on electronics from one origin, while rich consumers spend more on the other. The simplest way to capture this is by treating goods in each sector s and from each origin n as distinct varieties, following Armington (1969). This translates into $J = N \times S$. We can then model policies that include tax rates ($\tau_j = \tau_{n,s}$), emission factors ($e_j = e_{n,s}$), and income elasticities ($\beta_j = \beta_{n,s}$) that vary by type and origin. The real challenge is estimating these origin-specific parameters.

Parameter Estimates: The tax rates on emissions (τ_j) depend on the policy scenario. Emission intensities (e_j) can be based on engineering estimates or are derived using input-output based emissions accounting[10]. In a trade setting, the most challenging parameters to estimate are the income elasticities (β_j). Environmental trade measures often explicitly lead to differential changes in relative prices of the same types of goods from different origins. And income elasticities may differ, too. Iron-derived products from China may well act like necessities, while iron-derived products from Sweden are closer to luxury goods. Household expenditure surveys, which are usually used for 'use-side' analyses, do not differentiate goods by origin, making it difficult to estimate good-origin specific income elasticities. One way around that is provided by structural gravity models, which use data on between-country trade flows to estimate price and income elasticities of demand. One such method is proposed by Fajgelbaum and Khandelwal

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[10] Input-output based emissions accounting following Leontief (1970) calculates total emissions intensities $(\boldsymbol{I} - \boldsymbol{A})^{-1}\mathbf{d}$ where $\boldsymbol{A}$ is the direct requirement matrix and $\mathbf{d}$ is the J-vector of direct emissions intensities. In a trade setting, a slightly modified approach uses Multi-Region Input-Output tables to represent global value chains and only counts those emissions from (origin x source) pairs subject to the policy. This is easily achieved by pre-multiplying $\mathbf{d}$ with the appropriate pricing vector describing the bilateral policy mix.

(2016) who pair an AIDS demand model with an Armington model of trade differentiated by origin. This makes it possible to estimate origin-specific income elasticities from country-level trade flows. Simply put, if rich countries import more Swedish products and poorer countries import more Chinese products, then we can infer that Swedish products are luxury goods and Chinese ones are necessities. In my recent work (Sager 2019a), I extend this framework to study the global distributional effects of carbon pricing. In what follows, I use origin-specific elasticities estimated in Sager (2019a).[11]

Application 1: Use-Side Effects of Border Carbon Adjustments

Equation (1) provides an easy and comparable way to quantify the likely direction and magnitude of the distributional effects from climate policy. Here, we use it to compare the 'initial incidence' of a Border Carbon Adjustment introduced in different countries. BCA are usually added to counteract some of the adverse effects of domestic carbon prices on competitiveness. While the distributional effects of domestic carbon prices are well-studied, I focus on the trade-specific policy elements, assessing the standalone effects of BCA.

Figure 1 shows the generic 'use-side' cost to consumers within each country from introducing BCA of \$30/t of CO_2. These estimates apply the statistic in (1) to the 40 countries and 35 sectors in the 2013 release of WIOD. BCA are assumed to raise prices in each destination country in proportion to the content of non-domestic emissions contained in the value-chain (e_j).[12]

Income elasticities (β_j) are those estimated in Sager (2019a). The horizontal axis in Figure 1 shows the average welfare loss under BCA expressed as percentage share of overall expenditure. That's the first term of equation (1), $\sum_{j=1}^{J}(\tau_j e_j)S_j$. The vertical axis shows the relationship between consumer income and welfare losses. That's the second term of equation (1), $(\sum_{j=1}^{J}\beta_j\tau_j e_j)$.

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[11] These estimates rely on the World Input-Ouput Database (WIOD), which provides bilateral trade flows in intermediate inputs and final goods between 40 countries and 35 sectors (Dietzenbacher et al. 2013), as well as corresponding environmental satellite accounts with CO_2 emissions from fossil fuel combustion (Genty, Arto, and Neuwahl 2012). Data and methods are described in detail in Sager (2019a).

[12] This approach is equivalent to introducing a BCA even if there is no domestic carbon price, holding constant existing value chains and consumption patterns. The Case Study in Section 5 presents results from a more complete modeling exercise where BCA are added onto an EU-wide carbon price, and taking into account input substitution along value chains as well as consumer demand substitution.

Consumers in larger countries tend to face smaller costs from BCA, as shown in Figure 1 (horizontal axis). The average consumer cost from a \$30/t BCA is at or below 0.5% of incomes in China, France, India and the USA. But it is closer to 1% in smaller countries such as Hungary, Latvia and Estonia. This is likely because smaller countries import larger shares of both final goods and intermediate inputs.[13] In addition, countries importing more goods from more emissions-intensive origins face larger costs from BCA. For example, Eastern European countries trading relatively more with carbon-intensive Russia face some of the highest cost to consumers.

Figure 1 also suggests interesting distributional effects of BCA on the 'use-side' (vertical axis). In many countries, the cost to consumers falls by about -0.05 percentage points for each additional log-point of income (equivalent to multiplying income with about 2.5). In other words, BCA are mildly regressive across consumer income groups. This regressivity is more pronounced in countries where imported emissions—both from final goods and intermediates—are largely embedded in necessity goods ($\beta_j < 0$). The clearest case of this pattern can be seen in the United States. The opposite holds for Indonesia and India, where imported emissions appear largely linked to luxury goods ($\beta_j > 0$) and BCA are moderately progressive.

Overall, the distributional effect of BCA across consumer income groups within countries appears relatively mild. But Figure 1 suggests that there may be important exceptions, including some of the largest economies and those that are heavily exposed to emission-intensive trade.

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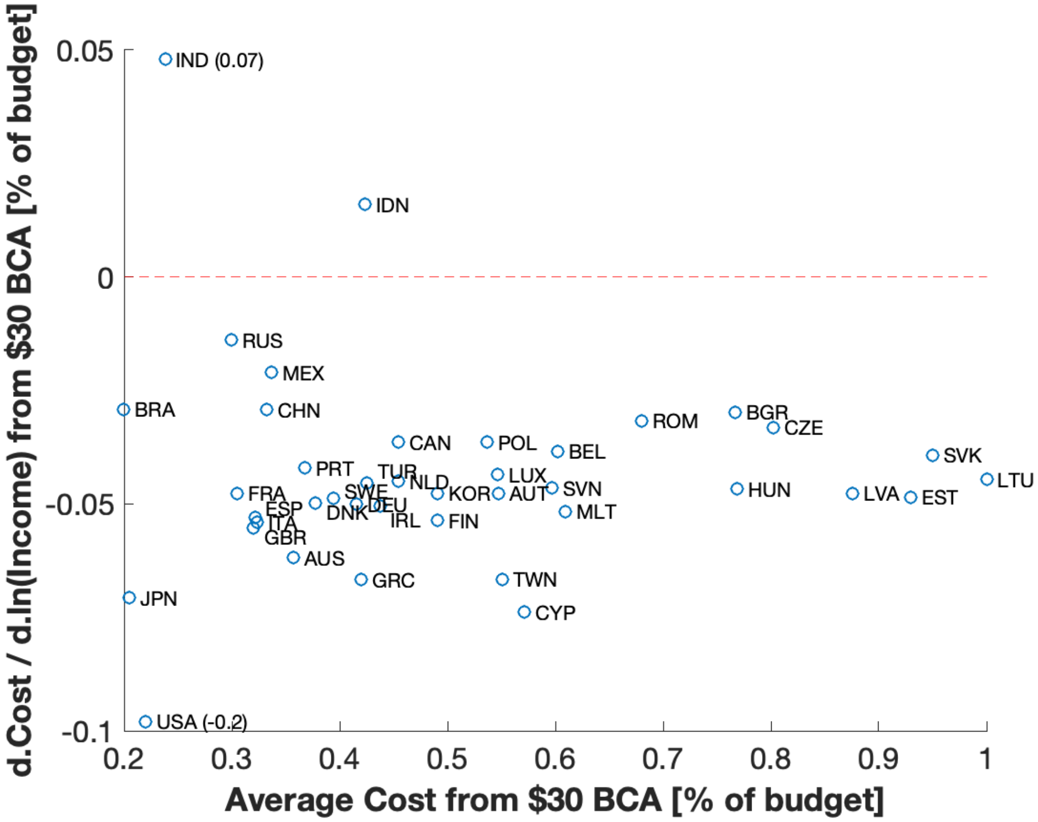
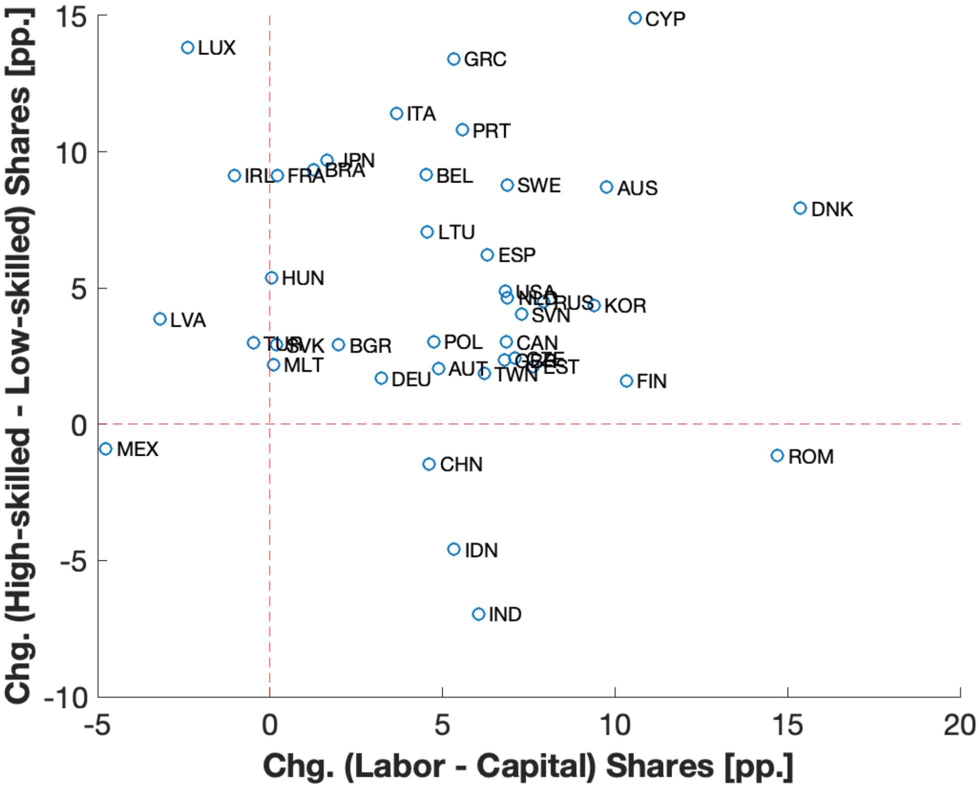
[13] In 1 trading bloc membership is ignored, so that trade between two EU-member states is also subject to BCA.

Figure 1: Use-side Incidence of Border Carbon Adjustments by Country



Notes: This figure shows the initial use-side incidence of Border Carbon Adjustments at a level of $30 per ton of CO2 emissions, calculated using equation 1 by country. The horizontal axis shows the average welfare cost (as % of annual expenditure) to domestic consumers (first term of equation 1). The vertical axis shows the relative change in the cost for each additional log-point of income (second term). Data are from WIOD, averaged over 2000- 2009. Parameter estimates follow methodology in Sager (2019a).

Figure 2: Source-side Incidence of Green Industrial Policy by Country



Notes: This figure shows the initial source-side incidence of Green Industrial Policy, interpreted as scaling sector output inversely proportional to their carbon-intensity and holding national aggregate output constant. Changes are calculated using equation 2 by country. The horizontal axis shows the predicted change in the difference between labor and capital compensation (as % of gross output). The vertical axis shows the predicted change in the difference between labor compensation shares going to high-skilled and low-skilled labor (as % of total labor compensation). Data are from WIOD, averaged over 2000-2009.

4. The ‘Source-side’: Income Effects from Sectoral Shifts

In addition to the ‘use-side’ effects discussed above, there can be important ‘source-side’ effects from climate policy. We may see income shifting between capital and labor, as well as effects on employment and compensation of different types of workers. This too can have important distributional implications.

The ‘source-side’ effects of climate policy involve non-linearities and feedback effects, mediated by market imperfections such as labor market frictions (Hafstead and Williams 2018; Castellanos and Heutel 2019). That is why specific climate policy proposals are best assessed using general equilibrium models (Fullerton and Heutel 2007; Rausch, Metcalf, and Reilly 2011). But when looking to understand the distributional tendencies of a range of policy options, we can again quantify the likely direction and magnitude of ‘source-side’ effects using a simple statistic. We begin by defining our object of interest, the aggregate ‘source-side’ characteristic $\bar{\lambda}$:

$$\bar{\lambda} = \sum_{\boldsymbol{k=1}}^{\boldsymbol{K}} (a_k \cdot \lambda_k)$$

This characteristic $\bar{\lambda}$ is the average of sector-level characteristics λ_k, weighted by the output share of each sector in the economy, $a_k = \frac{Y_k}{Y}$. A policy-relevant example of $\bar{\lambda}$ is the share of income flowing to workers rather than to the owners of capital. A policy can affect the income share of labor in two ways. First, it can raise the income share of labor within sectors, raising λ_k. Second, it can target composition, aiming to raise the output shares a_k of those sectors that already compensate workers more handsomely. In a stylized world of perfect competition and constant returns to scale, sectorial λ_k is immutable and composition is the only policy option.

Below, I consider a policy that shifts the composition of sectors, holding overall output constant. Some sectors grow, increasing their output share ($\Delta a_k > 0$), while others shrink ($\Delta a_k < 0$). The effect of this compositional shift on characteristic $\bar{\lambda}$, is our second distributional statistic:

$$\Delta\bar{\lambda} = \sum_{k=1}^{K} (\Delta a_k \cdot \lambda_k) \qquad (2)$$

I will use equation (2) to assess the likely ‘source-side’ effects of Green Industrial Policy next.

Application 2: Source-Side Effects of Green Industrial Policy

I define Green Industrial Policy (GIP) as policies that support low-emissions sectors, increasing their share in the economy, while shrinking that of high-emissions sectors. Label the emission-intensity of a sector e_k, describing how much CO_2 is emitted per \$ of output. Green Industrial Policy typically lowers the output shares ($\Delta a_k < 0$) of sectors that are emission-intensive (high e_k), and raises the output shares ($\Delta a_k > 0$) of greener sectors (low e_k). Many measures can achieve such shifts, including a carbon tax, subsidies or targeted investment. The net effect of Border Carbon Adjustments works in the opposite direction, protecting emission-intensive domestic industries that would fare worse under a domestic carbon price only. In what follows, I abstract from the specific policy instrument and focus on a generic definition of GIP as a set of changes in sector output levels that are negatively correlated with emissions, ($\mathrm{cov}(\Delta a_k, e_k) < 0$). Figure 2 shows the source-side incidence of such Green Industrial Policy (GIP) for 40 countries in the WIOD sample, averaged over the years 2000-2009. Specifically, I re-scale gross output in each domestic industry in inverse proportion to its carbon-intensity e_k, holding total output in each country constant.[14] For example, if the metal sector emits twice as much CO_2 per \$ of output as the economy as a whole, and initially constituted 20% of gross output, then the metal sector will be scaled down to 10% of total output after GIP.

Using equation (2), I calculate the change in two 'source-side' statistics $\bar{\lambda}$. First, I look at the share of gross output that flows to labor compensation minus the share that goes to capital. This measure broadly summarizes the participation of workers in the proceeds of economic activity. It is shown on the horizontal axis of Figure 2. Second, I consider the difference between the share of labor compensation that goes to high-skilled workers minus the share that goes to low-skilled workers. This measure broadly describes which segment of workers stands to benefit, or lose. It is shown on the vertical axis. Both are expressed as percentage point differences.

Figure 2 suggests that GIP favors sectors with higher shares of income going to labor in most countries (horizontal axis). Because carbon-intensive industries tend to also be relatively capital-intensive, sectoral shifts under GIP increase to overall share of gross output flowing to labor compensation relative to capital (Fullerton and Heutel 2007). Moreover, GIP favors sectors with relatively more demand for high-skilled labor (vertical axis). As we shift away from

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[14] Initial output shares a_k are transformed into new output shares $a_k^{new} = \frac{a_k}{e_k}\varphi$ s.t. $\sum_{k=1}^{K}(a_k^{new}) = 1$.

relatively carbon-intensive resource extraction and manufacturing towards less carbon-intensive services, demand for more skilled workers increases. But there are important exceptions. In some of the largest emerging market economies—India, China and Indonesia in particular—GIP appears to favor relatively low-skill labor sectors instead.

In Sections 3 and 4, we have seen that trade-targeted climate policy can have important distributional consequences through both ‘use-side’ and ‘source-side’ effects, affecting both the prices faced by consumers and the income shared going to capital and labor. I have suggested two simple statistics to describe the general direction of the distributional forces at play. We have seen two applications: Border Carbon Adjustments as an instrument that primarily operates through use-side effects, and Green Industrial Policy as an instrument that induces sectoral shifts and thus important ‘source-side’ effects.

The analysis suggests a number of general insights. The ‘use-side’ cost of BCA tends to be more pronounced in small economies with a higher trade share, and especially in those economies that are importing from carbon-intensive origins. And these costs are mildly regressive, affecting consumers with lower incomes a little more, with a few exceptions. Meanwhile, GIP aimed at reducing the output share of emission-intensive sectors tend to favor growth in green sectors that are more labor-intensive, raising the labor share of income in the economy. These sectors also tend to employ more skilled workers, and so GIP will raise the relative demand for high-skilled labor. However, the analysis has also shown that there are some important exceptions to these trends, notably amongst large developing economies.

5. Case Study: EU Border Carbon Adjustment

The above discussion has drawn out some general insights regarding the distributional effects of environmental trade measures, using simple statistics to quantify static effects on both the 'use-side' and the 'source-side'. Of course, these dynamics will vary across policy instruments and context. In this section, I more thoroughly assess one specific policy: A Border Carbon Adjustment that complements an EU-wide carbon price by taxing emissions embedded in imported goods and services and rebating carbon prices paid on exports. The simulations go beyond the simple statistics presented above, by allowing for additional margins of adjustment:

1) consumers react to final goods price changes by substituting consumption;
2) producers react to fuel price changes by adjusting their fuel mix; and
3) producers substitute intermediate inputs when their prices change, altering the structure of global value chains and the composition of trade flows.

All three adjustment dynamics lead to changes in the demand for output from different sectors and different origins. To isolate the effects of these compositional changes, I hold world output constant. The simulation methods are taken from my recent work (Sager 2019a). The data source is again WIOD and demand and supply elasticities are estimating using a structural gravity approach following Fajgelbaum and Khandelwal (2016) and Anderson and van Wincoop (2003). The technical details can be found in Sager (2019a).

All results show the difference between two scenarios. The baseline scenario is the introduction in 2005 of an EU-wide price of \$30/t on CO_2 emissions from fossil fuel use in all sectors. This is similar to recent EU ETS prices of around 25-30 EUR/t of CO_2 in 2020. The comparison scenario adds to this a Border Carbon Adjustments with two elements: (1) a carbon tariff on the carbon content of all non-EU imports, both of intermediates and final goods, and (2) rebates for carbon prices paid in goods traveling abroad. The difference between the two scenarios is shown here in order to isolate the net effect of Border Carbon Adjustments only.

The distribution of 'use-side' costs from higher final goods prices is shown in Figure 3. The horizontal axis shows percentiles of the EU-wide income distribution, with lower incomes on the left. Compared to a domestic carbon price only, adding BCA is moderately regressive—generating an additional cost equivalent to 0.5% of consumer budgets for the bottom 10% of the EU income distribution, compared to about 0.3% for those in the 70-90% range. Consumers at the very top experience higher costs again.

This regressive 'use-side' effect of an EU BCA is in line with Figure 1, which shows that imported emissions are disproportionately embedded in necessity goods. However, the EU-wide distribution in Figure 3(a) is not only driven by income elasticities of demand, but also by differences in the composition of imports between EU member countries. Figure 3(b) suggests that the 'use-side' cost from a BCA is larger in Eastern European and Baltic EU member states that import a more CO_2-intensive mix of goods.

The 'source-side' effects—changes in output, the relative returns to factor incomes, and labor demand—are shown in Figure 4. The BCA is predicted to significantly raise output demand for many EU industries, again relative to a scenario with a domestic carbon price only. Figure 4(a) compares countries' trade exposure (measured as share of gross output exported, horizontal axis) with the predicted change in country gross output (horizontal axis). Adding the BCA to a domestic carbon price raises the cost of imports into the EU and lowers the cost of exports consumed abroad. This raises demand for EU products, and more so in smaller and more trade-exposed EU member states.[15] In return, some trading partners experience lower demand for exports to the EU, especially from countries with high carbon-intensity, such as Russia or Indonesia. These shifts in output are qualitatively similar to changes in trade flows predicted by Larch and Wanner (2017) who simulate counterfactual carbon tariffs to harmonize implicit carbon taxes globally. They predict reductions in trade flows from developing nations into industrial nations adopting BCA, just like what Figure 4 (a) shows for the EU and trading partners.

Besides raising aggregate demand for European goods and lowering demand for imports, an EU BCA would likely affect sectors differently. Figure 4(b) breaks down the net change in gross output by country and sector. The output shifts described above—in favor of EU industries and at the cost of industries abroad—appear more intense for relatively carbon-intensive industries. This is again in line with previous simulations of similar scenarios within computational multi-sector, multi-region models of trade (Caron 2012; Takeda, Tetsuya, and Arimura 2012; Ward, Steckel, and Jakob 2019). The relative shifts in output demand in favor of

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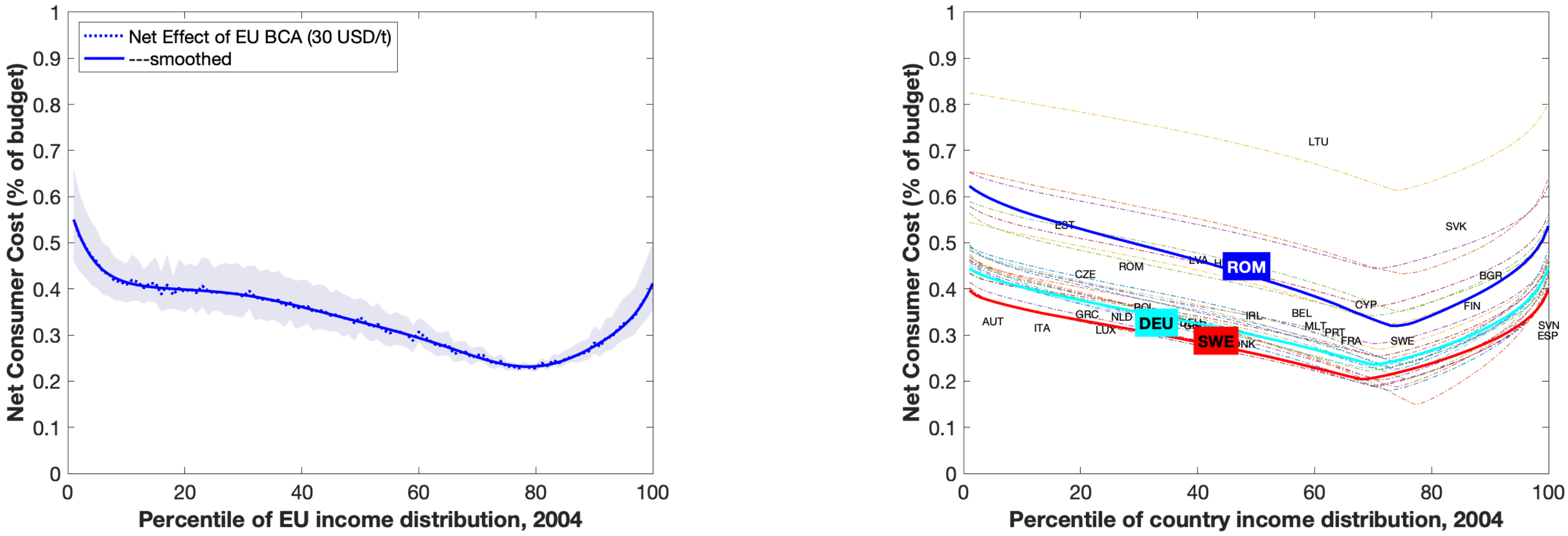
[15] Some of the predicted increases in output for small countries like Latvia or Malta exceed +20%, which may appear unreasonably large. The numbers shown are driven by the relatively large substitution elasticities and do not incorporate potentially important counter-veiling forces such as exchange rate appreciation or decreasing returns to scale. Still, the direction of output effects appears plausible and in line with previous contributions.

domestic energy-intensive trade-exposed industries may have important repercussions for relative factor returns as well as for political feasibility of a BCA mechanisms for the EU.

While an EU BCA is predicted to exert upward pressure on output levels in most EU countries and industries, it is less clear who will benefit from this. The incidence of higher output demand will depend on factors such as the degree of competition, the potential for returns to scale and the prevalent markups. Focusing on composition only, we can again derive some stylized results. Figure 5 provides shows how the predicted shifts in sectoral composition translate into relative factor demand, calculated again from equation (2). The sectoral shifts from adding a BCA to an EU-wide carbon price look neutral with regard to labor and capital compensation (horizontal axis). But the BCA appears to favor sectors with relatively higher shares of low-skilled labor, shifting the overall labor demand balance away from high skilled labor (vertical axis). This is in line with Figure 4(b) which shows that EU sectors that are both relatively energy-intensive and less skill-intensive experience a boost in demand. A European Border Carbon Adjustments, by protecting the competitiveness of carbon-intensive industries at home, may also lead to a shift in labor demand towards less skilled work in those same industries.

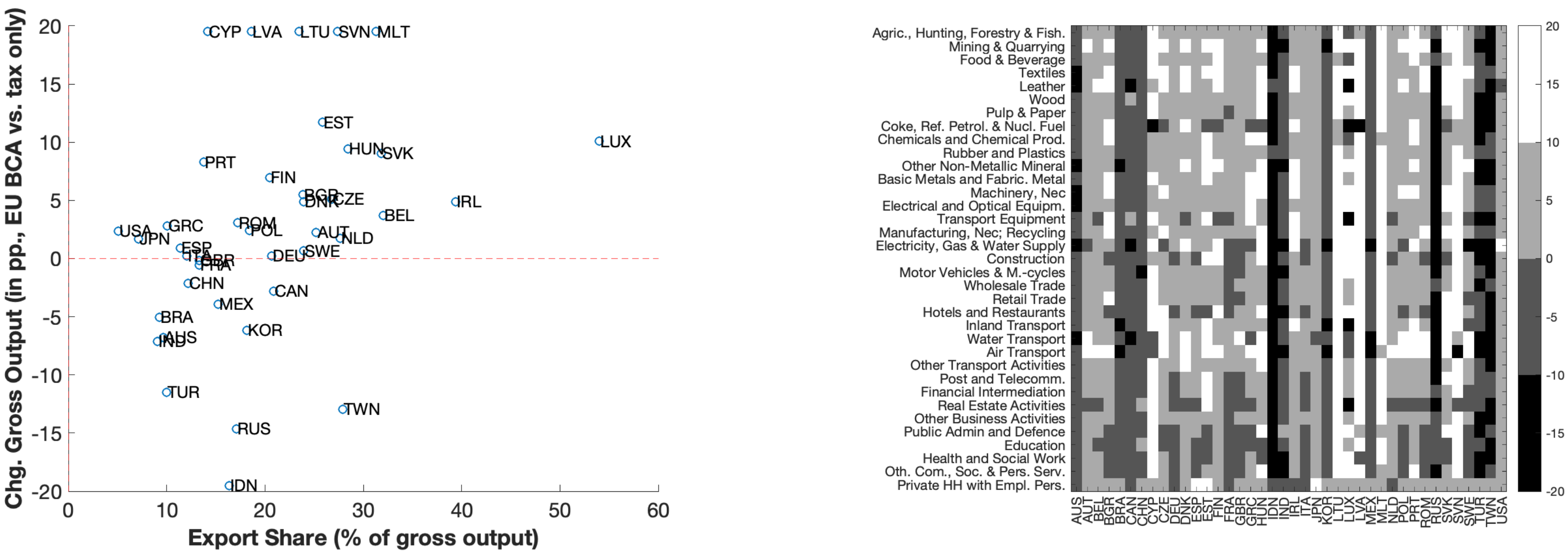
Figure 3: Use-side Effects of EU Border Carbon Adjustment (30 USD/t) vs. EU price only


(a) EU-wide distribution

(b) Within-country distribution

Notes: This figure shows the distribution of the consumer cost from an EU-wide (27 countries) Border Carbon Adjustment to complement a uniform carbon price of 30 USD per ton of CO2. Figures shown are based on the difference (net effect) relative to a scenario with a domestic EU-wide price only. Estimates shown are simulated using parameters from the 2004 WIOD (model includes 40 countries plus RoW and 35 sectors). The horizontal axis shows percentiles of the income/expenditure distribution, both EU-wide (Panel a) and within each of the 27 EU countries among the 40 WIOD countries (Panel b). This figure reproduces results first reported in Sager (2019a), where data and methods are described in more detail.

Figure 4: Source-side Effects of EU Border Carbon Adjustment (30 USD/t) vs. EU price only

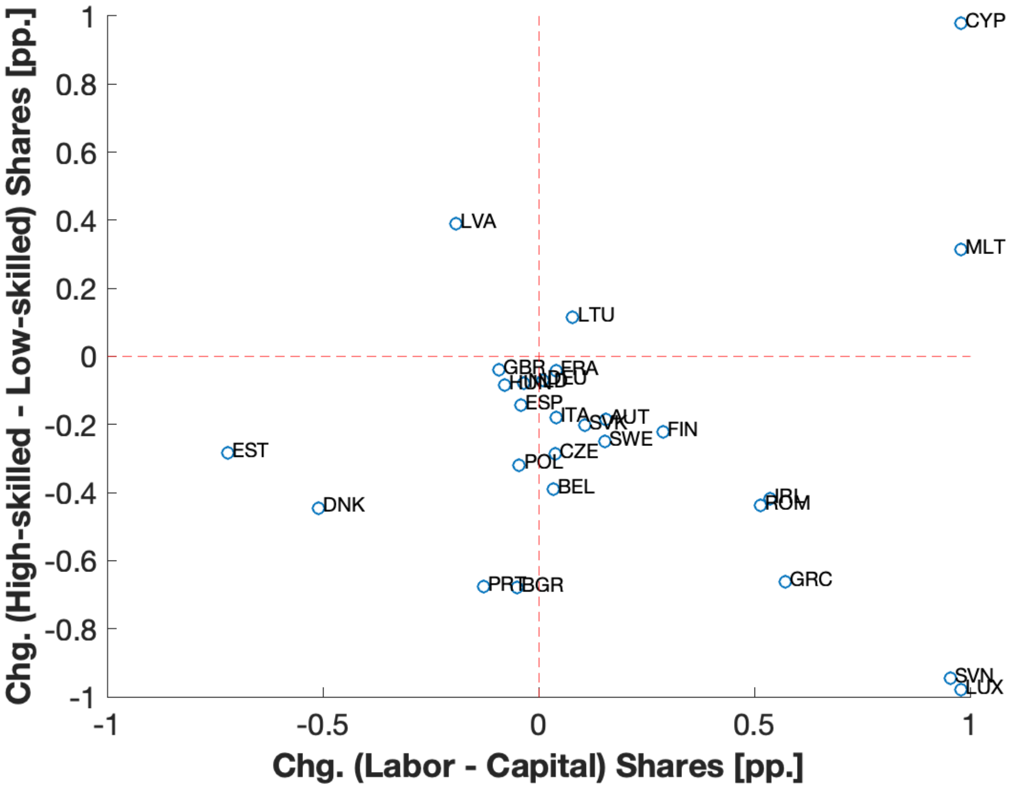


(a) Trade Exposure and Gross Output Effect (% chg.)

(b) Gross Output Effect by Sector (% chg.)

Notes: This figure shows the simulated gross output effects from an EU-wide (27 countries) Border Carbon Adjustment to complement a uniform carbon price of 30 USD per ton of CO_2. Figures shown are based on the difference (net effect) relative to a scenario with a domestic EU-wide price only. Estimates shown are simulated using parameters from the 2004 WIOD (model includes 40 countries plus RoW and 35 sectors). Panel (a): The horizontal axis shows country-level export shares (the share of gross output flowing abroad for both intermediates and final consumption as share of total gross output) and the vertical axis shows the country-level average change in gross output. Green markers represent EU member states, red markers non-member states. Panel (b): Each square corresponds to one sector (vertical axis) in one country (horizontal axis), with color shading indicating the simulated relative net change in gross output for that sector in that country. Data and methods are from Sager (2019a).

Figure 5: Source-side Incidence of EU BCA (30 USD/t) vs. EU price only



Notes: This figure shows the initial source-side incidence of an EU-wide (27 countries) Border Carbon Adjustment to complement a uniform carbon price of 30 USD per ton of CO_2. Figures shown are based on the difference (net effect) relative to a scenario with a domestic EU-wide price only. Estimates shown are simulated using parameters from the 2004 WIOD (model includes 40 countries plus RoW and 35 sectors). Changes in sector output are translated into source-side shifts using equation 2 by country. The horizontal axis shows the predicted change in the difference between labor and capital compensation (as %of gross output). The vertical axis shows the predicted change in the difference between labor compensation shares going to high-skilled and low-skilled labor (as % of total labor compensation). Data and methods are from Sager (2019a).

6. Conclusion

This paper has shown that environmental trade measures can have important distributional effects. These effects can be divided into 'use-side' effects, describing the cost to consumers from changing prices, and 'source-side' effects, describing changes in economic output, the share of income flowing to capital, and the demand for labor. I proposed two statistics to capture these distributional effects and applied them to two policies: (1) Border Carbon Adjustments (BCA) to complement unilateral domestic carbon prices, and (2) Green Industrial Policy (GIP) aimed at shifting the composition of an economy towards less carbon-intensive sectors.

BCA are likely to have regressive 'use-side' effects because imported carbon emissions are embedded in necessity goods, at least in rich countries. Meanwhile, the 'source-side' effect of BCA will likely benefit domestic sectors that are carbon-intensive and trade exposed, which may raise the demand for low-skilled labor. GIP, on the other hand, would likely raise the aggregate share of income flowing to labor rather than capital, and boost the demand for high-skilled labor.

Ultimately, each policy proposal needs to be assessed in in context, using a range of methods. I presented a case study of Border Carbon Adjustments to complement an EU-wide carbon price. The results suggest that an EU BCA would have regressive 'use-side' effects—both across income groups and between EU member states—while raising output demand for EU sectors, in particular those that are carbon-intensive and relatively low-skill.

Future research will be needed to better understand the distributional effects of environmental trade measures. On the 'use-side', it is important to estimate income elasticities of demand that are differentiated by country of origin. Regarding 'source-side' dynamics, more work is needed to better understand the consequences of shifts in sector output for the welfare of citizens, in particular when competition is not perfect and industries are subject to economies of scale.

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