Unilateral Environmental Policy and Offshoring*

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February 28, 2023

Abstract

This paper analyzes the impacts of a unilateral environmental policy reform on emissions, income, and inequality in the context of offshoring. We set up a general equilibrium model of offshoring with heterogeneous firms. Each firm can allocate labor to different production tasks and emission abatement. It also decides whether to offshore an emissions-intensive part of the production to benefit from lower labor and/or emissions costs abroad. We identify international differences in the ratio of input prices as a key determinant of the environmental impact of the offshoring decision. With a policy reform leading to an increase in offshoring, the input price ratio in both countries changes due to general equilibrium effects. This reinforces the relocation of emissions toward the host country of offshoring. Given a high level of offshoring, emissions may increase globally. In an extension, we analyze the introduction of a border carbon adjustment.

JEL-Classification: F18, F12, F15, Q58

Keywords: Offshoring; Environmental policy; Heterogeneous firms; Emissions leakage; Income inequality; BCA

*We thank the participants at the ETSG Conference in Ghent, the 9^{th} CGDE Doctoral Workshop, the Göttingen Workshop in International Economics, the BSE Insights Workshop, the Research Seminar at Sabancı University, the ISEFI Conference in Paris, the PET Conference in Marseille, the EAERE Conference in Rimini and the CEPIE Brown Bag Seminar at TU Dresden for helpful comments and fruitful discussions.

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1 Introduction

The practice of offshoring, encompassing the relocation of production tasks to foreign destinations, is subject to controversial public debates, mainly in the context of distributional and environmental consequences. In the context of man-made global warming, the environmental impact of spatial shifts in global production patterns is a highly relevant field of analysis. As data reveals, shifting of carbon-intensive production follows a certain pattern closely along a North-South division: Most OECD countries are net importers of embodied CO_2, while most non-OECD countries are net exporters.This pattern, indicating an outsourcing of pollution towards the Global South strongly intensified over the last 25 years (OECD, 2021). Countries aim to reduce national CO_2 emissions, most notably by raising taxation of carbon-intensive production inputs. However, there is substantial heterogeneity with respect to carbon pricing across countries (OECD, 2022), making international price asymmetries a key determinant of production relocation (Cherniwchan, 2017). Thus, stringency in environmental regulation to a great extent could be undermined by the firm-level capability to evade and shift "dirty" parts of its production elsewhere. The question arises how effective unilateral environmental policy can be in a highly globalized economy.

Countries are adopting several approaches to encounter the carbon leakage problem. Border carbon adjustments (BCAs) are clearly among the most widely discussed mechanisms in literature. By imposing a BCA, the national government closes a potential carbon price wedge between production at home versus production in countries with lower environmental stringency. A firm that relocates parts of its production has to pay the carbon price difference at the border upon re-importing the intermediate good. Recent literature reviews the BCA with respect to effectiveness and economic cost (cf. Böhringer et al., 2022; Farrokhi and Lashkaripour, 2021). BCAs are being implemented as policy instruments. Complementing its emission trading scheme, the European Union is currently introducing a Carbon Border Adjustment Mechanism (CBAM) (European Commission, 2021).

Against this background, we aim to depict the firm-level possibility to offshore abroad in the presence of an emission-intensive production process with emissions pricing. By increasing the emission tax in the home country, we firstly analyse how offshoring decisions are affected at the firm-level. For this purpose, we develop a general equilibrium model with heterogeneous firms given the option to offshore an emissions-intensive part of their production. We regard the firm-level to be a highly important scope of analysis, as changes in the emissions intensities of firms ("technique effect") are identified as the most important channel through which trade impacts aggregate emissions (Cf. Copeland et al., 2022). Secondly, we derive effects on emissions, aggregate income and inequality measures. To build our framework, we extend the offshoring model of Egger et al. (2015) with an emissions-generating process as introduced by Copeland and Taylor (1994). Accordingly, each active firm, which produces a unique variety of an intermediate differentiated good, allocates labor to a non-routine and a routine task as well as to emissions abatement. We assume that conducting the routine task generates emissions but can be offshored at fixed costs, while subsequent importing is subject to variable transport costs. Firms self-select into offshoring if profits can be increased, while we build on occupational choice decisions of heterogeneous agents with different managerial abilities to model the initial firm entry process. Under monopolistic competition, active firms supply their varieties to a final goods sector, whose output is consumed both in the source country and host country of offshoring, which closes the model.

Our model framework draws from several features of the trade literature. Our asymmetric two country setting captures the idea of the North-South literature (in the tradition of Feenstra and Hanson, 1997). We borrow from Grossman and Rossi-Hansberg (2008) and Acemoglu and Autor (2011) in modelling production as the combination of routine and non-routine tasks using the respective taxonomy established by Becker et al. (2013). Furthermore, we add to the still quite scarce literature on offshoring considering firm heterogeneity (e.g. Antras and Helpman, 2004, Antràs et al., 2006, Egger et al., 2019). We thereby aim to fill a research gap that has been identified at the intersection between trade liberalization, offshoring and emissions (cf. Cherniwchan et al., 2017).

There are several empirical contributions that investigate the impact of offshoring on emissions, such as Hanna (2010), Antonietti et al. (2017); Cherniwchan (2017), Cole et al. (2014), Akerman et al. (2021) and Tanaka et al. (2021). At the example of Japanese manufacturing, Cole et al. (2021) also features the role of carbon pricing on the firm-level decision to offshore.

Capturing general-equilibrium-effects, there are theoretical frameworks that link the dimension of exporting or final goods trade to emissions, such as Kreickemeier and Richter (2014), Forslid et al. (2018), Shapiro and Walker (2018) and LaPlue (2019). Egger et al. (2021) also investigate the role of environmental policy in the context of exporting. However, as we argue, the perspective of final goods trade is insufficient for a comprehensive analysis of the effects of unilateral environmental policy, as it does not take shiftings in the production process into account. To the best of our knowledge, we provide one of the first contributions that analyses environmental stringency in the context of offshoring. Schenker et al. (2018) investigate the effects of environmental policy on firm-level offshoring decisions and market structures. They also show how the introduction of a border carbon adjustment stops production relocation. The model setup strongly deviates from our setting as they incorporate a multi-stage production process with a continuum of goods and do not feature firm heterogeneity.

We derive our findings analytically as well as by numerical simulations. At the firm-level, we show that differences in effective emission taxation (tax-wage ratios) across countries determine the environmental impact of the firm-level decision to offshore. We then increase the source country's emission tax rate in order to derive effects in the economy. The unilateral policy reform incentivizes more firms to offshore, inducing general equilibrium effects on emissions, income and inequality. As the share of offshorers rises, firms adjust their production process at the micro-level. This reduces emissions per unit of output for purely domestic firms, while emission intensity levels increase among offshorers. At the aggregate level, we show that emissions in the source country (home) reduce while emissions in the host country (abroad) increase substantially. Interestingly, we highlight a non-monotonous effect of the source country's emission tax rate on global emissions: If the source country emission tax rate is sufficiently high, the leakage rate between the two countries may surpass 100%, implying a net increase in global emissions. However, this scenario implies a high initial level of offshoring in the economy.

Extending our view to income and inequality, we show that the increase in offshoring induced by the unilateral environmental policy reform mitigates the income losses associated to the tax increase. Furthermore – via increased offshoring – the environmental policy reform increases inequality within the source country and decreases inequality between the source country and the host country.

In order to assess effectiveness and economic cost of a BCA, we extend our analysis. We show that an emission tax increase – in the presence of a BCA – would no longer increase offshoring. Thus, the environmental policy reform clearly prevents leakage and reduces global emissions. However, under a border adjustment, the loss of global income induced by the unilateral emission tax increase shows to be larger as compared to the previous scenario without the border adjustment.

The remainder of this paper is structured as follows: Section 2 introduces the model framework, while Section 3 determines the offshoring equilibrium. Section 4 analyses a unilateral environmental policy reform focusing on the effects on firm selection into offshoring, on the factor allocation, emissions and income inequality. Section 5 extends our model framework to analyse the impacts of a BCA. Section 6 concludes.

2 The model setup

We consider an economy that consists of a final goods sector and an intermediate goods sector as in Egger et al. (2015). The production of the final good relies on the processing of different varieties of the intermediate product as only input. It does not generate emissions. By contrast, the production of intermediates, based on the performance of two tasks, generates emissions. While a non-routine task is emissions-free and needs to be performed at the headquarter, a routine task, which is emissions-intensive, can be offshored. Hence, an individual firm, which is constituted by a manager and workers allocated to tasks and emissions abatement, either exclusively produces domestically or offshores part of the production to a second country.[1]

Each of the two countries is populated by an exogenous mass of agents, N in the source country of offshoring and N^* in the host country of offshoring, respectively.[2] Individuals in the source country are heterogeneous in their managerial ability and can choose an occupation (cf. Lucas, 1978). If deciding to run a firm, an individual's managerial ability materialises in the productivity of the firm. Heterogeneity in abilities translates into heterogeneity of firms. In the host country of offshoring, by contrast, individuals can only perform the routine task as workers. Neither final nor intermediate goods production takes place. In both countries, income is solely used to consume the source country's final good, which is freely tradable. We assume balanced trade between the two asymmetric countries. Accordingly, final goods are shipped in one direction in exchange for the output of offshored routine tasks being shipped in the other direction.

2.1 The final goods sector

Following Ethier (1982) and Matusz (1996), we define final goods output as a CES-aggregate of differentiated intermediate goods $y(v)$:

$$Y = \left[\int_{v\in V} y(v)^{\frac{\sigma-1}{\sigma}} dv\right]^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

[1] For our conceptual understanding, we follow Grossman and Rossi-Hansberg (2008) who consider offshoring as international displacement of tasks "either within or beyond the boundaries" of the firm (p. 1981). From this perspective, regardless of the specific organizational structure, the term "offshoring" includes geographical relocation of production both within the same company (in-house) and to external suppliers (foreign outsourcing).

[2] We indicate expressions for the host country of offshoring with an asterisk.

where V denotes the set of available varieties of the intermediate good with $\sigma > 1$ being the elasticity of substitution. Final output Y is used as numéraire and its price is normalised to unity. Profit maximisation under assumed perfect competition leads to the demand for each intermediate variety v as

$$y(v) = Yp(v)^{-\sigma}, \tag{2}$$

which positively depends on aggregate income (of the two countries) being equal to Y and negatively on a variety's own price.

2.2 The intermediate goods sector

Firms in the intermediate goods sector operate under monopolistic competition, each producing a unique variety v of the differentiated intermediate good. The productivity of a firm is determined by its manager's managerial ability φ, which is Pareto distributed with lower bound of one and shape parameter $k > \sigma$: $G(\varphi) = 1 - \varphi^{-k}$. Each manager decides on worker employment and allocation, on offshoring activity, and on the production of her variety v.

We specify the production technology as

$$y = \varphi \left(\frac{x^n}{\eta}\right)^{\eta} \left(\frac{x^r}{1-\eta}\right)^{1-\eta} \qquad \text{with} \quad \eta \in (0.5, 1), \tag{3}$$

where x^n and x^r denote the output of a non-routine task and the output of a routine task, respectively.[3] The routine task generates emissions. It can be conducted domestically or offshored, based on the same technology independently of the production location. As in Acemoglu and Autor (2011) and Egger et al. (2015), labor can be allocated across tasks.[4] In addition, in our framework labor can also be used to reduce emissions as in Copeland and Taylor (2003). With the details deferred to Appendix A.1, we use the following functional forms to describe the execution of tasks

$$x^n = l^n \qquad \text{and} \qquad x^r = \beta\,(e)^{\alpha}\,(l^r)^{1-\alpha} \qquad \text{with} \quad \alpha \in (0,1), \quad \beta > 0, \tag{4}$$

where l^n and l^r denote labor allocated to the non-routine and routine task, respectively, and with

[3] The lower limit of $\eta > 0.5$ is in line with Egger et al. (2015) and backed by empirical findings (cf. Baldwin and Dingel, 2021).

[4] Task differentiation has gained increasing relevance in the context of offshoring frameworks. Carluccio et al. (2019) present empirical evidence for offshoring-induced changes in skill composition (and thus task assignment) of domestic labor employment.

e being the generated emissions. Accordingly, and as common in the literature (e.g. Copeland and Taylor, 1994; Shapiro and Walker, 2018; Egger et al., 2021), we treat emissions as an input factor in the production process that is imperfectly substitutable with labor. This formulation entails a declining marginal effectiveness of emissions abatement. Parameter α can be interpreted as the costs share of emissions in the production of the routine task. Jointly, Eqs. (3) and (4) yield a nested Cobb-Douglas production function.

We are now equipped to specify the optimal behaviour of purely domestic firms and offshoring firms, subject to entry and sorting (see Section 3 on the selection mechanism). Taking factor prices exogenously, each firm allocates labor to tasks and emissions abatement in order to minimize costs subject to technology constraints. A purely domestic firm thereby accounts for the economy-wide wage rate w and the emissions tax $t > 0$. An offshoring firm, in turn, employs domestic workers at wage w for the non-routine task only, and imports the offshored input at price p^{r*}. The routine task is executed abroad with the same technology but using foreign labor and generating emissions abroad. Under assumed perfect competition, the host country firm offers its product at marginal costs, i.e. at $p^{r*} = (t^*)^{\alpha}(w^*)^{1-\alpha}$, with $t^* \in (0; t]$.[5] We assume iceberg transport costs $\tau \geq 1$ for international shipments. Hence, in order to use $x^{or}(v)$ units in the production process, $\tau x^{or}(v)$ units need to be purchased.[6]

As formally shown in Appendix A.2, we derive marginal costs of a purely domestic firm and an offshoring firm, respectively, as

$$c^d(v) = \left[\left(\frac{t}{w}\right)^{\alpha}\right]^{1-\eta} \frac{w}{\varphi(v)} \qquad \text{and} \qquad c^o(v) = \left(\frac{\tau p^r}{w}\right)^{1-\eta} \frac{w}{\varphi(v)}. \tag{5}$$

Only if there is an incentive to offshore from marginal costs savings, a particular firm would want to do so. Accordingly, by means of Eq. (5) we express the ratio between marginal costs of a firm with productivity φ in case of offshoring or solely producing domestically as

$$\kappa \equiv \frac{c^d(v)}{c^o(v)} = \left[\frac{1}{\tau}\left(\frac{t}{t^*}\right)^{\alpha}\left(\frac{w}{w^*}\right)^{1-\alpha}\right]^{1-\eta}, \tag{6}$$

where the last expression follows from replacing p^r.[7] Only for $\kappa > 1$, an offshoring equilibrium materialises and κ represents the marginal cost savings factor of offshoring. Note that κ in-

[5] We, hence, restrict the model to the empirically plausible case that the emissions tax of the host country of offshoring does not exceed that of the source country.

[6] Note that, in the given model setup, iceberg transport costs are equivalent to an assumption of lower (Hicks-neutral) productivity of the routine task's production in the host country than in the source country of offshoring. More inputs need to the employed per usable output of the routine tasks.

[7] This is a generalisation of Eq. (4) in Egger et al. (2015), which it collapses to in the special case of $\alpha \to 0$.

corporates two incentives to offshore: *i.)* an across-country environmental tax differential and *ii.)* an across-country wage gap. Hence, the decision to offshore can either be driven by a less stringent environmental policy in the host country, by lower wages in the host country, or by both. Transport costs τ, by contrast, reduce the incentive to offshore. Importantly, emissions taxes t and t^* and transport costs τ are exogenous model parameters, while wages w and w^* are endogenous and, hence, adjust to policy changes.

Equipped with these insights, and noting that in our setting, firms in the intermediate goods sector charge a constant markup $\sigma/(\sigma-1) > 1$ over marginal costs,[8] we can express the role of a firm's offshoring status for her price, output and operating profits:

$$\frac{p^o(v)}{p^d(v)} = \kappa^{-1}, \qquad \frac{y^o(v)}{y^d(v)} = \kappa^{\sigma} \qquad \text{and} \qquad \frac{\pi^o(v)}{\pi^d(v)} = \kappa^{\sigma-1}. \tag{7}$$

Accordingly, by offshoring a firm can offer its variety at a lower price and still earn higher operating profits due to larger volumes sold.[9]

Within each status (purely domestic or offshoring), the more productive a firm, the higher her operating profits from more volumes sold at a lower price:

$$\frac{p(\varphi_1)}{p(\varphi_2)} = \left(\frac{\varphi_1}{\varphi_2}\right)^{-1}, \qquad \frac{y(\varphi_1)}{y(\varphi_2)} = \left(\frac{\varphi_1}{\varphi_2}\right)^{\sigma} \qquad \text{and} \qquad \frac{\pi(\varphi_1)}{\pi(\varphi_2)} = \left(\frac{\varphi_1}{\varphi_2}\right)^{\sigma-1}. \tag{8}$$

Importantly, the ratio of operating profits of two firms (as well as the ratios of all other firm performance measures) solely depends on the ratio of the productivity levels of the two firms. Hence, in the following we suppress firm index v and use productivity level φ, which perfectly distinguishes the different firms.

Before closing the model and determining the offshoring equilibrium in the next section, let us finally investigate the difference in emissions across firms. Recall that emissions in our model are linked to the routine task only. A purely domestic firm generates emissions in the source country. An offshoring firm, by contrast, does not generate emissions; it does not have to pay an emissions tax directly. Indirectly, however, it causes emissions in the host country by importing the output of the routine task; the host country's emissions tax is factored in the price of the imported input. In the following, we take into account these *embedded* emissions of offshoring firms to allow for a fair comparison of environmental footprints across firms.[10] Similarly, for

[8] This follows from the constant price elasticity of demand in Eq. (2) and the assumed monopolistic competition.
[9] In Appendix A.3, we additionally derive different labor employment ratios between purely domestic and offshoring and firms.
[10] This particularly matters for global pollutants, like CO_2, where the location of emissions generation is irrelevant to its environmental impact.

each firm, we define its emissions intensity as the ratio between (direct of embedded) emissions and output, i.e. $i(\varphi) \equiv e(\varphi)/y(\varphi)$.

Complementing Eq. (7) and with formal derivations deferred to Appendix A.4, we can state the role of a firm's offshoring status on emissions and emissions intensity as:

$$\frac{e^o(\varphi)}{e^d(\varphi)} = \frac{t}{t^*}\kappa^{\sigma-1} \qquad \text{and} \qquad \frac{i^o(\varphi)}{i^d(\varphi)} = \frac{t}{t^*}\kappa^{-1}. \tag{9}$$

Accordingly, the decision to offshore is associated with higher emissions,[11] whereas the difference in emissions intensity is ambiguous.[12]

Suppose that the emissions taxes were equal across the two countries. In order for an incentive to offshore to exist, i.e. for $\kappa > 1$ to hold in light of transport costs τ, there must be a sufficiently large difference in the wage rates between the two countries. From $w > w^*$ and $t = t^*$ it directly follows that the tax-wage ratio, i.e. the *effective* emissions tax, is necessarily higher in the host country. Accordingly, the routine task is produced less emissions-intensively if offshored, leading to an overall lower emissions intensity from offshoring. Importantly, this reasoning also holds for sufficiently small differences in the emissions tax rates with $t > t^*$, while $\kappa > 1$.[13] If, by contrast, the difference in emissions tax rates is sufficiently large, and constitutes the incentive to offshore to begin with, the emissions intensity of an offshoring firm is higher.

The ambiguity in the ratio of emissions intensities stands in contrast to settings with emitting heterogeneous firms that select into exporting: controlling for productivity, exporters are either found to produce equally emission-intensively as purely domestic competitors, since they adjust to the same domestic wage-tax-ratio (cf. Egger et al., 2021), or are characterised by lower emissions intensities due to higher abatement investments (cf. Forslid et al., 2018).

Here, whether the decision to offshore leads to a higher or lower emissions intensity, controlling for productivity, crucially depends on the determinants of offshoring. If the (main) motive to offshore is the international difference in emissions tax rates, a firm's emissions intensity is unambiguously higher in case of offshoring. By contrast, if the offshoring decision is (largely) driven by across-country differences in labor costs, the emissions intensity may be lower in case of offshoring. Importantly, such a firm-level clean-up can take place even in case of a lower emis-

[11] This directly follows from $t \geq t^*$ (by assumption) and $\kappa > 1$ as precondition for an offshoring equilibrium. It is driven by the higher output of an offshoring firm.

[12] Recall that our comparison builds on embedded emissions for offshoring firms. Looking at domestic emissions only, by construction, offshoring unambiguously leads to a decline in a firm's emissions intensity: going to zero in our setup.

[13] It is straightforward to derive the following condition for $i^o(\varphi) < i^d(\varphi)$ from Eqs. (6) and (9): $1 \leq t/t^* < (w/w^*)^{(1-\alpha)(1-\eta)/[1-\alpha(1-\eta)]}(1/\tau)^{(1-\eta)/[1-\alpha(1-\eta)]}$.

sions tax rate in the host country of offshoring, a pollution haven setting, as it is the emissions tax ratio *relative* to the wage ratio that matters.

Finally, note that, for a given status (purely domestic or offshoring), a more productive firm produces less emissions-intensively, while, due to its larger scale, it nevertheless generates more emissions:

$$\frac{e(\varphi_1)}{e(\varphi_2)} = \left(\frac{\varphi_1}{\varphi_2}\right)^{\sigma-1} \qquad \text{and} \qquad \frac{i(\varphi_1)}{i(\varphi_2)} = \left(\frac{\varphi_1}{\varphi_2}\right)^{-1}. \tag{10}$$

Let us summarize our findings in the following lemma:

Lemma 1. *Controlling for productivity, a firm's emission intensity is smaller in case of offshoring, if the source country's emissions tax exceeds that of the host country only slightly. It is larger otherwise. Controlling for the offshoring status, a more productive firm produces less emissions-intensively.*

3 The offshoring equilibrium

We assume that each individual chooses her occupation solely based on her income from the different occupations, either becoming manager, worker or offshoring consultant. If an individual decides to become a worker or offshoring consultant, her managerial ability remains unexploited. Accordingly, all non-managers are homogeneous and paid the same endogenous wage rate w. In addition to wage payments (workers and offshoring consultants) or profit income (managers), each individual receives a uniform per capita transfer $b \equiv tE/N$ from redistributed tax revenues from aggregate domestic emissions E.

Denoting the threshold ability to become a manager by φ^d, all individuals with ability at least as high ($\varphi \geq \varphi^d$) decide to run a firm, while all individuals with lower managerial ability ($\varphi < \varphi^d$) become workers or offshoring consultants. In line with the empirical evidence of self-selection of the most productive firms into offshoring (cf. Paul and Yasar, 2009; Hummels et al., 2014), our least productive firm, i.e. the firm run by the marginal manager, does not offshore. This leads to the following condition of the individual who is just indifferent between becoming a manager and a wage-remunerated occupation:

$$\pi^d(\varphi^d) + b = w + b, \tag{11}$$

where, intuitively, the per capita transfer b does not distort the decision and cancels out.

There is a second choice to be made by all managers, i.e. whether to produce purely domestically or to move part of the production process offshore. Offshoring promises higher operating profits from lower variable production costs, see Eq. (7), but requires to hire one offshoring consultant as fixed input requirement. Accordingly, only the most productive firms can afford to offshore. The marginal offshoring firm with productivity φ^o is determined by

$$\pi^o(\varphi^o) - \pi^d(\varphi^o) = w, \tag{12}$$

where the additional operating profits of offshoring (LHS) must cover the costs of hiring an offshoring consultant (RHS).

Jointly, under our Pareto assumption, the two cutoff productivity levels, φ^d and φ^o, determine the share of offshoring firms

$$\chi \equiv \frac{1 - G(\varphi^o)}{1 - G(\varphi^d)} = \left(\frac{\varphi^d}{\varphi^o}\right)^k. \tag{13}$$

We are able to determine all aggregate variables as function of χ as sole endogenous variable and will emphasise the impact of a unilateral environmental policy reform on this key endogenous variable in the next section.

In order to solve for an offshoring equilibrium (i.e. with at least some firms offshoring), we derive two links between the share of offshoring firms χ and the marginal cost savings factor κ. We then set out the conditions for an interior solution.

A first link originates from the indifference conditions Eqs. (11) and (12) together with Eq. (7) on relative operating profits:[14]

$$\kappa = A(\chi) \equiv (1 + \chi^{\frac{\sigma-1}{k}})^{\frac{1}{\sigma-1}}. \tag{14}$$

This condition captures a positive relationship between κ and χ. A higher marginal costs savings factor of offshoring makes offshoring more attractive and relatively more firms offshore part of their production.

We derive a second link between κ and χ via the labor market equilibrium in both countries. Given the (exogenous) population sizes and the possible occupations, we define the following

[14] See Appendix A.5 for the derivation.

resource constraints for the source country and the host country, respectively:

$$N = L + (1+\chi)M \qquad \text{and} \quad N^* = L^*, \tag{15}$$

where L and L^* denote the mass of workers, M the mass of managers, while χM subsumes all offshoring consultants. From these conditions and with the formal details deferred to Appendix A.6, we can derive the relative wage w/w^* as declining function of χ. Inserted in our definition of κ in Eq. (6), we finally get the second link:

$$\kappa = B(\tau, t, t^*, \chi) \equiv \left[\frac{1}{\tau} \left(\frac{t}{t^*} \right)^{\alpha} \left(\frac{\gamma^l(\chi)}{\lambda(\chi)\gamma^{l*}(\chi)} \frac{N^*}{N} \right)^{1-\alpha} \right]^{1-\eta}. \tag{16}$$

where each γ^l, γ^{l*} and λ is a share ranging between zero and one. The two terms γ^l and γ^{l*} denote the share of factor income that accrues to workers in the source country and in the host country, respectively. The term λ is defined as the share of workers in the source country's population, i.e. L/N. This second condition in Eq. (16) shows a negative relation between κ and χ. It is an increase in the share of offshoring firms χ that leads to a rise in labor demand in the host country, *ceteris paribus*. This, in turn, leads to a relative rise in the host country's wage rate, reducing the attractiveness to offshore, expressed by a declining κ.

Jointly, these two links, Eqs. (14) and (16), determine κ and χ. For an interior equilibrium of offshoring with $\chi \in (0,1)$ to hold, the level of iceberg trade cost τ must not be too small and, or the environmental tax differential must not be too large.[15] Figure 1 illustrates an interior offshoring equilibrium, where the black line represents the upward-sloping $A(\chi)$-function and the dashed line the downward-sloping $B(\chi)$-function.

4 Unilateral environmental policy reform

In this section, we analyse the effects of a unilateral environmental policy reform in an offshoring equilibrium as derived in the previous sections. To this end, we focus on an increase in the source country's emissions tax, while the emissions tax in the host country remains unchanged.

[15] In Appendix A.7, we derive the necessary conditions for τ and t/t^* in order to guarantee $\chi \in (0,1)$. We need to exclude the case of $\chi > 1$ that would violate our assumption of the marginal firm being a purely domestic firm, and, hence, Eq. (11).

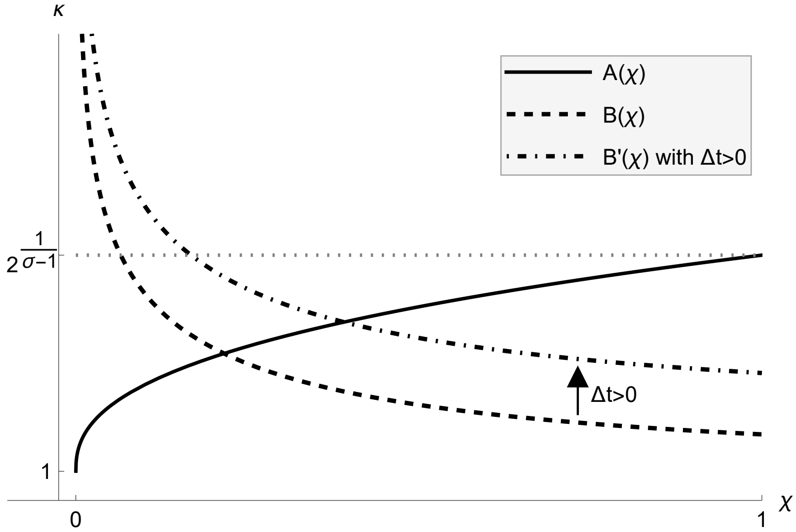

Figure 1: Determining the offshoring equilibrium

4.1 Effect on the share of offshoring firms

Let us first analyse how individuals respond to the emissions tax reform by altering their occupational choices and how firms adjust their decisions to offshore. On aggregate, this determines the change in the factor allocation and gives valuable insights on how the economy will be affected by a unilateral increase in the emissions tax.

Acknowledging the importance of χ, we begin our analysis with an investigation on how this variable is altered by a rise in t. We apply the implicit function theorem to derive the change in χ w.r.t. a rise in t, as it is not possible to solve the model in closed-forms (see above). To this end, we make use of Eqs. (14) and (16), the two links between κ and χ, and define the following implicit function:

$$F(\chi, \tau, t, t^*) \equiv B(\chi, \tau, t, t^*) - A(\chi) = 0. \tag{17}$$

Implicit differentiation yields $d\chi/dt = -(\partial F/\partial t)/(\partial F/\partial \chi) > 0$, as formally shown in Appendix A.8. Hence, a rise in the source country's emissions tax monotonously increases the share of offshoring firms. This is intuitive, as it is the rise in production costs in the source country that makes offshoring the emissions-intensive routine task more attractive for a larger share of firms; κ, the marginal cost savings factor increases. At the extensive margin, more firms avoid to pay the domestic emissions tax by offshoring part of the production process.

Figure 1 highlights this new offshoring equilibrium from the upward shift from $B(\chi)$ to $B'(\chi)$

(the dashed-dotted line) resulting in an increase in both χ and κ.[16]

4.2 Factor allocation

We can use this result to derive changes in the factor allocation. Note from Eq. (A.29) that t neither directly affects the mass of managers M nor the mass of workers L. All effects run indirectly via χ. An increase in t unambiguously leads to a decline in the mass of workers. It is both the rise in production costs and the increasingly attractive option to offshore (with offshoring firms only employing workers for non-routine tasks) that leads to lower labor demand in the source country, thereby decreasing the mass of workers. Put differently, we can observe a decline in the labor income share γ^l that ultimately determines λ, the share of workers in the population.

Consequently, $1-\lambda$, the share of non-workers (managers and offshoring consultants) increases. For our discussion on emissions later it is useful to distinguish between purely domestic firms $(1-\chi)M$ and offshoring firms χM. We can relate both to the two cutoff productivities using Pareto:

$$(1-\chi)M = N\left[(\varphi^d)^{-k} - (\varphi^o)^{-k}\right] \qquad \text{and} \qquad \chi M = N(\varphi^o)^{-k} \tag{18}$$

The rise in source country production costs opens up the possibility of offshoring for the most productive purely domestic firms, meaning the cutoff productivity of the marginal offshoring firm falls, $d\varphi^o/dt < 0$, hence the mass of offshoring firms increases $d(\chi M)/dt > 0$. The implication of this result is remarkable, although not surprising in our model framework of self-selection into offshoring: it is the most productive domestic firms and, hence, those domestic firms with the lowest emissions intensity (see Lemma 1) that start to offshore in response to a rise in the emissions tax rate. This runs against the common perception of the dirtiest firms to offshore and is a direct consequence of fixed costs of offshoring in our model.[17]

While firms leave on the upper end of the domestic firms distribution, the effect on the lower end is ambiguous. This result is known from Egger et al. (2015) and we link it to an increase in the source country emission tax rate. The following threshold represents the level of χ where

[16] Formally, this can be seen by a direct effect of t on $B(\chi)$ in Eq. (16), whereas $A(\chi)$ in Eq. (14) remains unaffected.

[17] We acknowledge the possibility of across-sector differences in emissions-intensities with an emissions tax rise potentially leading to offshoring of firms particularly from dirty sectors. This is not featured in our one (intermediate) sector model.

the sign of the effect changes:

$$\tilde{\chi} = \left[\frac{(\sigma - 1)(k - \sigma + 1)(1 - \alpha)(1 - \eta)}{k - \sigma + 1 + k\eta(\sigma - 1)} \right]^{\frac{k}{\sigma - 1}}, \tag{19}$$

such that for $\chi < \tilde{\chi}$ an increase in the source country's emissions tax leads to a decrease in the cutoff productivity of the marginal firm, while for $\chi > \tilde{\chi}$ it leads to an increase.[18] That means, in the second case both cutoffs decrease the mass of purely domestic firms as we have exit on both ends of the domestic productivity distribution. In the first case, however, the total effect is ex ante not clear as firms enter the market at the lower end.

With knowledge on the emissions tax-induced changes in occupational choices and firm selection, we can finally analyse the impact on average productivity of both domestic and offshoring firms. To this end, and with formal derivations in Appendix A.14 and A.15, we first compute

$$\bar{\varphi}^d = \frac{k - \sigma + 1}{k - \sigma} \frac{1 - \chi^{(k-\sigma)/k}}{1 - \chi^{(k-\sigma+1)/k}} \varphi^d \qquad \text{and} \qquad \bar{\varphi}^o = \frac{k - \sigma + 1}{k - \sigma} \varphi^o. \tag{20}$$

We show that both averages decline in t, i.e. $d\bar{\varphi}^d/dt < 0$ and $d\bar{\varphi}^o/dt < 0$.[19] New offshoring firms (see Proposition 1) are less productive than the existing ones leading to a decline in the average output of offshoring firms $d\bar{y}^o/dt < 0$.

We can summarize these findings as follows:

Proposition 1. *A unilateral increase in the source country's emissions tax leads to a decline in the mass of workers, while the effect on the mass of managers and, hence, the mass of active firms depends on the initial share of offshoring. If this share is sufficiently high, the effect on the mass of managers is negative, corresponding to a tax-induced increase in the marginal productivity. A unilateral increase in the source country's emissions tax rate unambiguously leads to a rising share of offshoring firms.*

4.3 Effects on domestic aggregate emissions

It is common in the literature to decompose aggregate emissions in order to isolate the partial effects of a policy reform (cf. Grossman and Krueger, 1995; Antweiler et al., 2001). Accordingly, we can express aggregate emissions in the source country as

$$E = M(1 - \chi)\bar{y}^d \bar{i}^d, \tag{21}$$

[18] See Appendix A.10 for a derivation of the threshold level $\tilde{\chi}$.
[19] Preliminary analytical proof in Appendix A.14 and A.15 supported by numerical simulations.

which is the product of the mass of domestic firms, their average production volume and their average emissions intensity. In detail, as shown in Appendix A.14 and A.16, we derive the averages as follows:

$$\bar{y}^d = \frac{k(\sigma-1)}{k-\sigma+1}\frac{1-\chi^{(k-\sigma+1)/k}}{1-\chi}\left(\frac{w}{t}\right)^{\alpha(1-\eta)}\bar{\varphi}^d \quad \text{and} \tag{22}$$

$$\bar{i}^d = \alpha(1-\eta)\left(\frac{w}{t}\right)^{1-\alpha(1-\eta)}\frac{1}{\bar{\varphi}^d} \tag{23}$$

Importantly, it is both the decision of each individual firm on labor allocation, abatement and production volumes (Section 2), and the composition of the heterogeneous firms that determine the averages among purely domestic firm.[20]

Both the academic literature and the public debate pay great attention to the change in average emissions intensity, the *technique effect*. Our expectations of a decline in this measure seems to be satisfied by the direct effect of t in Eq. (23). However, it is general equilibrium effects that we have to account for, as both the economy-wide wage rate and the average productivity of domestic firms adjust to the tax. As we have shown above, domestic firms are less productive on average, which increases the average emissions intensity, *ceteris paribus*. By contrast, a decline in the economy-wide wage rate enforces the reducing impact of the tax reform.[21] The wage-tax-ratio unambiguously decline, leading to a less emissions intensive production of the routine task and a shift towards the non-routine task. With formal derivations deferred to the Appendix A.18.1, we show that the net impact of t on $\bar{i}^d$ is negative, domestic firms become cleaner on average.

Moreover, this cleaning effect is complemented by a decline in average output, and a reduction in the mass of domestic firms. Hence, three partial effects that all lead to the reduction in domestic aggregate emissions.

We summarize our findings as follows

Proposition 2. *A unilateral increase in the source country's emissions tax leads to a decline in aggregate domestic emissions. This effect jointly originates from a tax-induced reduction in the mass of purely domestic firms, a decline in average production and a decline in average emissions intensity.*

[20] The product of average output and average emissions intensity, in turn, gives the average generation of emissions of domestic firms:

$$\bar{e}^d = \bar{y}^d\bar{i}^d = \frac{k(\sigma-1)}{k-\sigma+1}\alpha(1-\eta)\frac{1-\chi^{\frac{k-\sigma+1}{k}}}{1-\chi}\frac{w}{t}.$$

[21] In Appendix A.19 we show that t reduces w.

4.4 Emission leakage and global emissions

In order to understand the total environmental consequences of the source country's emissions tax reform, we have to look at aggregate emissions in the host country also. In case of a global pollutant what matters are aggregate world emissions, $E^W \equiv E + E^*$.

In analogy to the derivation of E, we compute aggregate emissions from production in the host country as:[22]

$$E^* = M\chi\bar{i}^o\bar{y}^o, \tag{24}$$

with

$$\bar{y}^o = \frac{k(\sigma-1)}{k-\sigma+1}\frac{\left(1+\chi^{(\sigma-1)/k}\right)^{\sigma/(\sigma-1)}}{\chi^{(\sigma-1)/k}}\left(\frac{w}{t}\right)^{\alpha(1-\eta)}\bar{\varphi}^o. \tag{25}$$

$$\bar{i}^o = \tau\alpha(1-\eta)\left(\frac{w^*}{t^*}\right)^{1-\alpha(1-\eta)}\left(\frac{w}{\tau w^*}\right)^{\eta}\frac{1}{\bar{\varphi}^o}. \tag{26}$$

Since there is no change in t^* (by construction of our analysis), only indirect effects are at work when looking at (26). With an increase in offshoring, labor demand in the host country rises leading to an increase in the host country wage. Accordingly, the wage-tax ratio is increasing. Put differently, the *effective emissions tax* in the host country is decreasing; generating emissions gets relatively cheaper. Accordingly, emissions per unit of the routine task's output are increasing. Yet, there is a second opposing channel working via w/w^*. Due to the reduced difference in wages, offshoring firms rely to a larger extent on the emissions-free non-routine task (similarly to domestic firms). Finally, as shown above, offshoring firms become less productive on average. Accounting for all these general equilibrium effects, we can prove that the average emissions intensity of offshoring firms is increasing in t (see Appendix A.18.2).

Depending on the difference between the emissions tax rates across countries, this increase might well take place at a lower average emissions intensity of offshoring firms than domestic firms, i.e. at $\bar{i}^o < \bar{i}^d$. This follows from Lemma 1 and the fact that $\bar{\varphi}^o > \bar{\varphi}^d$ from self-selection of the most productive firms into offshoring.

The increased share of offshoring firms, their larger market share and the fact that offshoring firms become more emissions-intensive on average, all contribute to a rise in aggregate host

[22] Average emissions of offshoring firms:

$$\bar{e}^o = \frac{k(\sigma-1)}{k-\sigma+1}\alpha(1-\eta)\frac{1+\chi^{\frac{\sigma-1}{k}}}{\chi^{\frac{\sigma-1}{k}}}\frac{w}{t^*}$$

country's emissions. We, hence, observe emissions leakage via the possibility to offshore.

Remarkably this emissions leakage can exceed the decline in domestic emissions, i.e. leakage of more than 100%. We show this by expressing for global emissions as the product of three channels, i.e. the mass of firms, average output and average emission intensity.[23]

$$E^W = M\bar{e} = M\bar{y}\bar{i} = M\left[(1-\chi)\bar{y}^d + \chi\bar{y}^o\right]\left[\frac{(1-\chi)\bar{y}^d}{\bar{y}}\bar{i}^d + \frac{\chi\bar{y}^o}{\bar{y}}\bar{i}^o\right]. \tag{27}$$

The first channel, displaying the mass of firms, decreases in the source country's emission tax rate provided the initial share of offshoring firms is sufficiently high (cf. Proposition 1). The second channel (first squared bracket) features the scale effect. We can show that average output per firm $\bar{y}$ decreases in response to the source country's emission tax increase. However, at the same time, the increased level of offshoring χ causes some production inputs to relocate across firm types, i.e. from non-offshorers towards offshorers.

This relocation of production inputs towards offshoring firms turns out to be a decisive mechanism when discussing the impact of the third channel, featuring average emission intensity across all firms (technique effect, second squared bracket): As we explain in the discussion of (23) and (26), an increase in the level of offshoring (induced by the unilateral environmental policy reform) causes labor market responses in both countries. This incentivizes firms to adjust their production process. With this general equilibrium effect at work, emission intensity levels among purely domestic firms $\bar{i}^d$ fall, while average embedded emission intensity levels of offshorers $\bar{i}^o$ rise. Thus, at low levels of χ, the environmental policy reform causes production inputs to be relocated towards (very few), relatively low emission-intensive offshoring firms. In this scenario, this type of across-firm relocation lowers aggregate emission levels. On the contrary, at high levels of χ, resources are shifted towards (many), relatively high emission-intensive offshoring firms. In this case, across-firm relocation is likely to raise aggregate emissions.

In numerical simulations, this ambiguous mechanism (hinging on the initial level of offshoring χ) proves to be decisive channel for the overall effect of the unilateral environmental policy reform on global emissions: While the unilateral emission tax increase in our simulation exercise generates a net decrease in global emissions at low levels of offshoring, a net increase is generated at higher levels of offshoring, implying a leakage rate of more than 100%. As χ is an endogenous

[23] See Appendix A.20.1 for a derivation of average emission intensity across all firms as well as Appendix A.20.2 for a derivation of global emissions in closed form.

value, there is a threshold level of t[24], inducing a sufficiently high level of offshoring for an increase in global emissions.[25]

We summarize our findings as follows

Proposition 3. *A unilateral increase in the source country's emissions tax leads to an increase in aggregate emissions in the host country. More than complete emissions leakage is possible due to the shift of production of offshoring firms, given a sufficiently high level of offshoring.*

4.5 Effects on aggregate income and income inequality

Our model allows us to analyse the distributional effects of the unilateral environmental policy reform from different perspectives. First, we compare the impact on aggregate income in the two countries. Second, we develop a measure of between-country inequality based on minimum income. Finally, we analyse the policy impact on the within-country income inequality in the reforming source country.

Joint aggregate income of the two countries equals aggregate output of the final good at normalised price of one, $I + I^* = Y$. While aggregate income of the source country consists of operating profits (income of managers and offshoring consultants), worker income and emission tax revenues, $I = \bar{\pi}M + wL + tE$, aggregate income of the host country only consists of the latter two elements, $I^* = w^*N^* + t^*E^*$. Our assumptions of CES and Cobb-Douglas production technology determine how income is distributed,[26] allowing us to rewrite aggregate income of the two countries as

$$I = \left[\frac{1}{\sigma} + \frac{\sigma-1}{\sigma}\left(\gamma^l + \gamma^e\right)\right]Y \qquad \text{and} \qquad I^* = \left[\frac{\sigma-1}{\sigma}\left(\gamma^{l*} + \gamma^{e*}\right)\right]Y. \tag{28}$$

With formal derivations deferred to Appendix A.22, we get the following inequality chain in the income effects induced by the unilateral environmental policy reform:

$$\frac{dI}{dt} < \frac{dY}{dt} < 0 < \frac{dI^*}{dt}. \tag{29}$$

Accordingly, world aggregate income Y declines, where the possibility of offshoring in the open

[24] In our simulations, this threshold level is at around 0.5 for χ as well as 3.3 for t in our baseline scenario.

[25] Interestingly, as our simulations suggest, emission intensity levels of offshorers show to be below those of purely domestic firms even at those threshold levels for t and χ.

[26] Given monopolistic competition and constant markup-pricing, operating profits of each firm equals the share $1/\sigma$ of total revenues, while the share $(\sigma-1)/\sigma$ is spent on worker remuneration and emissions tax payments. This aggregates to the final goods revenues, where γ^l and γ^e (and the respective variables for the host country γ^{l*} and γ^{e*}) describe the distribution of production factor income.

economy attenuates the decline in aggregate economic activity (thereby leading to a rise in emissions abroad, as discussed above).[27]

The decline in world income, however, is not evenly spread across the two countries. Since more firms relocate parts of their production process abroad, a higher share of income accrues to the host country of offshoring. Indeed, I^* rises not only relative to total income, but in absolute terms. This rise is due to induced increases in w^* (for a given N^*) and E^* (for a given t^*). It necessarily follows that aggregate income in the source country I, in turn, is reduced more than world aggregate income by a unilateral increase in its emission tax rate.

The convergence in aggregate income across countries translates into the convergence of average individual income. Comparing the group of wage-earners only, thereby accounting for the uniform per capita transfer of emissions tax revenues, we define between-country inequality as $\Xi \equiv (w+b)/(w^*+b^*)$.[28] As shown in the Appendix A.23, between-country inequality negatively depends on the level of offshoring and hence on t, i.e. $d\Xi/dt < 0$. A unilateral increase in emissions tax harms the domestic workers relative to the non-reforming country's workers due to the shift of production and the following decrease in local labor demand. As a consequence wage rates converge.[29]

In the source country, heterogeneity in managerial ability and the occupational choice translates into income inequality with individuals being either paid the economy-wide wage rate or earn firm-profits plus transfer b. We look at source country inequality in two ways: i) inter-group inequality ii) Lorentz dominance. We define inter-group inequality as a relative measure of average secondary managerial income (i.e. post-transfer managerial income net of labor income for the offshoring consultant) and post-transfer income of workers and offshoring consultants: $\Theta \equiv (\bar{\pi} - \chi w + b)/(w+b)$. As shown in Appendix (A.24), the emission tax rate does not impact this inequality measure directly, only indirectly via the share of offshoring firms. We show an induced increase in inter-group inequality, i.e. $d\Theta/dt > 0$. This result is driven by two components: first, the uniform transfer b declines, which workers benefit more than proportionally from, relative to managers with higher income level. Second, the ratio between profits and wage income increases with offshoring. Managers loose relatively less capturing the tax avoidance

[27] While we find a production increase from newly offshoring firms, which make use of cheaper foreign production inputs (an indirect effect of t on Y via χ), the dominant effect is a reform-induced decline in the intermediate production of purely domestic firms following the cost increase (a direct effect of t on Y). Purely domestic firms end up with an increase in marginal costs, as can be seen in Eq. (5). They allocate more labor to abatement efforts rather than productive usage and have higher costs for the remaining emissions.

[28] While $w+b$ equals the minimum income level in the source country by virtue of Eq. (11), it equals the average income of individuals in the host country of offshoring.

[29] As long as the population size in the host country N^* is smaller or equal to the population size in the source country N or not too much larger, it holds that $w > w^*$. This follows from our assumption of $\eta > 0.5$.

possibility of offshoring firms on the one side and the downward pressure on source country's wage due to production relocation on the other side.

A similar conclusion can be drawn from investigating the impact of the unilateral emissions tax increase on the source country's Lorentz curve. In Appendix A.24 we derive and plot the Lorenz curves and find an increase in inequality after the environmental policy reform.

We can summarize over findings as follows:

Proposition 4. *A unilateral increase in the source country's emissions tax leads to a convergence in aggregate income levels and wages between the source and host country. Aggregate income in the host country increases, while worldwide aggregate income and aggregate income in the source country decline. The rise in the emissions tax induces a rise in the inter-group income inequality in the reforming country.*

5 Extension: Policy Reform with Border Carbon Adjustment

5.1 Consequences of implementation

We now extent our asymmetric two-country model in order to investigate the implementation of a BCA. The host country emission tax shall now be denoted by $\tilde{t^*} = t^* + \hat{t}$ with $\hat{t} = t - t^*$. Hence, the offshorer faces the (implicit) emission tax $\tilde{t^*} = t$ post the introduction of BCA. It is strictly assumed that $t > \tilde{t^*}$ holds prior to the introduction of the border adjustment.

Using $t/\tilde{t^*} = 1$, the ratio of emission levels and emission intensities between an offshoring and a purely domestic firm of equal productivity as provided in Eq. (9) simplifies to $e^o(\varphi)/e^d\varphi) = \kappa^{\sigma-1}$ and $i^o(\varphi)/i^d(\varphi) = \kappa^{-1}$. As $\kappa > 1$ has to hold for any firm to offshore, the change in emission use induced by the offshoring decision is still positive, but clearly smaller than before the implementation of the border adjustment. This comes due to two reasons: Firstly, the multiplier $t/t^* > 1$ in Eq. (9) collapses to 1 and therefore no longer affects the ratio e^o/e^d. Secondly, the elimination of the environmental tax differential to $t/\tilde{t^*} = 1$ induced by implementation of the border adjustment also reduces the offshoring cost savings factor to $\kappa = \left[\frac{1}{\tau}\left(\frac{w}{w^*}\right)^{1-\alpha}\right]^{1-\eta} > 1$, linking the offshoring decision solely to the international wage gap and iceberg transport costs. Furthermore, the firm's offshoring decision unambiguously decreases its emission intensity. Thus, Lemma 1, as stated in Section 2, no longer holds in presence of the BCA. As outlined in Section 3, the equilibrium share of offshoring firms is given at the intersection of two conditions. The B-condition (Eq. (14)) is sensitive to the change of the host country's emission tax to $\tilde{t^*}$. With $t/\tilde{t^*} = 1$, the B-condition shifts downwards, reducing the share of offshoring firms in equilibrium.

Proposition 5. *The introduction of the border adjustment reduces production cost advantage of the host country. A new equilibrium is set with a lower share of offshoring firms. Facing the BCA, the firm's decision to offshore unambiguously decreases its (embedded) emission intensity.*

5.2 Environmental policy reform under a BCA

We now outline how the presence of the BCA affects the results of our Comparative Static Analysis of Section 4. Firstly, the policy's effect on the share of offshoring firms is investigated. The implicit function theorem simplifies to:

$$\begin{aligned} F(\chi,\tau) &\equiv B(\chi,\tau) - A(\chi) = 0 \\ &= \left[\frac{1}{\tau}\left(\frac{w}{w^*}\right)^{1-\alpha}\right]^{1-\eta} - (1+\chi^{\frac{\sigma-1}{k}})^{\frac{1}{\sigma-1}} \\ &= \left[\frac{1}{\tau}\left(\frac{\gamma^l}{\lambda\gamma^{l*}}\frac{N^*}{N}\right)^{1-\alpha}\right]^{1-\eta} - (1+\chi^{\frac{\sigma-1}{k}})^{\frac{1}{\sigma-1}} \end{aligned} \tag{30}$$

As seen in in the second line, the B-condition no longer directly depends on changes in emission taxation. However, it is still influenced by both countries' endogenous wage rates w and w^*. Via general equilibrium channels[30], each of them is negatively affected by a rise in $t = \tilde{t}$. However, as the third line shows, their ratio w/w^* is insensitive to changes in environmental policy. Hence, the unilateral policy reform does not impact the share of offshoring firms in equilibrium:

$$\frac{d\chi}{dt} = -\underbrace{\frac{\partial F/\partial t}{\partial F/\partial \chi}}_{\frac{=0}{<0}} = 0 \tag{31}$$

Implications for our subsequent analysis are immediate: As the share of offshoring firms χ is insensitive to changes in environmental policy, several expressions do not react to the environmental policy reform either, such as the mass of workers (L) and firms (M), cut-off productivities φ^d and φ^o as well as average productivities $\bar{\varphi}^d$ and $\bar{\varphi}^o$.[31] Equipped with this insight, we now turn to the analysis of average intermediate output levels of purely domestic and offshoring firms:

$$\frac{d\bar{y}^j}{dt} = \underbrace{\frac{d\bar{y}^j}{dt}}_{<0} + \underbrace{\frac{\partial\bar{y}^j}{\partial w}}_{>0}\underbrace{\frac{dw}{dt}}_{<0} < 0 \quad \text{with } j \in d, o \tag{32}$$

[30] Cf. expressions (A.26) and (A.31) as well as Appendix A.19
[31] This finding is straightforward as these expressions are solely linked to the emission tax via χ.

As seen in (22) and (25), both expressions only react to the environmental policy reform via changes to their wage-tax ratio. Whereas average outputs decrease in the source country's emission tax rate (denominator of wage-tax-ratio), both outputs increase in the source country's wage rate. As we show, the decline in the wage rate w induced by the environmental policy reform would be even stronger in presence of the BCA.[32] Thus, in comparison to the scenario without a BCA, the policy reform reduces average output among purely domestic firms more strongly and decreases average average output among offshoring firms.

Next, we investigate the impact of the policy reform on average emission intensities of both firm types. It largely stands in analogy to the previous analysis of average outputs:

$$\frac{d\bar{i}^j}{dt} = \underbrace{\frac{d\bar{i}^j}{dt}}_{<0} + \underbrace{\frac{\partial \bar{i}^j}{\partial w}}_{>0} \underbrace{\frac{dw}{dt}}_{<0} < 0 \quad \text{with } j \in d, o \tag{33}$$

As shown in (23), the average emission intensity of purely domestic firms is only influenced by the policy reform via its wage-tax ratio. Recalling the discussion on the policy's effect on average output levels and the source country wage rate w, it follows that the policy reform induces emission intensity levels of purely domestic firms to decrease more strongly than in absence of the BCA. Inspecting expression (26), the policy reform only impacts the average emission intensity level of offshoring firms via the host country's wage-tax-ratio as well as the ratio of wages across countries. With the BCA in place, the latter is unaffected by the environmental policy reform.[33] The host country's wage-tax ratio $\frac{w^*}{\tilde{t}*}$ unambigously decreases with the policy reform.[34] Hence, average emission intensity levels of offshoring firms also decrease due to the policy reform.

We now turn to the discussion of the reform's impact on global emissions under the BCA. Let us recall the expression for global emissions as the sum of (embedded) emissions over all purely domestic and offshoring firms, expressed as the product of output and emission intensity:

$$E^W = M\bar{e} = M\bar{y}\bar{i} = M\left[(1-\chi)\bar{y}^d + \chi\bar{y}^o\right]\left[\frac{(1-\chi)\bar{y}^d}{\bar{y}}\bar{i}^d + \frac{\chi\bar{y}^o}{\bar{y}}\bar{i}^o\right]. \tag{34}$$

[32] In Appendix A.19, we identify a negative direct effect of the emission tax $\frac{dw}{dt} < 0$ as well as a (weaker) positive indirect effect via increased offshoring $\frac{\partial w}{\partial \chi}\frac{d\chi}{dt} > 0$. As the BCA eliminates the positive indirect effect of offshoring, we can state that the environmental policy reform lowers the source country's wage rate even stronger in the presence of a border adjustment.

[33] This is shown in the discussion on the B-condition for expression (30).

[34] As $\tilde{t}*$ holds in presence of the BCA, the increase in the source country's emission tax directly transmits to the host country's emission tax from the perspective of the offshoring firm. Furthermore, as indicated in expression (A.31), it is straightforward for the host country's wage rate to decrease in the environmental policy reform via its effect on final goods output Y.

Neither the mass of firms M nor the share of offshoring firms χ react to the environmental policy change in the presence of the border adjustment. Average output $\bar{y}$ as well as average (embedded) emission intensity $\bar{i}$ falls across all firms.[35] This results in a non-monotonous decline source country, host country and global emissions in the presence of the border adjustment.[36]

Finally, we analyse the impact of the policy reform on income and its distribution. Under the border adjustment, aggregate income in the source country, as shown in expression (28), is only influenced by the policy reform through its effect on final good output Y. It is straightforward to show that final good output decreases more strongly than in absence of the border adjustment.[37]

Secondly, aggregate income in the source country depends on the endogenous income shares for labor (γ_l) and emissions (γ_e) in the source country. However, the policy reform's effect on them is eliminated by the presence of the BCA.[38] Consequently, due to the BCA, the environmental policy reform induces a stronger decrease of global income. On the other hand, with the border adjustment in place, a larger share of global income remains within the source country.

Proposition 6. *In the presence of a BCA, an environmental policy reform in the source country does not influence the level of offshoring in the economy. Aggregate emissions reduce across both countries. The decline in global income induced by the policy reform is unambiguously larger as compared to the scenario without a BCA. This largely comes at the expense of the host country.*

6 Conclusion

This paper investigates the effects of a unilateral environmental policy reform on emissions, income and inequality in the presence of offshoring. The analysis builds on an asymmetric two-country general equilibrium model with heterogeneous firms and occupational choice. In the source country, firms use labor to perform a non-routine task and a routine task, where latter production is subject to taxed emission generation and can be offshored. They can allot routine labor to emission-intensive production as well as to abatement efforts. Firms differ in their productivity, hence in profits and only the most productive ones offshore parts of the production.

[35] This is a direct implication of the results for average output and emission intensity levels for both firm types.

[36] See expression (A.112) in the Appendix for global emissions in closed form in the presence of the BCA.

[37] As shown in Appendix (A.21)) Y decreases in the emission tax t (direct effect). In absence of the border adjustment, the policy reform $dt > 0$ leads to an increase in offshoring, which partly offsets the reduction in aggregate final good output (indirect effect). However, in the presence of a BCA, the latter channel is absent ($\frac{\partial Y}{\partial \chi}\frac{d\chi}{dt} = 0$). Hence, with a border adjustment in place, environmental policy reform turns out to reduce aggregate final good output more strongly.

[38] As we explain in Appendix (A.22), in absence of a border adjustment, the unilateral environmental policy reform – by raising the level of offshoring – may cause income shares to move to the host countries.

At the firm-level, we show that differences in effective emission taxation (tax-wage ratios) across countries determine the environmental impact of firms' decision to offshore. The unilateral policy reform, modelled as a rise in the source country emission tax rate, incentivizes more firms to offshore, causing effects on emissions, income and inequality. Firms adjust their production input mix due to direct and general equilibrium channels. This reduces emissions per unit of output for purely domestic firms, while embedded emission intensity levels among offshorers increase.

At the aggregate level, we show that the environmental policy reform reduces emissions in the source country while emissions in the host country increase due to leakage. As a major insight, we highlight a non-monotonous effect of the unilateral policy reform on global emissions: If the initial level of offshoring is sufficiently high, the higher emission tax rate might increase global emissions, implying a leakage rate of more than 100%.

Extending our analysis to income and inequality, we show that the increase in offshoring induced by the environmental policy reform mitigates losses in terms of aggregate income associated to the tax increase. Furthermore, via increases in the level of offshoring, inequality within the source country rises and inequality between the source country and the host country falls.

In order to assess effectiveness and economic costs of a BCA, we extend our analysis. As we show, an emission tax increase no longer increases offshoring. Thus, the environmental policy reform does not lead to leakage and reduces global emissions. However, under a BCA, the loss of global income induced by the unilateral emission tax increase shows to be larger.

A Appendix

A.1 Emissions abatement

We follow Copeland and Taylor (2003) in specifying the emissions-generating process and the abatement technology by two assumptions. First, we assume

$$x^r = l^r \xi, \tag{A.1}$$

where $\xi \in (0;1)$ is the (endogenous) share of l^r that is employed in the production process, while the share $1-\xi$ is devoted to emissions abatement. Second, we assume that emissions are generated as

$$e = \left(\frac{\xi}{\beta}\right)^{\frac{1}{\alpha}} l^r \qquad \text{with} \quad \beta \equiv (1-\alpha)^{-(1-\alpha)}\alpha^{-\alpha}, \tag{A.2}$$

Solving Eq. (A.2) for ξ and inserting into Eq. (A.1) yields Eq. (4) in the main text.

A.2 Derivation of marginal costs

A.2.1 Purely domestic firm

A purely domestic firm minimizes its costs $wl^{dn}(v) + wl^{dr}(v) + te^d(v)$ subject to the nested Cobb-Douglas production technology from Eqs. (3) and (4).

Following Lagrange optimization, constraint cost-minimisation allows us to derive the optimal factor demands:

$$l^{dn}(v) = \eta \, \frac{y^d(v)}{\varphi(v)} \left(\frac{t}{w}\right)^{(1-\eta)\alpha} \tag{A.3}$$

$$l^{dr}(v) = (1-\eta)\,(1-\alpha)\frac{y^d(v)}{\varphi(v)} \left(\frac{t}{w}\right)^{(1-\eta)\alpha} \tag{A.4}$$

$$e^d(v) = (1-\eta)\,\alpha\,\frac{y^d(v)}{\varphi(v)} \left(\frac{t}{w}\right)^{(1-\eta)\alpha-1} \tag{A.5}$$

Inserting Eqs. (A.3), (A.4) and (A.5) into the cost minimization of the purely domestic firm and simplifying yields the respective cost function:

$$C^d(v) = y^d(v)\,\frac{w}{\varphi}\left(\left(\frac{t}{w}\right)^{\alpha}\right)^{1-\eta}. \tag{A.6}$$

While only a part ξ of routine task labor is used for production, the other part $(1-\xi)$ is allotted to emission abatement efforts. Solving Eq. (A.2) for ξ yields:

$$\xi(v) = \beta \left[\frac{e^d(v)}{l^{dr}(v)}\right]^{\alpha} \qquad \text{with} \quad \beta \equiv (1-\alpha)^{-(1-\alpha)}\alpha^{-\alpha} \tag{A.7}$$

Inserting the purely domestic firm's cost minimizing inputs Eqs. (A.4) and (A.5) simplifies this expression to:

$$\xi = \frac{1}{1-\alpha}\left(\frac{w}{t}\right)^{\alpha} \tag{A.8}$$

Hence, the share of routine task labor allotted to production increases in the wage rate as well as in the Cobb-Douglas emission parameter α while it decreases in the environmental tax rate.

A.2.2 Offshoring firm

An offshoring firm uses the routine task good $x^{or}(v)$, imported from the host country. Due to iceberg trade costs, the firm effectively imports $\tau x^{or}(v)$. For that, a routine task output price p^{r*} has to be paid. The offshoring firm minimizes its costs $w\, l^{on}(v) + \tau p^{r*} x^{or}(v)$ subject to the nested Cobb-Douglas production technology from Eqs. (3) and (4). Performing Lagrange optimization allows to derive cost-minimizing demands for non-routine labor l^{on} and routine task x^{or}.

$$l^{on}(v) = \eta \frac{y^o(v)}{\varphi(v)} \left[\frac{\tau\, p^{r*}}{w}\right]^{1-\eta} \qquad \text{and} \quad x^{or}(v) = (1-\eta) \frac{y^o(v)}{\varphi(v)} \left[\frac{w}{\tau\, p^{r*}}\right]^{\eta} \tag{A.9}$$

Inserting these two cost-minimizing demands into the costs of the offshoring firm yields the cost function of the offshoring firm:

$$C^o(v) = y^o(v) \left(\frac{\tau p^{r*}}{w}\right)^{1-\eta} \frac{w}{\varphi(v)} \tag{A.10}$$

To derive p^{r*} in closed form, we turn to the homogeneous host country firm. It minimizes costs $w^* l^{r*} + t^* e^*$ subject to the routine production technology $x^{r*} = \beta\, (e^*)^{\alpha}\, (l^{r*})^{1-\alpha}$. Lagrange optimization yields the following cost minimizing inputs:

$$l^{r*} = x^{r*}(1-\alpha) \left(\frac{t^*}{w^*}\right)^{\alpha} \qquad \text{and} \quad e^* = x^{r*} \alpha \left(\frac{w^*}{t^*}\right)^{1-\alpha} \tag{A.11}$$

Inserting the host country firm's optimal labor input from Eq. (A.11) into its cost minimization yields the cost function of the host country firm:

$$C^* = x^{r*} (t^*)^{\alpha} (w^*)^{1-\alpha}. \tag{A.12}$$

Due to perfect competition in the host country, marginal costs correspond to the offshored routine task output's price, i.e. $p^{r*} = (t^*)^{\alpha}(w^*)^{1-\alpha}$. This is used for deriving Eq. (6) in the main text.

A.3 Comparison of labor employment between firm types

A.3.1 Non-routine labor

In analogy to Eqs. (7) and (8), we look at firm-level labor employment in two comparative frameworks. We start with non-routine labor demand. The LHS of Eq. (A.13) depicts a comparison of two firms of equal offshoring status, but different productivity levels. The RHS of Eq. (A.13) compares non-routine labor employment of an offshoring and a purely domestic firm at the margin, i.e. at equal productivity levels. In order to form ratios of labor demand, we use expressions for non-routine labor employment as given in Eqs. (A.9) and (A.3).

$$\frac{l^n(\varphi_1)}{l^n(\varphi_2)} = \left(\frac{\varphi_1}{\varphi_2}\right)^{\sigma-1} > 1 \qquad \text{and} \qquad \frac{l^{on}(\varphi)}{l^{dn}(\varphi)} = \kappa^{\sigma-1} > 1 \tag{A.13}$$

As the ratio on the left side reveals, a firm of a higher productivity employs more non-routine labor demand than a firm of lower productivity and same offshoring status. Looking at the comparison on the right side, an offshoring firm's demand for (domestic) non-routine task labor is strictly larger than that of its purely domestic (and equally productive) counterpart.This holds due to $\kappa > 1$.

A.3.2 Routine labor

We now compare employment of routine-task labor. Routine labor demand of a purely domestic firm is given by Eq. (A.4). For the offshoring firm, (embedded) routine labor demand is obtained by multiplying the optimal (purely routine) labor input of the host country firm (given in Eq. (A.11)) by iceberg transport costs, i.e. $l^{or} \equiv \tau\, l^{r*}$. Forming the ratio of routine labor employment yields:

$$\frac{l^r(\varphi_1)}{l^r(\varphi_2)} = \left(\frac{\varphi_1}{\varphi_2}\right)^{\sigma-1} > 1 \qquad \text{and} \qquad \frac{l^{or}(\varphi)}{l^{dr}(\varphi)} = \frac{w}{w^*}\kappa^{\sigma-1} > 1 \tag{A.14}$$

Given the same offshoring status, a firm of figher productivity employs more routine task labor than a firm of lower productivity. Looking at the right side of Eq. (A.14), an offshoring firm's (embedded) routine labor demand is strictly larger than routine labor demand of a purely domestic firm as $w/w* > 1$ holds in light of $\eta > 1/2$.

A.3.3 Domestic labor

Given equal productivities, we now investigate whether an offshoring firm's domestic (non-routine) labor demand l^{on} is larger or smaller than overall labor demand of its purely domestic firm counterpart. Note that total labor demand of the purely domestic firm can be obtained by adding up non-routine and routine labor demand as provided in Eqs. (A.3) and (A.4):

$$l^d(\varphi) \equiv l^{dn}(\varphi) + l^{dr}(\varphi) = [1 - \alpha(1-\eta)]\, \frac{y^d(\varphi)}{\varphi}\left(\frac{t}{w}\right)^{(1-\eta)\alpha}. \tag{A.15}$$

Forming the ratio of labor demands between the firm types yields:

$$\frac{l^{on}(\varphi)}{l^d(\varphi)} = \left[\frac{\eta}{1-\alpha(1-\eta)}\right]\kappa^{\sigma-1} \lesseqgtr 1. \tag{A.16}$$

As the expression within the squared bracket is smaller than 1, the comparison hinges on the size of $\kappa > 1$. For $\kappa > [(1-\alpha(1-\eta))/\eta]^{\frac{1}{\sigma-1}} > 1$, it holds that $l^{on}(\varphi)/l^d(\varphi) > 1$. Note that, due to $\alpha > 0$ and $\eta > 1/2$, this threshold strictly stays below the upper bound of κ derived for an interior equilibrium in Eq. (A.33). Hence, our framework allows for scenarios in which the offshorer's domestic employment may be greater than that of its purely domestic counterpart. In consequence, at a high level of offshoring, the decision of the firm to offshore may raise its labor employment at home.

A.3.4 Total labor

We finally at the total labor employment for each firm type. Total labor input of the purely domestic firm is given in Eq. (A.15). For the offshoring firm's total labor employment, we add its (embedded) routine labor demand (as derived for expression (A.14)) to its domestic non-routine labor demand.

$$l^o(\varphi) \equiv l^{or}(\varphi) + l^{on}(\varphi) = \frac{y^o(\varphi)}{\varphi}\frac{1}{\kappa}\left(\frac{t}{w}\right)^{\alpha(1-\eta)}\left[(1-\eta)(1-\alpha)\frac{w}{w^*} + \eta\right] \tag{A.17}$$

Forming the ratio of total labor employments for both firm types yields:

$$\frac{l^o(\varphi)}{l^d(\varphi)} = \left[\frac{[(1-\eta)(1-\alpha)\frac{w}{w^*} + \eta]}{1-\alpha(1-\eta)}\right]\kappa^{\sigma-1} > 1 \tag{A.18}$$

In light of $w/w^* > 1$, the large squared bracket is strictly greater than 1. Thus, the ratio of total labor employments must be larger than 1 as well. As a consequence, the offshoring firm always employs more labor (domestic and foreign) as compared to its purely domestic counterpart.

A.4 Derivation of firm-level emissions and emission intensity levels

The optimal emission level for the purely domestic firm is provided in Eq. (A.5). For the offshoring firm, recall that, due to iceberg transport costs, more output of the routine task is produced in the host country than used by the offshoring firm in the source country. Thus, the offshoring firm's (embedded) emission level e^o is derived by multiplying iceberg transport costs τ by the host country firm's emission demand as given in Eq. (A.11). Inserting the closed-form expressions for x^{r*} and p^r yields the (embedded) emission level of the offshoring firm.

$$e^d(\varphi) = \frac{\alpha\,(1-\eta)}{\frac{1}{y^d(\varphi)}\,\varphi}\left(\frac{w}{t}\right)^{1-\alpha(1-\eta)} \qquad \text{and} \qquad e^o(\varphi) = \frac{\alpha\,(1-\eta)}{\frac{1}{y^o(\varphi)}\,\varphi}\left(\frac{w^*}{t^*}\right)^{1-\alpha}\tau\left(\frac{w}{\tau(t^*)^{\alpha}\,(w^*)^{(1-\alpha)}}\right)^{\eta} \tag{A.19}$$

Dividing firm-level emissions A.5 and A.19 by their respective intermediate output level $y^d(\varphi)$ and $y^o(\varphi)$ gives the following expressions for emission intensity levels:

$$i^d(\varphi) = \frac{\alpha\,(1-\eta)}{\varphi}\left(\frac{w}{t}\right)^{1-\alpha(1-\eta)} \qquad \text{and} \qquad i^o(\varphi) = \frac{\alpha\,(1-\eta)}{\varphi}\left(\frac{w^*}{t^*}\right)^{1-\alpha}\tau\left(\frac{w}{\tau(t^*)^{\alpha}\,(w^*)^{(1-\alpha)}}\right)^{\eta} \tag{A.20}$$

Dividing $e^o(\varphi)$ by $e^d(\varphi)$ as well as $i^o(\varphi)$ by $i^d(\varphi)$ yields the emission ratios derived in Eq. (9). While it is well-established in trade models with emitting heterogeneous firms that both a firm's productivity level and the wage-tax ratio play an important role for the emissions intensity of an individual firm (cf. Egger et al., 2021), it is specific to the offshoring context that also factor price differences across countries are vital.

A.5 Derivation of A(χ)

In order to derive the upward-sloping offshoring indifference condition (A-function), we first re-arrange the indifference condition of the marginal offshoring firm as provided in Eq. (12) by subtracting w to the left side and adding $\pi^d(\varphi^o)$ to the left side. Using the occupational choice condition of the marginal manager as provided in Eq. (11), we can eliminate w and transform the expression to:

$$\pi^o(\varphi^o) - \pi^d(\varphi^d) = \pi^d(\varphi^o) \tag{A.21}$$

We now divide both sides of the equation by $\pi^d(\varphi^o)$.

$$\frac{\pi^o(\varphi^o)}{\pi^d(\varphi^o)} - \frac{\pi^d(\varphi^d)}{\pi^d(\varphi^o)} = 1 \tag{A.22}$$

Due to $\pi^o(\varphi)/\pi^d(\varphi) = \kappa^{\sigma-1}$, $\pi^d(\varphi^d)/\pi^d(\varphi^o) = \left(\varphi^d/\varphi^o\right)^{\sigma-1}$ as well as $\varphi^d/\varphi^o = \chi^{\frac{1}{k}}$, the expression transforms to:

$$\kappa^{\sigma-1} - \chi^{\frac{\sigma-1}{k}} = 1 \tag{A.23}$$

Solving for κ yields the offshoring indifference condition as provided in Eq. (14).

A.6 Derivation of wage rates, labor income share and the factor allocation

We follow Egger et al. (2015) and first express both the operating profits of the marginal firm and the economy-wide wage rate, i.e. the two sides of Eq. (11), in terms of aggregate variables and χ. We account for the property of the Pareto distribution, according to which the average operating profits are a constant multiple of the marginal firm's operating profits. This yields

$$\pi^d(\varphi^d) = \frac{k-\sigma+1}{k}\frac{1}{1+\chi}\bar{\pi}. \tag{A.24}$$

In order to derive the wage rate we compute labor income in the source country. For this purpose, we aggregate revenue shares of purely domestic and offshoring firms. We know from the Cobb-Douglas production technology that a share of $(1-\alpha)(1-\eta)$ of purely domestic firms' revenue goes into routine task labor and a share η of both offshoring and purely domestic firms goes into non-routine task labor. Accordingly, aggregate labor income is determined as

$$wL = N\frac{\sigma-1}{\sigma}\left[((1-\alpha)(1-\eta)+\eta)\int_{\varphi^d}^{\varphi^o} r^d(\varphi)dG(\varphi) + \eta\int_{\varphi^o}^{\infty} r^o(\varphi)dG(\varphi)\right]. \tag{A.25}$$

Solving this for the wage rate by means of $dG(\varphi) = k\varphi^{-(k+1)}$, $r^d(\varphi)/r^d(\varphi^d) = \left(\varphi/\varphi^d\right)^{\sigma-1}$ and $r^o(\varphi)/r^o(\varphi^o) = (\varphi/\varphi^o)^{\sigma-1}$ respectively, we get the RHS of expression (A.26). Making use of $M\bar{\pi} = \sigma^{-1}Y$, i.e. the result that aggregate operating profits are a constant share of aggregate income, we get the LHS of expression (A.26). Accordingly, we derive

$$\pi^d(\varphi^d) = \frac{k-\sigma+1}{k}\frac{1}{1+\chi}\frac{1}{\sigma}\frac{Y}{M} = \gamma^l\frac{\sigma-1}{\sigma}\frac{Y}{L} = w \tag{A.26}$$

with

$$\gamma^l = \frac{[1-\alpha(1-\eta)] + \eta\chi - (1-\alpha)(1-\eta)\chi^{\frac{k-\sigma+1}{k}}}{1+\chi} \tag{A.27}$$

being the share of production factor income allotted to the source country's workers. As shown by its derivative, this share negatively depends on χ

$$\frac{\partial\gamma^l}{\partial\chi} = -\frac{(k-\sigma+1)\chi^{\frac{k-\sigma+1}{k}-1}(1-\alpha)(1-\eta) + k(\gamma^l-\eta)}{k(1+\chi)}, \tag{A.28}$$

where α and $\eta < 1$, $k > \sigma - 1$ and $\gamma^l > \eta$. This highlights the shift of income to the host country with relatively more firms offshoring.[39]

Substituting for either M or L in expression (A.26) by means of the source country's resource constraint in Eq. (15), we can solve for the equilibrium factor allocation depending on χ. This yields

$$L = \lambda N \qquad \text{and} \qquad M = \frac{1-\lambda}{1+\chi} N \qquad \text{with} \quad \lambda = \left[1 + \frac{k-\sigma+1}{\gamma^l k(\sigma-1)} \right]^{-1} \tag{A.29}$$

where λ is the share of workers in the source country's population.

In analogy to expression (A.25), we can express labor income in the host country as

$$w^* N^* = \frac{\sigma-1}{\sigma} N(1-\alpha)(1-\eta) \int_{\varphi^o}^{\infty} r^o(\varphi) dG(\varphi). \tag{A.30}$$

With $(1 - G(\varphi^o))\chi = (1 - G(\varphi^d))$, $r^o(\varphi^o) = \sigma\pi^o(\varphi^o)$ and $\pi^o(\varphi^o) = (1 + \chi^{-\frac{\sigma-1}{k}})\pi^d(\varphi^d)$ as well as $Y/M = \sigma\bar{\pi}$ we solve for the host country's wage:

$$w^* = \gamma^{l*} \frac{\sigma-1}{\sigma} \frac{Y}{N^*} \qquad \text{with} \qquad \gamma^{l*} = \frac{(1-\alpha)(1-\eta)(\chi + \chi^{\frac{k-\sigma+1}{k}})}{1+\chi} \tag{A.31}$$

being the share of aggregate payments to production factors that accrues to workers in the host country. This share positively depends on χ: With a rise in the level of offshoring, relatively more income is generated in the host country.[40]

By means of Eqs. (A.26), (A.29) and (A.31), we can derive the relative wage rate as:

$$\frac{w}{w^*} = \frac{\gamma^l(\chi)}{\lambda(\chi)\gamma^{l*}(\chi)} \frac{N^*}{N} = \frac{\gamma^l + \frac{k-\sigma+1}{k(\sigma-1)}}{\gamma^{l*}} \frac{N^*}{N}. \tag{A.32}$$

Since both, the share of source country labor income γ^l and the share of workers in the source country λ are decreasing in χ, the total effect of offshoring on the wage ratio is not clear, ex ante. Combining the two reveals that the effect of offshoring on the source country labor income share γ^l dominates. This is further amplified by an increase in the share of host country labor income λ. Hence, the wage ratio unambiguously decreases in the level of offshoring.

A.7 Interior solution to offshoring equilibrium

For an interior equilibrium with $\chi \in (0,1)$, the upward-sloping offshoring indifference condition (A-function) as well as the downward-sloping labor market constraint (B-function) need to intersect within the interval $\chi\,(0,1)$. In order to ensure such an intersection, the value of the downward-sloping labor market constraint $\kappa = B(\tau, t, t^*, \chi)$ has to be smaller than the value of the upward-sloping offshoring indifference condition $\kappa = A(\chi)$ with χ approaching its upper boundary. Accordingly, We obtain the upper bound of κ for an interior equilibrium from $\lim_{\chi \to 1} B < A$, while noting that γ^l collapses to η:

$$\left[\frac{1}{\tau} \left(\frac{t}{t^*} \right)^{\alpha} \left(\frac{(k-\sigma+1) + \eta k(\sigma-1)}{(1-\eta)(1-\alpha)k(\sigma-1)} \frac{N^*}{N} \right)^{1-\alpha} \right]^{1-\eta} < 2^{\frac{1}{\sigma-1}}. \tag{A.33}$$

We further express this condition in terms of two exogenous parameters, i.e. iceberg transport

[39] It holds that $\lim_{\chi\to 0} \gamma^l = 1 - \alpha(1-\eta)$ under autarky and $\lim_{\chi\to 1} \gamma^l = \eta$ approaching the case of all firms being offshorers.

[40] For $\chi \to 0$ (autarky) it holds that $\gamma^{l*} = 0$, while it converges to $(1-\alpha)(1-\eta)$ with $\chi \to 1$.

cost τ as well as the between-country emission tax differential t/t^*. Solving for these yields the minimum level of iceberg trade cost τ as well as well as the maximum international emissions tax differential t/t^* permitted in order to ensure an interior equilibrium of offshoring:

$$\tau > 2^{\frac{1}{(1-\sigma)(1-\eta)}} \left(\frac{t}{t^*}\right)^{\alpha} \left(\frac{(k-\sigma+1)+\eta k(\sigma-1)}{(1-\eta)(1-\alpha)k(\sigma-1)}\frac{N^*}{N}\right)^{1-\alpha} \tag{A.34}$$

$$\frac{t}{t^*} < 2^{\frac{1}{\alpha(\sigma-1)(1-\eta)}} \tau^{\frac{1}{\alpha}} \left(\frac{(1-\eta)(1-\alpha)k(\sigma-1)}{(k-\sigma+1)+\eta k(\sigma-1)}\frac{N}{N^*}\right)^{\frac{1-\alpha}{\alpha}} \tag{A.35}$$

A.8 Comparative statics: implicit function theorem

The implicit function is given by:

$$F(\chi,\tau,t,t^*) = \left[\frac{1}{\tau}\left(\frac{t}{t^*}\right)^{\alpha}\left(\frac{(k-\sigma+1)+\gamma^l k(\sigma-1)}{(1-\gamma^l-\alpha(1-\eta))k(\sigma-1)}\frac{N^*}{N}\right)^{1-\alpha}\right]^{1-\eta} - (1+\chi^{\frac{\sigma-1}{k}})^{\frac{1}{\sigma-1}} = 0. \tag{A.36}$$

The effect of t on F is derived as:

$$\begin{aligned}\frac{\partial F}{\partial t} &= (1-\eta)\left(\frac{1}{\tau}\left(\frac{t}{t^*}\right)^{\alpha}\left(\frac{(k-\sigma+1)+\gamma^l k(\sigma-1)}{1-\gamma^l-\alpha(1-\eta)}\frac{N^*}{N}\right)^{1-\alpha}\right)^{-\eta} \\ &\times \frac{1}{\tau}\left(\frac{(k-\sigma+1)+\gamma^l k(\sigma-1)}{1-\gamma^l-\alpha(1-\eta)}\frac{N^*}{N}\right)^{1-\alpha}\alpha\left(\frac{t}{t^*}\right)^{\alpha-1}\frac{1}{t^*} > 0\end{aligned} \tag{A.37}$$

The effect of χ is given by:

$$\begin{aligned}\frac{\partial F}{\partial \chi} =& (1-\eta)\left(\frac{1}{\tau}\left(\frac{t}{t^*}\right)^{\alpha}\left(\frac{(k-\sigma+1)+\gamma^l k(\sigma-1)}{1-\gamma^l-\alpha(1-\eta)}\frac{N^*}{N}\right)^{1-\alpha}\right)^{-\eta}\frac{1}{\tau}\left(\frac{t}{t^*}\right)^{\alpha}\left(\frac{N^*}{N}\right)^{1-\alpha}(1-\alpha)\left[\frac{(k-\sigma+1)+\gamma^l k(\sigma-1)}{1-\gamma^l-\alpha(1-\eta)}\right]^{-\alpha} \\ &\times\left[\frac{\frac{\partial\gamma^l}{\partial\chi}k(\sigma-1)[(1-\gamma^l-\alpha(1-\eta))k(\sigma-1)]+\frac{\partial\gamma^l}{\partial\chi}k(\sigma-1)[(k-\sigma+1)+\gamma^l k(\sigma-1)]}{[(1-\gamma^l-\alpha(1-\eta))k(\sigma-1)]^2}\right] \\ &-\frac{1}{\sigma-1}(1+\chi^{\frac{\sigma-1}{k}})^{\frac{1}{\sigma-1}-1}\frac{\sigma-1}{k}\chi^{\frac{\sigma-1}{k}-1} < 0\end{aligned} \tag{A.38}$$

because of $\partial\gamma^l/\partial\chi < 0$. Accordingly,

$$\frac{d\chi}{dt} = -\underbrace{\frac{\partial F/\partial t}{\partial F/\partial\chi}}_{\frac{\geq 0}{<0}} > 0. \tag{A.39}$$

A.9 Effects of $dt > 0$ on the factor allocation

According to Eq. (A.29), L is decreasing in χ via an indirect effect through γ^l, while a positive indirect dependence of M on χ (via γ^l) is complemented by a direct negative effect, which highlights the sorting of individuals into managers or offshoring consultants.

The factor allocation is only indirectly affected by the source country emission tax rate, namely via the share of offshoring firms with $d\chi/dt > 0$. With this result and $\partial\gamma^l/\partial\chi < 0$ we can state:

$$\frac{d\lambda}{dt} < 0, \tag{A.40}$$

hence, the mass of workers decreases in t

$$\frac{dL}{dt} < 0 \quad \text{with} \quad L = \lambda N \tag{A.41}$$

and the mass of offshoring firms increases in t

$$\frac{d\chi M}{dt} > 0 \quad \text{with} \quad \chi M = \frac{\chi}{1+\chi}(1-\lambda)N. \tag{A.42}$$

A.10 Derivation of threshold for offshoring effect on M and φ^d

The effect on mass of total firms depends on the initial level of χ where we can solve for the threshold given by (19) by setting the following derivative equal to zero and solving it for χ:

$$\frac{dM}{d\chi} = \frac{-(k-\sigma+1)[(k-\sigma+1)] + (\sigma-1)(k-\sigma+1)[(k-\sigma+1)\chi^{\frac{k-\sigma+1}{k}-1}(1-\alpha)(1-\eta) - k\eta)]}{[(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]]^2}. \tag{A.43}$$

A.11 Derivation of threshold for offshoring effect on $(1-\chi)M$

To derive the threshold for the effect of χ on $(1-\chi)M$ we start with closed form equation of purely domestic firms:

$$(1-\chi)M = \frac{(1-\chi)(k-\sigma+1)}{(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1]} \tag{A.44}$$

$$\begin{aligned}\frac{d(1-\chi)M}{d\chi} =& \frac{(\sigma-1)(k-\sigma+1)(k-\sigma+1)(1-\alpha)(1-\eta)\chi^{\frac{k-\sigma+1}{k}-1} + (\sigma-1)(\sigma+1)(k-\sigma+1)(1-\alpha)(1-\eta)\chi^{\frac{k-\sigma+1}{k}}}{[(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]]^2} \\ &- \frac{2(k-\sigma+1)(k-\sigma+1) + (k-\sigma+1)k(\sigma-1)(1+\eta-\alpha(1-\eta))}{[(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]]^2}\end{aligned} \tag{A.45}$$

Setting last equation equal to zero, ignore $(k-\sigma+1)$ as constant. We move second row to RHS, multiply with the first χ term and divide by RHS factor term to have only the χ term on RHS

$$\left[\frac{(\sigma-1)(1-\alpha)(1-\eta)(k-\sigma+1) + (\sigma-1)(\sigma-1)(1-\alpha)(1-\eta)\chi}{k-\sigma+1+\eta k(\sigma-1) + k-\sigma+1+(1-\alpha(1-\eta))k(\sigma-1)}\right]^{\frac{k}{\sigma-1}} = \hat{\chi}_{dom} \tag{A.46}$$

First term in the numerator and first two terms in denominator are $\hat{\chi}$. It is easy to see that the rest of the LHS is smaller than 1, hence this threshold is smaller than $\hat{\chi}$. If LHS<RHS we have a negative effect of χ and t on mass of domestic firms.

A.12 Derivation of average output purely domestic firms

We start with deriving the average output level of purely domestic firms:

$$\bar{y}^d = \int_{\varphi^d}^{\varphi^o} y^d(\varphi)\frac{g(\varphi)}{G(\varphi^o)-G(\varphi^d)}d\varphi \tag{A.47}$$

Using

$$g(\varphi) = k\varphi^{-k-1} \tag{A.48}$$

$$G(\varphi^o) = 1 - (\varphi^o)^{-k} \tag{A.49}$$

$$G(\varphi^d) = 1 - (\varphi^d)^{-k} \tag{A.50}$$

$$\frac{y^d(\varphi)}{y^d(\varphi^d)} = \left(\frac{\varphi}{\varphi^d}\right)^{\sigma} \tag{A.51}$$

we arrive at:

$$\bar{y}^d = \int_{\varphi^d}^{\varphi^o} y^d(\varphi^d)\left(\frac{\varphi}{\varphi^d}\right)^{\sigma} k\varphi^{-k-1}\frac{(\varphi^d)^k}{1-\chi}d\varphi \tag{A.52}$$

Rearranging and solving the integral yields the expression for the average output level of purely domestic firms:

$$\bar{y}^d = \frac{k}{k-\sigma}\frac{(1-\chi^{\frac{k-\sigma}{k}})}{(1-\chi)}y^d(\varphi^d) \tag{A.53}$$

The increase in t directly lowers $y^d(\varphi^d)$. Furthermore, as shown in Appendix A.19, the increase in t lowers w through general equilibrium effects. This further reduces $y^d(\varphi^d)$. Finally, the increase in t (via χ) also raises φ^d as well as $y^d(\varphi^d)$, but the first two effects dominate. Hence, quite intuitively, average intermediate output of non-offshorers falls due to the environmental policy reform.

A.13 Derivation of average output offshoring firms

Similarly, we now start with deriving the average output level of offshoring firms:

$$\bar{y}^o = \int_{\varphi^o}^{\infty} y^o(\varphi)\frac{g(\varphi)}{1-G(\varphi^o)}d\varphi \tag{A.54}$$

Following the same steps as in (A.12) and using $y^o(\varphi) = y^d(\varphi)\kappa^{\sigma}$ we get:

$$\bar{y}^o = \int_{\varphi^o}^{\infty} y^d(\varphi^d)\left(\frac{\varphi}{\varphi^d}\right)^{\sigma}\kappa^{\sigma}\frac{k\varphi^{-k-1}}{(\varphi^o)^{-k}}d\varphi \tag{A.55}$$

Rearranging and solving the integral leads to:

$$\bar{y}^o = y^d(\varphi^d)\frac{k}{k-\sigma}\frac{(1+\chi^{\frac{\sigma-1}{k}})^{\frac{\sigma}{\sigma-1}}}{\chi^{\frac{\sigma}{k}}} \tag{A.56}$$

As t raises the level of offshoring, we know that the marginal purely domestic firm's intermediate output $y^d(\varphi^d)$ decreases in χ. Furthermore, the term $\frac{(1+\chi^{\frac{\sigma-1}{k}})^{\frac{\sigma}{\sigma-1}}}{\chi^{\frac{\sigma}{k}}}$ decreases in χ. Hence, we can conclude that $\frac{d\bar{y}^o}{dt} < 0$.

A.14 Derivation of average productivity of purely domestic firms

We now derive the inverse of the average productivity level of purely domestic firms by aggregating over all purely domestic firms' productivity level:

$$\frac{1}{\bar{\varphi}^d} = \int_{\varphi^d}^{\varphi^o}\frac{y^d(\varphi)}{\bar{y}^d}\frac{1}{\varphi}\frac{g(\varphi)}{G(\varphi^o)-G(\varphi^d)}d\varphi \tag{A.57}$$

Rearranging and solving the integral yields:

$$\frac{1}{\bar{\varphi}^d} = \frac{k}{k-\sigma+1}\frac{1-\chi^{\frac{k-\sigma+1}{k}}}{1-\chi}\frac{y^d(\varphi^d)}{\bar{y}^d}\frac{1}{\varphi^d} \tag{A.58}$$

We make use (A.53) for $y^d(\varphi^d)/\bar{y}^d$ and arrive at the inverse of (20):

$$\frac{1}{\bar{\varphi}^d} = \frac{k-\sigma}{k-\sigma+1}\frac{1-\chi^{\frac{k-\sigma+1}{k}}}{1-\chi^{\frac{k-\sigma}{k}}}\frac{1}{\varphi^d} \tag{A.59}$$

An increase in t raises χ. While the term $\frac{1-\chi^{(k-\sigma)/k}}{1-\chi^{(k-\sigma+1)/k}}$ clearly decreases in χ, φ^d falls in χ when χ is near 0 and rises in χ if χ is sufficiently large. Hence, $\bar{\varphi}^d$ unambiguously decreases at low levels of χ, while there are opposing effects at higher levels of χ. Simulations suggest that the negative effect dominates even at higher levels of χ, so that we have reasonable ground to assume that $\frac{d\bar{\varphi}^d}{dt} < 0$ holds.

A.15 Derivation of average productivity offshoring firms

We now derive the inverse of the average productivity level of offshoring firms by aggregating over all offshoring firms' productivity level:

$$\frac{1}{\bar{\varphi}^o} = \int_{\varphi^o}^{\infty} \frac{y^o(\varphi)}{\bar{y}^o}\frac{1}{\varphi}\frac{g(\varphi)}{1-G(\varphi^o)}d\varphi \tag{A.60}$$

Following the same steps as in (A.13) we get:

$$\frac{1}{\bar{\varphi}^o} = \frac{y^d(\varphi^d)}{\bar{y}^o}\frac{(1+\chi^{\frac{\sigma-1}{k}})^{\frac{\sigma}{\sigma-1}}}{\chi^{\frac{\sigma}{k}}}\frac{k}{k-\sigma+1}\frac{1}{\varphi^o} \tag{A.61}$$

Inserting $y^d(\varphi^d)/\bar{y}^o$ from (A.56) yields:

$$\frac{1}{\bar{\varphi}^o} = \frac{k-\sigma}{k}\frac{\chi^{\frac{\sigma}{k}}}{(1+\chi^{\frac{\sigma-1}{k}})^{\frac{\sigma}{\sigma-1}}}\frac{(1+\chi^{\frac{\sigma-1}{k}})^{\frac{\sigma}{\sigma-1}}}{\chi^{\frac{\sigma}{k}}}\frac{k}{k-\sigma+1}\frac{1}{\varphi^o} \tag{A.62}$$

Which simplifies to

$$\frac{1}{\bar{\varphi}^o} = \frac{k-\sigma}{k-\sigma+1}\frac{1}{\varphi^o} \tag{A.63}$$

being the inverse of the expression shown in (20). As the productivity level of the marginal offshoring firm φ^0 decreases in the source country's emission tax rate t via χ, it can be easily seen that the same applies for the average productivity, i.e. $\frac{d\bar{\varphi}^o}{dt} < 0$.

A.16 Derivation of average emission intensity purely domestic firms

We start by aggregating over all non offshoring firms' emission intensity levels:

$$\bar{i}^d = \int_{\varphi^d}^{\varphi^o} i^d(\varphi)\frac{y^d(\varphi)}{\bar{y}^d}\frac{g(\varphi)}{G(\varphi^o)-G(\varphi^d)}d\varphi. \tag{A.64}$$

The expression can be rearranged to using the steps as in (A.12) and $i^d(\varphi) = i^d(\varphi^d)\varphi^d/\varphi$:

$$\bar{i}^d = \int_{\varphi^d}^{\varphi^o} i^d(\varphi^d) y^d(\varphi^d) \left(\frac{\varphi}{\varphi^d}\right)^{\sigma-1} \frac{1}{\bar{y}^d} k\varphi^{-k-1} \frac{(\varphi^d)^k}{1-\chi} d\varphi \tag{A.65}$$

Solving the integral and simplifying yields:

$$\bar{i}^d = i^d(\varphi^d) y^d(\varphi^d) \frac{1-\chi^{\frac{k-\sigma+1}{k}}}{1-\chi} \frac{k}{k-\sigma+1} \frac{1}{\bar{y}^d} \tag{A.66}$$

Inserting the expression for $\bar{y}^d$ from (A.53) yields:

$$\bar{i}^d = i^d(\varphi^d) \frac{1-\chi^{\frac{k-\sigma+1}{k}}}{1-\chi^{\frac{k-\sigma}{k}}} \frac{k-\sigma}{k-\sigma+1} \tag{A.67}$$

Using the explicit expression for the marginal firm's emission intensity level $i^d(\varphi^d) = e^d(\varphi^d)/y^d(\varphi^d)$ from cost minimization finally gives:

$$\bar{i}^d = \alpha(1-\eta)\left(\frac{w}{t}\right)^{1-\alpha(1-\eta)} \frac{1}{\varphi^d} \frac{1-\chi^{\frac{k-\sigma+1}{k}}}{1-\chi^{\frac{k-\sigma}{k}}} \frac{k-\sigma}{k-\sigma+1} \tag{A.68}$$

As the last three terms equal $\frac{1}{\tilde{\varphi}^d}$, we arrive at the expression provided in the main text.

A.17 Derivation of average emission intensity offshoring firms

Again, we integrate over all offshoring firms' emission intensity levels:

$$\bar{i}^o = \int_{\varphi^o}^{\infty} i^o(\varphi) \frac{y^o(\varphi)}{\bar{y}^o} \frac{g(\varphi)}{1-G(\varphi^o)} d\varphi \tag{A.69}$$

We use the same equations as in (A.13) and $i^o(\varphi) = i^d(\varphi)t/t^*\kappa^{-1}$:

$$\bar{i}^o = \int_{\varphi^o}^{\infty} i^d(\varphi^d) \frac{\varphi^d}{\varphi} \frac{t}{t^*} \kappa^{-1} \frac{y^d(\varphi^d)\left(\frac{\varphi}{\varphi^d}\right)^{\sigma} \kappa^{\sigma}}{\bar{y}^o} \frac{k\varphi^{-k-1}}{(\varphi^o)^{-k}} d\varphi \tag{A.70}$$

Extracting $i^d(\varphi^d), \varphi^d, t/t^*, \kappa, \varphi^o$ out of the integral as well as solving the integral yields:

$$\bar{i}^o = i^d(\varphi^d) \frac{y^d(\varphi^d)}{\bar{y}^o} \kappa^{\sigma-1} (\varphi^d)^{1-\sigma} (\varphi^o)^k \frac{t}{t^*} \frac{k}{k-\sigma+1} (\varphi^o)^{-k+\sigma-1} \tag{A.71}$$

Using $(\varphi^d)^{1-\sigma} = (\varphi^o)^{1-\sigma}\chi^{\frac{1-\sigma}{k}}$ and combining the φ^o-terms yields:

$$\bar{i}^o = i^d(\varphi^d) \frac{y^d(\varphi^d)}{\bar{y}^o} \kappa^{\sigma-1} \frac{1}{\chi^{\frac{\sigma-1}{k}}} \frac{t}{t^*} \frac{k}{k-\sigma+1} \tag{A.72}$$

Making use of the offshoring indifference condition for κ and inserting the expression for emission intensity of the marginal purely domestic firm $i^d(\varphi^d)$ yields:

$$\bar{i}^o = \alpha(1-\eta)\left(\frac{w}{t}\right)^{1-\alpha(1-\eta)} \frac{1}{\varphi^d} \frac{y^d(\varphi^d)}{\bar{y}^o} \frac{1+\chi^{\frac{\sigma-1}{k}}}{\chi^{\frac{\sigma-1}{k}}} \frac{t}{t^*} \frac{k}{k-\sigma+1} \tag{A.73}$$

We now use

$$\frac{y^d(\varphi^d)}{\bar{y}^o} = \frac{k-\sigma}{k}\frac{\chi^{\frac{\sigma}{k}}}{(1+\chi^{\frac{\sigma-1}{k}})^{\frac{\sigma}{\sigma-1}}}$$

in order to arrive at:

$$\bar{i}^o = \alpha(1-\eta)\left(\frac{w}{t}\right)^{1-\alpha(1-\eta)}\frac{1}{\varphi^d}\frac{\chi^{\frac{1}{k}}}{(1+\chi^{\frac{\sigma-1}{k}})^{\frac{1}{\sigma-1}}}\frac{t}{t^*}\frac{k-\sigma}{k-\sigma+1} \tag{A.74}$$

Using $\chi^{\frac{1}{k}}/\varphi^d = 1/\varphi^o$, using κ for the RHS of the offshoring indifference condition, as well as replacing $\frac{k-\sigma}{k-\sigma+1}\frac{1}{\varphi^o}$ by $\frac{1}{\bar{\varphi}^o}$ gives:

$$\bar{i}^o = \alpha(1-\eta)\left(\frac{w}{t}\right)^{1-\alpha(1-\eta)}\kappa^{-1}\frac{t}{t^*}\frac{1}{\bar{\varphi}^o} \tag{A.75}$$

This expression is equal to the one in the main text when inserting the definition of κ.

A.18 Effect on average emission intensities

A.18.1 Effect on average emission intensity domestic firms

The emission intensity level of the purely domestic firm is given by:

$$\bar{i}^d = \alpha(1-\eta)\left(\frac{w}{t}\right)^{1-\alpha(1-\eta)}\frac{1}{\varphi^d}\frac{k-\sigma}{k-\sigma+1}\frac{1-\chi^{\frac{k-\sigma+1}{k}}}{1-\chi^{\frac{k-\sigma}{k}}} \tag{A.76}$$

Which we rewrite by using the definition of the marginal firm's emission intensity $i^d(\varphi^d)$ as well as extending by $\frac{\chi^{\frac{1}{k}}}{\chi^{\frac{1}{k}}}$:

$$\bar{i}^d = i^d(\varphi^d)\chi^{\frac{1}{k}}\frac{k-\sigma}{k-\sigma+1}\frac{1-\chi^{\frac{k-\sigma+1}{k}}}{\chi^{\frac{1}{k}}-\chi^{\frac{k-\sigma+1}{k}}} \tag{A.77}$$

There is direct effect of t as well as an indirect effect via χ. Totally differentiating this expression with respect to t yields:

$$\begin{aligned}\frac{d\bar{i}^d}{dt} &= \alpha(1-\eta)\frac{\sigma-1}{\sigma}\left[\frac{k}{k-\sigma+1+\gamma^l k(\sigma-1)}N\right]^{\frac{1}{\sigma-1}}\frac{1}{t}\frac{k-\sigma}{k-\sigma+1}\chi^{\frac{1}{k}} \\ &\times\left[-\frac{1}{t}+\left[\frac{(k-\sigma+1)(1-\eta)(1-\alpha)\chi^{\frac{k-\sigma+1}{k}-1}+k(\gamma^l-\eta)}{(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]}+\frac{1}{k}\frac{1}{\chi}\right]\right. \\ &\times\left.\frac{\left[\left(\frac{1}{\tau}\right)\left(\frac{t}{t^*}\right)^{\alpha}\left(\frac{k-\sigma+1+\gamma^l k(\sigma-1)}{(1-\gamma^l-\alpha(1-\eta))k(\sigma-1)}\frac{N^*}{N}\right)^{(1-\alpha)}\right]^{1-\eta}\alpha(1-\eta)\frac{1}{t}}{\left[\left[\left(\frac{1}{\tau}\right)\left(\frac{t}{t^*}\right)^{\alpha}\left(\frac{k-\sigma+1+\gamma^l k(\sigma-1)}{(1-\gamma^l-\alpha(1-\eta))k(\sigma-1)}\frac{N^*}{N}\right)^{(1-\alpha)}\right]^{1-\eta}(1-\alpha)(1-\eta)\left(\frac{-\frac{\partial\gamma^l}{\partial\chi}k(\sigma-1)[(1-\alpha(1-\eta))k(\sigma-1)+k-\sigma+1]}{[k-\sigma+1+\gamma^l k(\sigma-1)][(1-\gamma^l-\alpha(1-\eta))k(\sigma-1)]}\right)+\frac{1}{k}(1+\chi^{\frac{\sigma-1}{k}})^{\frac{1}{\sigma-1}}\frac{1}{\chi^{\frac{k-\sigma+1}{k}}+\chi}\right]}\right]\end{aligned} \tag{A.78}$$

The χ effect of same denominator

$$
\begin{aligned}
&\alpha(1-\eta)\frac{\sigma-1}{\sigma}\left[\frac{k}{k-\sigma+1+\gamma^l k(\sigma-1)}N\right]^{\frac{1}{\sigma-1}}\frac{1}{t}\frac{k-\sigma}{k-\sigma+1}\chi^{\frac{1}{k}} \\
&\times\left[-\frac{1}{t}+\left[\frac{\chi k\left[(k-\sigma+1)(1-\eta)(1-\alpha)\chi^{\frac{k-\sigma+1}{k}-1}+k(\gamma^l-\eta)\right]+(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]}{\chi k(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]}\right]\right. \\
&\times\left.\frac{\left[\left(\frac{1}{\tau}\right)\left(\frac{t}{t^*}\right)^{\alpha}\left(\frac{k-\sigma+1+\gamma^l k(\sigma-1)}{(1-\gamma^l-\alpha(1-\eta))k(\sigma-1)}\frac{N^*}{N}\right)^{(1-\alpha)}\right]^{1-\eta}\alpha(1-\eta)\frac{1}{t}}{\left[\left[\left(\frac{1}{\tau}\right)\left(\frac{t}{t^*}\right)^{\alpha}\left(\frac{k-\sigma+1+\gamma^l k(\sigma-1)}{(1-\gamma^l-\alpha(1-\eta))k(\sigma-1)}\frac{N^*}{N}\right)^{(1-\alpha)}\right]^{1-\eta}(1-\alpha)(1-\eta)\left(\frac{-\frac{\partial\gamma^l}{\partial\chi}k(\sigma-1)[(1-\alpha(1-\eta))k(\sigma-1)+k-\sigma+1]}{[k-\sigma+1+\gamma^l k(\sigma-1)][(1-\gamma^l-\alpha(1-\eta))k(\sigma-1)]}\right)+\frac{1}{k}(1+\chi^{\frac{\sigma-1}{k}})^{\frac{1}{\sigma-1}}\frac{1}{\chi^{\frac{k-\sigma+1}{k}}+\chi}\right]}\right] \\
&\gtrless 0
\end{aligned}
\tag{A.79}
$$

Direct effect to RHS. Then, B-term back to LHS, rearranging and extracting B-term. Ignore first row

$$
\begin{aligned}
&\left[\frac{\chi k\left[(k-\sigma+1)(1-\eta)(1-\alpha)\chi^{\frac{k-\sigma+1}{k}-1}+k(\gamma^l-\eta)\right]+(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]}{\chi k(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]}\alpha(1-\eta)\right. \\
&\left.-\frac{[(k-\sigma+1)(1-\alpha)(1-\eta)\chi^{\frac{k-\sigma+1}{k}-1}+k(\gamma^l-\eta)][(1-\alpha(1-\eta))k(\sigma-1)+k-\sigma+1]}{[k-\sigma+1+\gamma^l k(\sigma-1)](\chi+\chi^{\frac{k-\sigma+1}{k}})k}\right] \\
&\times\left[\left(\frac{1}{\tau}\right)\left(\frac{t}{t^*}\right)^{\alpha}\left(\frac{k-\sigma+1+\gamma^l k(\sigma-1)}{(1-\gamma^l-\alpha(1-\eta))k(\sigma-1)}\frac{N^*}{N}\right)^{(1-\alpha)}\right]^{1-\eta}\frac{1}{t} \\
&\gtrless \\
&\frac{1}{k}(1+\chi^{\frac{\sigma-1}{k}})^{\frac{1}{\sigma-1}}\frac{1}{\chi^{\frac{k-\sigma+1}{k}}+\chi}\frac{1}{t}
\end{aligned}
\tag{A.80}
$$

First two rows of same denominator. Canceling out $1/t$, $(\chi+\chi^{\frac{k-\sigma+1}{k}})$ and k on both sides.

$$
\begin{aligned}
&\left[\frac{\alpha(1-\eta)(\chi+\chi^{\frac{k-\sigma+1}{k}})\left[\chi k\left[(k-\sigma+1)(1-\eta)(1-\alpha)\chi^{\frac{k-\sigma+1}{k}-1}+k(\gamma^l-\eta)\right]+(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]\right]}{\chi(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]}\right. \\
&\left.-\frac{(1+\chi)\chi\left[[(k-\sigma+1)(1-\alpha)(1-\eta)\chi^{\frac{k-\sigma+1}{k}-1}+k(\gamma^l-\eta)][(1-\alpha(1-\eta))k(\sigma-1)+k-\sigma+1]\right]}{\chi(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]}\right] \\
&\times\left[\left(\frac{1}{\tau}\right)\left(\frac{t}{t^*}\right)^{\alpha}\left(\frac{k-\sigma+1+\gamma^l k(\sigma-1)}{(1-\gamma^l-\alpha(1-\eta))k(\sigma-1)}\frac{N^*}{N}\right)^{(1-\alpha)}\right]^{1-\eta} \\
&\gtrless \\
&(1+\chi^{\frac{\sigma-1}{k}})^{\frac{1}{\sigma-1}}
\end{aligned}
\tag{A.81}
$$

Except of the last term in the first row, LHS is the same as in the calculation of the marginal firm multiplied by χ. Hence we can rearrange in a similar way

$$\left[\frac{\chi\left[(k-\sigma+1)(1-\eta)(1-\alpha)\chi^{\frac{k-\sigma+1}{k}-1}+k(\gamma^l-\eta)\right]\left[(\chi+\chi^{\frac{k-\sigma+1}{k}})k\alpha(1-\eta)-(1+\chi)[(1-\alpha(1-\eta))k(\sigma-1)+k-\sigma+1]\right]}{\chi(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]}\right.$$
$$\left.+\frac{(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]\alpha(1-\eta)(\chi+\chi^{\frac{k-\sigma+1}{k}})}{\chi(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]}\right]$$
$$\times\left[\left(\frac{1}{\tau}\right)\left(\frac{t}{t^*}\right)^{\alpha}\left(\frac{k-\sigma+1+\gamma^l k(\sigma-1)}{(1-\gamma^l-\alpha(1-\eta))k(\sigma-1)}\frac{N^*}{N}\right)^{(1-\alpha)}\right]^{1-\eta}$$
$$\gtrless$$
$$(1+\chi^{\frac{\sigma-1}{k}})^{\frac{1}{\sigma-1}} \tag{A.82}$$

We have shown that first is negative. Setting A=B we can move RHS to LHS, of same denominator

$$\frac{\chi\left[(k-\sigma+1)(1-\eta)(1-\alpha)\chi^{\frac{k-\sigma+1}{k}-1}+k(\gamma^l-\eta)\right]\left[(\chi+\chi^{\frac{k-\sigma+1}{k}})k\alpha(1-\eta)-(1+\chi)[(1-\alpha(1-\eta))k(\sigma-1)+k-\sigma+1]\right]}{\chi(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]}$$
$$+\frac{(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]\alpha(1-\eta)(\chi+\chi^{\frac{k-\sigma+1}{k}})-(1+\chi)\chi[k-\sigma+1+\gamma^l k(\sigma-1)]}{\chi(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]}$$
$$\gtrless$$
$$0 \tag{A.83}$$

Rearrange second row

$$\frac{\chi\left[(k-\sigma+1)(1-\eta)(1-\alpha)\chi^{\frac{k-\sigma+1}{k}-1}+k(\gamma^l-\eta)\right]\left[(\chi+\chi^{\frac{k-\sigma+1}{k}})k\alpha(1-\eta)-(1+\chi)[(1-\alpha(1-\eta))k(\sigma-1)+k-\sigma+1]\right]}{\chi(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]}$$
$$+\frac{(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]\left[\alpha(1-\eta)\chi^{\frac{k-\sigma+1}{k}}-(1-\alpha(1-\eta))\chi\right]}{\chi(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]}$$
$$\gtrless$$
$$0 \tag{A.84}$$

The total effect of t on average emission intensity for domestic firms is negative if second row is negative (as well). This holds if

$$\left[\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}\right]^{\frac{k}{\sigma-1}}<\chi \tag{A.85}$$

which already holds for very low levels of offshoring.

A.18.2 Effect on average emission intensity offshoring firms

First, we aim to get a closed form solution for the emission intensity level of the marginal purely domestic firm:

$$i^d(\varphi^d)=\alpha(1-\eta)\left(\frac{w}{t}\right)^{1-\alpha(1-\eta)}\frac{1}{\varphi^d} \tag{A.86}$$

We use the following

To get a closed form solution we use the following:

$$w = \gamma^l \frac{\sigma - 1}{\sigma} \frac{Y}{L} \tag{A.87}$$

$$L = \lambda N \tag{A.88}$$

$$\varphi^d = \left(\frac{1+\chi}{1-\lambda}\right)^{\frac{1}{k}} \tag{A.89}$$

$$M = \frac{1-\lambda}{1+\chi} N \tag{A.90}$$

$$Y = (1-\lambda)^{\frac{k(\sigma-1)(1-\alpha(1-\eta))+k-\sigma+1}{k(\sigma-1)(1-\alpha(1-\eta))}} \left[N \frac{k}{k-\sigma+1}\right]^{\frac{(\sigma-1)(1-\alpha(1-\eta))+1}{(\sigma-1)(1-\alpha(1-\eta))}} \left(\frac{1}{t\sigma}\right)^{\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}} \left((1+\chi)^{\frac{1}{k}} (\sigma-1)\right)^{\frac{1}{1-\alpha(1-\eta)}} \tag{A.91}$$

and – after simplifying – arrive at:

$$i^d(\varphi^d) = \alpha(1-\eta) \frac{\sigma-1}{\sigma} \frac{1}{t} \left(\frac{k}{k-\sigma+1+\gamma^l k(\sigma-1)} N\right)^{\frac{1}{\sigma-1}} \tag{A.92}$$

We can rewrite this expression for the marginal offshoring firm

$$i^d(\varphi^o) = \alpha(1-\eta) \frac{\sigma-1}{\sigma} \frac{1}{t} \left(\frac{k}{k-\sigma+1+\gamma^l k(\sigma-1)} N\right)^{\frac{1}{\sigma-1}} \chi^{\frac{1}{k}} \tag{A.93}$$

using $i^o(\varphi) = i^d(\varphi) \frac{t}{t^*} \kappa^{-1}$ we get

$$i^o(\varphi^o) = \alpha(1-\eta) \frac{\sigma-1}{\sigma} \frac{1}{t} \left(\frac{k}{k-\sigma+1+\gamma^l k(\sigma-1)} N\right)^{\frac{1}{\sigma-1}} \chi^{\frac{1}{k}} \frac{t}{t^*} \kappa^{-1} \tag{A.94}$$

We can rewrite $\chi^{\frac{1}{k}}$ using offshoring indifference condition and combine it with κ^{-1}

$$\chi = \left[\kappa^{\sigma-1} - 1\right]^{\frac{k}{\sigma-1}}$$

$$\chi^{\frac{1}{k}} = \left[\kappa^{\sigma-1} - 1\right]^{\frac{1}{\sigma-1}} \tag{A.95}$$

$$i^o(\varphi^o) = \alpha(1-\eta) \frac{\sigma-1}{\sigma} \frac{1}{t} \left(\frac{k}{k-\sigma+1+\gamma^l k(\sigma-1)} N\right)^{\frac{1}{\sigma-1}} \frac{t}{t^*} \kappa^{-1} \left[\kappa^{\sigma-1} - 1\right]^{\frac{1}{\sigma-1}} \tag{A.96}$$

$$i^o(\varphi^o) = \alpha(1-\eta) \frac{\sigma-1}{\sigma} \left(\frac{k}{k-\sigma+1+\gamma^l k(\sigma-1)} N\right)^{\frac{1}{\sigma-1}} \frac{1}{t^*} \kappa^{-1} \left[\kappa^{\sigma-1} - 1\right]^{\frac{1}{\sigma-1}} \tag{A.97}$$

$$i^o(\varphi^o)^{\sigma-1} = \left[\alpha(1-\eta) \frac{\sigma-1}{\sigma} \frac{1}{t^*}\right]^{\sigma-1} \left(\frac{k}{k-\sigma+1+\gamma^l k(\sigma-1)} N\right) \frac{1}{\kappa^{\sigma-1}} \left[\kappa^{\sigma-1} - 1\right] \tag{A.98}$$

$$i^o(\varphi^o)^{\sigma-1} = \left[\alpha(1-\eta) \frac{\sigma-1}{\sigma} \frac{1}{t^*}\right]^{\sigma-1} \left[\frac{k}{k-\sigma+1+\gamma^l k(\sigma-1)} N\right] \left[1 - \frac{1}{\kappa^{\sigma-1}}\right] \tag{A.99}$$

From the last expression, it is evident that $i^o(\varphi^o)$ rises in t. The first squared bracket is independent of t. As t raises χ and lowers γ_l, we know that the second squared bracket (with γ_l in the denominator) has to increase. Also the third squared bracket has to increase, as κ in the denominator is subtracted. Hence, emission intensity of the marginal offshoring must increase due to an increase of the source country emission tax rate.

Since this cutoff term is linked to its average solely via the pareto multiplier we thus also confirm that the average emission intensity of the offshoring firm increases as well.

$$\bar{i}^o = \alpha(1-\eta)\left(\frac{w}{t}\right)^{1-\alpha(1-\eta)}\kappa^{-1}\frac{t}{t^*}\frac{k-\sigma}{k-\sigma+1}\frac{1}{\varphi^o} \tag{A.100}$$

Rearranging the expression for average offshorer's emission intensity yields a term equal to expression (A.94) multiplied by $\frac{k-\sigma}{k-\sigma+1}$.

$$\bar{i}^o = \alpha(1-\eta)\frac{\sigma-1}{\sigma}\frac{1}{t}\left(\frac{k}{k-\sigma+1+\gamma^l k(\sigma-1)}N\right)^{\frac{1}{\sigma-1}}\chi^{\frac{1}{k}}\frac{t}{t^*}\kappa^{-1}\frac{k-\sigma}{k-\sigma+1} \tag{A.101}$$

As the multiplier does not depend on t, it can be concluded that $\bar{i}^o$ increases in t as well.

A.19 Effect on source country wage

We use (A.26), (A.29) and (A.120) to get our starting equation for w:

$$w = \left[\frac{1}{k-\sigma+1+\gamma^l k(\sigma-1)}\right]^{\frac{k-\sigma+1}{k(\sigma-1)(1-\alpha(1-\eta))}}[Nk]^{\frac{1}{(\sigma-1)(1-\alpha(1-\eta))}}\left(\frac{\sigma-1}{\sigma}\right)^{\frac{1}{1-\alpha(1-\eta)}}\left(\frac{1}{t}\right)^{\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}}(1+\chi)^{\frac{1}{k(1-\alpha(1-\eta))}} \tag{A.102}$$

Comparative statics reveal a negative direct effect of t

$$\frac{\partial w}{\partial t} = -\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}\left(\frac{1}{t}\right)^{\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}-1}\frac{1}{t^2}\left[\frac{1}{k-\sigma+1+\gamma^l k(\sigma-1)}\right]^{\frac{k-\sigma+1}{k(\sigma-1)(1-\alpha(1-\eta))}}[Nk]^{\frac{1}{(\sigma-1)(1-\alpha(1-\eta))}}\left(\frac{\sigma-1}{\sigma}\right)^{\frac{1}{1-\alpha(1-\eta)}}(1+\chi)^{\frac{1}{k(1-\alpha(1-\eta))}} \tag{A.103}$$

and an opposing positive indirect effect of t via χ with $d\chi/dt > 0$ and

$$\begin{aligned}\frac{\partial w}{\partial \chi} = &\left(\frac{1}{t}\right)^{\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}}\left[\frac{1}{k-\sigma+1+\gamma^l k(\sigma-1)}\right]^{\frac{k-\sigma+1}{k(\sigma-1)(1-\alpha(1-\eta))}}[Nk]^{\frac{1}{(\sigma-1)(1-\alpha(1-\eta))}}\left(\frac{\sigma-1}{\sigma}\right)^{\frac{1}{1-\alpha(1-\eta)}}(1+\chi)^{\frac{1}{k(1-\alpha(1-\eta))}} \\ &\times\left[\frac{(k-\sigma+1)(k-\sigma+1)(1-\alpha)(1-\eta)\chi^{\frac{k-\sigma+1}{k}-1}+(k-\sigma+1)k(\gamma^l-\eta)+k-\sigma+1+\gamma^l k(\sigma-1)}{k(1+\chi)(1-\alpha(1-\eta))[k-\sigma+1+\gamma^l k(\sigma-1)]}\right].\end{aligned} \tag{A.104}$$

After tedious calculations we can show that the negative direct effect dominates the positive indirect effect for all $\chi \in (0,1)$, hence $\frac{dw}{dt} < 0$.

A.20 Global Emissions

A.20.1 Derivation of average emissions across all firms

All domestic firms have the same input ratio $e(\varphi)/l^r(\varphi) = \bar{e}/\bar{l} = (w/t)[\alpha/(1-\alpha)]$. To derive $\bar{l}$ we use the integral for purely domestic firms:

$$\bar{l} = \int_{\varphi^d}^{\varphi^o} l^r(\varphi)\frac{dG(\varphi)}{G(\varphi^o)-G(\varphi^d)}. \tag{A.105}$$

Following similar steps as for the wage rate, using $\frac{l^r(\varphi^o)}{l^r(\varphi^d)} = \left(\frac{\varphi^o}{\varphi^d}\right)^{\sigma-1}$ and then again $\frac{\varphi^d}{\varphi^o}^{-(\sigma-1)} = \chi^{-\frac{\sigma-1}{k}}$ we end at:

$$\bar{l} = l^r(\varphi^d)\frac{k}{k-\sigma+1}\frac{1-\chi^{\frac{k-\sigma+1}{k}}}{1-\chi}. \tag{A.106}$$

The result includes all routine labor used by source country firms minus routine labor which has been offshored. We further know that a constant fraction $(1-\alpha)(1-\eta)(\sigma-1)/\sigma$ of revenues is earned by routine task labor. This implies for the marginal firm $l^r(\varphi^d) = (1-\alpha)(1-\eta)(\sigma-1)$ using the indifference condition of the marginal firm. Insert into $\bar{l}$:

$$\bar{l} = \frac{k}{k-\sigma+1}\frac{1-\chi^{\frac{k-\sigma+1}{k}}}{1-\chi}(1-\alpha)(1-\eta)(\sigma-1) \tag{A.107}$$

We can then derive average emissions as:

$$\bar{e} = \frac{k}{k-\sigma+1}\frac{1-\chi^{\frac{k-\sigma+1}{k}}}{1-\chi}\alpha(1-\eta)(\sigma-1)\frac{w}{t}. \tag{A.108}$$

A.20.2 Aggregate emissions in closed form via income shares

Making use of the decomposition of aggregate income, we can derive aggregate emissions of the two countries as

$$E = \gamma^e\frac{\sigma-1}{\sigma}\frac{Y}{t} \qquad \text{and} \qquad E^* = \gamma^{e*}\frac{\sigma-1}{\sigma}\frac{Y}{t^*} \tag{A.109}$$

$$\text{with} \qquad \gamma^e \equiv \frac{\alpha(1-\eta)(1-\chi^{\frac{k-\sigma+1}{k}})}{1+\chi} \qquad \text{and} \qquad \gamma^{e*} \equiv \frac{\alpha(1-\eta)(\chi+\chi^{\frac{k-\sigma+1}{k}})}{1+\chi}. \tag{A.110}$$

The terms γ^e and γ^{e*} share of aggregate income net of aggregate operating profits that is linked to the source country's emissions taxation.[41]

Making use of Eqs. (A.109) and (A.110), we derive

$$E^W = \frac{\sigma-1}{\sigma}\left(\frac{\gamma^e}{t}+\frac{\gamma^{e*}}{t^*}\right)Y = \alpha(1-\eta)\left(\frac{1-\chi^{\frac{k-\sigma+1}{k}}}{1+\chi}\frac{1}{t}+\frac{\chi+\chi^{\frac{k-\sigma+1}{k}}}{1+\chi}\frac{1}{t^*}\right)\frac{\sigma-1}{\sigma}Y. \tag{A.111}$$

Furthermore, in the context of a BCA, due to $\tilde{t^*} = t$, this expression reduces from Eq. (A.111) to:

$$(E^W) = \alpha(1-\eta)\frac{\sigma-1}{\sigma}Y\frac{Y}{t} \tag{A.112}$$

A.21 Effect on aggregate final goods output

To get a closed form solution we must derive Y. We start with $Y = (M(1+\chi))^{\frac{\sigma}{\sigma-1}}q(\bar{\varphi})$. We can use pareto and insert $q(\bar{\varphi}) = (\frac{\bar{\varphi}}{\varphi^d})^{\sigma}q(\varphi^d)$. Solve it for $q(\varphi^d)$ and insert into $q(\varphi^d) = Y/Pp^{-\sigma}/P$ with $P = 1$.

$$\frac{Y}{(M(1+\chi))^{\frac{\sigma}{\sigma-1}}}\left(\frac{\bar{\varphi}}{\varphi^d}\right)^{-\sigma} = Yp(\varphi^d)^{-\sigma} \tag{A.113}$$

Solve it for the price and insert the price equation

$$\frac{\sigma}{\sigma-1}\frac{w}{\varphi^d}\left(\left(\frac{t}{w}\right)^{\alpha}\right)^{1-\eta} = \left(\frac{\bar{\varphi}}{\varphi^d}\right)(M(1+\chi))^{\frac{1}{\sigma-1}} \tag{A.114}$$

[41] In Appendix A.21 we derive Y to get closed form solution for E.

We can now use Pareto for average productivity

$$\frac{\sigma}{\sigma-1}\frac{w}{\varphi^d}\left(\left(\frac{t}{w}\right)^{\alpha}\right)^{1-\eta}=\left(\frac{k}{k-\sigma+1}\right)^{\frac{1}{\sigma-1}}(M(1+\chi))^{\frac{1}{\sigma-1}} \tag{A.115}$$

Next, we solve it for the wage rate

$$w=\left[\frac{\sigma-1}{\sigma}\varphi^d\left(M(1+\chi)\frac{k}{k-\sigma+1}\right)^{\frac{1}{\sigma-1}}\left(\frac{1}{t}\right)^{\alpha(1-\eta)}\right]^{\frac{1}{1-\alpha(1-\eta)}} \tag{A.116}$$

We now use the marginal firm indifference condition (A.26). Solve it for Y:

$$Y=\left[\frac{\sigma-1}{\sigma}\varphi^d\left(M(1+\chi)\frac{k}{k-\sigma+1}\right)^{\frac{1}{\sigma-1}}\left(\frac{1}{t}\right)^{\alpha(1-\eta)}\right]^{\frac{1}{1-\alpha(1-\eta)}}M(1+\chi)\frac{k}{k-\sigma+1}\sigma \tag{A.117}$$

$$Y=\sigma\left[M(1+\chi)\frac{k}{k-\sigma+1}\right]^{\frac{(\sigma-1)(1-\alpha(1-\eta))+1}{(\sigma-1)(1-\alpha(1-\eta))}}\left[\frac{1}{t}\right]^{\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}}\left[\frac{\sigma-1}{\sigma}\varphi^d\right]^{\frac{1}{1-\alpha(1-\eta)}} \tag{A.118}$$

We use that $\varphi^d=M^{-\frac{1}{k}}N^{\frac{1}{k}}$ and combine both expressions of M.

$$Y=\sigma\left[(1+\chi)\frac{k}{k-\sigma+1}\right]^{\frac{(\sigma-1)(1-\alpha(1-\eta))+1}{(\sigma-1)(1-\alpha(1-\eta))}}\left[\frac{1}{t}\right]^{\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}}\left[\frac{\sigma-1}{\sigma}\right]^{\frac{1}{1-\alpha(1-\eta)}}M^{1+\frac{1}{1-\alpha(1-\eta)}\left(\frac{1}{\sigma-1}-\frac{1}{k}\right)}N^{\frac{1}{k(1-\alpha(1-\eta))}} \tag{A.119}$$

By inserting the explicit expression for M, we can rearrange to

$$Y=\left(\frac{1}{\sigma t}\right)^{\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}}(1+\chi)^{\frac{1}{k(1-\alpha(1-\eta))}}\left[\frac{k-\sigma+1}{k-\sigma+1+\gamma^l k(\sigma-1)}\right]^{\frac{k(\sigma-1)(1-\alpha(1-\eta))+k-\sigma+1}{k(\sigma-1)(1-\alpha(1-\eta))}}(\sigma-1)^{\frac{1}{1-\alpha(1-\eta)}}\left(\frac{k}{k-\sigma+1}N\right)^{\frac{(\sigma-1)(1-\alpha(1-\eta))+1}{(\sigma-1)(1-\alpha(1-\eta))}} \tag{A.120}$$

We can use and rewrite (A.120) to get our starting equation:

$$Y=\left[\frac{1}{k-\sigma+1+\gamma^l k(\sigma-1)}\right]^{\frac{k(\sigma-1)(1-\alpha(1-\eta))+k-\sigma+1}{k(\sigma-1)(1-\alpha(1-\eta))}}[Nk]^{\frac{(\sigma-1)(1-\alpha(1-\eta))+1}{(\sigma-1)(1-\alpha(1-\eta))}}\left(\frac{1}{t\sigma}\right)^{\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}}\left(\left(\frac{1+\chi}{k-\sigma+1}\right)^{\frac{1}{k}}(\sigma-1)\right)^{\frac{1}{1-\alpha(1-\eta)}} \tag{A.121}$$

Similar to the effect on source country wage rate, comparative statics reveal a negative direct and a positive indirect effect (via χ with $d\chi/dt$):

$$\begin{aligned}\frac{\partial Y}{\partial t}&=-\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}\left(\frac{1}{t}\right)^{\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}-1}\frac{1}{t^2}\left[\frac{1}{k-\sigma+1+\gamma^l k(\sigma-1)}\right]^{\frac{k(\sigma-1)(1-\alpha(1-\eta))+k-\sigma+1}{k(\sigma-1)(1-\alpha(1-\eta))}}[Nk]^{\frac{(\sigma-1)(1-\alpha(1-\eta))+1}{(\sigma-1)(1-\alpha(1-\eta))}}\left(\frac{1}{\sigma}\right)^{\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}}\\&\times\left(\left(\frac{1+\chi}{k-\sigma+1}\right)^{\frac{1}{k}}(\sigma-1)\right)^{\frac{1}{1-\alpha(1-\eta)}}<0\end{aligned} \tag{A.122}$$

$$\begin{aligned}\frac{\partial Y}{\partial \chi}&=\left[\frac{1}{k-\sigma+1+\gamma^l k(\sigma-1)}\right]^{\frac{k(\sigma-1)(1-\alpha(1-\eta))+k-\sigma+1}{k(\sigma-1)(1-\alpha(1-\eta))}}[Nk]^{\frac{(\sigma-1)(1-\alpha(1-\eta))+1}{(\sigma-1)(1-\alpha(1-\eta))}}\left(\frac{1}{t\sigma}\right)^{\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}}\left(\left(\frac{1+\chi}{k-\sigma+1}\right)^{\frac{1}{k}}(\sigma-1)\right)^{\frac{1}{1-\alpha(1-\eta)}}\\&\times\left[\frac{[k(\sigma-1)(1-\alpha(1-\eta))+(k-\sigma+1)](k-\sigma+1)(1-\alpha)(1-\eta)\chi^{\frac{k-\sigma+1}{k}-1}+[k(\sigma-1)(1-\alpha(1-\eta))+(k-\sigma+1)]k(\gamma^l-\eta)+k-\sigma+1+\gamma^l k(\sigma-1)}{k(1+\chi)(1-\alpha(1-\eta))[k-\sigma+1+\gamma^l k(\sigma-1)]}\right]\\&>0\end{aligned} \tag{A.123}$$

Similar to source country wage rate, after tedious calculations we can show that the negative direct effect dominates the positive indirect effect for all $\chi\in(0,1)$, hence $dY/dt<0$.

A.22 Derivation of the effect on aggregate income

Since we have shown that $\frac{dY}{dt} < 0$ and together with $\frac{\partial \gamma^e}{\partial \chi} < 0$ and $\frac{\partial \gamma^l}{\partial \chi} < 0$ we can state that aggregate income decreases in source country emission tax rate: $\frac{dI}{dt} < 0$.

$\gamma^l + \gamma^e = \gamma$. Inserting Y:

$$I = \left[\frac{1}{\sigma} + \gamma \frac{\sigma - 1}{\sigma}\right] \sigma \left[M(1+\chi)\frac{k}{k-\sigma+1}\right]^{\frac{(\sigma-1)(1-\alpha(1-\eta))+1}{(\sigma-1)(1-\alpha(1-\eta))}} \left[\frac{1}{t}\right]^{\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}} \left[\frac{\sigma-1}{\sigma}\varphi^d\right]^{\frac{1}{1-\alpha(1-\eta)}} \tag{A.124}$$

$$I = [1+\gamma(\sigma-1)] \left[\frac{k}{(k-\sigma+1+\gamma^l k(\sigma-1))}\right]^{\frac{(\sigma-1)(1-\alpha(1-\eta))+1}{(\sigma-1)(1-\alpha(1-\eta))}} \left[\frac{1}{t}\right]^{\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}} \left[\frac{\sigma-1}{\sigma}\left[\frac{(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]}{k-\sigma+1}\right]^{\frac{1}{k}}\right]^{\frac{}{1-}} \tag{A.125}$$

Doing comparative statics with respect to t we find:

$$\frac{dI}{dt} = \underbrace{\frac{\partial I}{\partial t}}_{<0} + \underbrace{\frac{\partial I}{\partial \chi}}_{\gtreqless 0} \underbrace{\frac{d\chi}{dt}}_{>0} \tag{A.126}$$

The direct effect of t is rather obvious since an increase in the source country emission tax rates makes production (i.e. emission generation) more expensive and firms shift away from production to abatement efforts which decreases output. The indirect effect via the share of offshoring is derived below.

A.23 Derivation of the effect on between-country inequality

We make use of Eqs. (A.26) and (A.31), which show the two countries' wage rates and the income share of workers, as well as (A.110) on aggregate emissions and the income share of the emissions tax revenues:

$$\Xi = \frac{\gamma^l \frac{\sigma-1}{\sigma} \frac{k-\sigma+1+\gamma^l k(\sigma-1)}{\gamma^l k(\sigma-1)} \frac{Y}{N} + \frac{\gamma^e \frac{\sigma-1}{\sigma} Y}{N}}{\gamma^{l*} \frac{\sigma-1}{\sigma} \frac{Y}{N^*} + \frac{\gamma^{e*} \frac{\sigma-1}{\sigma} Y}{N^*}}. \tag{A.127}$$

For convenience, we define $\gamma \equiv \gamma^e + \gamma^l$ and $1 - \gamma \equiv \gamma^{e*} + \gamma^{l*}$, where we know $\partial\gamma/\partial\chi < 0$. We end at:

$$\Xi = \frac{N^*}{N} \frac{(k-\sigma+1) + \gamma k(\sigma-1)}{k(\sigma-1)(1-\gamma)} \tag{A.128}$$

Analysing the effect of an increase in t we get:

$$\frac{d\Xi}{dt} = \underbrace{\frac{\partial \Xi}{\partial \gamma}}_{>0} \underbrace{\frac{\partial \gamma}{\partial \chi}}_{<0} \underbrace{\frac{d\chi}{dt}}_{>0} < 0 \tag{A.129}$$

A.24 Source Country Inequality

Using our solutions for average profits, wage and transfer, in closed form we get:

$$\Theta = \frac{\frac{k}{k-\sigma+1}(1+\chi)\pi^d(\varphi^d) - \chi\pi^d(\varphi^d) + \frac{k}{k-\sigma+1}(1+\chi)\pi^d(\varphi^d)\frac{(k-\sigma+1)N}{(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]}\frac{1}{N}\gamma^e(\sigma-1)}{\pi^d(\varphi^d) + \frac{k}{k-\sigma+1}(1+\chi)\pi^d(\varphi^d)\frac{(k-\sigma+1)N}{(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]}\frac{1}{N}\gamma^e(\sigma-1)} \tag{A.130}$$

We can cancel out $\pi^d(\varphi^d)$ and some terms in b:

$$\Theta = \frac{\frac{k+\chi(\sigma-1)}{k-\sigma+1} + \frac{\gamma^e k(\sigma-1)}{[k-\sigma+1+\gamma^l k(\sigma-1)]}}{1 + \frac{\gamma^e k(\sigma-1)}{[k-\sigma+1+\gamma^l k(\sigma-1)]}} \tag{A.131}$$

$$\Theta = \frac{[k+\chi(\sigma-1)][k-\sigma+1+\gamma^l k(\sigma-1)] + \gamma^e k(\sigma-1)(k-\sigma+1)}{(k-\sigma+1)[k-\sigma+1+\gamma^e k(\sigma-1)+\gamma^l k(\sigma-1)]} \tag{A.132}$$

Since we do have the transfer on both levels, a constant at denominator and a term which depends positively on χ we can easily confirm that inter-group Inequality is increasing with χ.

$$\frac{d\Theta}{dt} = \underbrace{\frac{\partial\Theta}{\partial\chi}}_{>0}\underbrace{\frac{d\chi}{dt}}_{>0} > 0 \tag{A.133}$$

A.24.1 Lorenz Curve

We calculate the Lorenz curve. It consists of three parts:

$$Q(\mu;\chi) \equiv \begin{cases} Q_1(\mu;\chi) & \text{if} \quad \mu \in [0, b_1(\chi)) \\ Q_2(\mu;\chi) & \text{if} \quad \mu \in [b_1(\chi), b_2(\chi)) \\ Q_3(\mu;\chi) & \text{if} \quad \mu \in [b_2(\chi), 1]. \end{cases} \tag{A.134}$$

The first part of the curve includes (non-)production workers only. Their income share is given by:

$$\frac{I_1}{I} = \frac{wL + w\chi M + bL + b\chi M}{wL + \bar{\pi}M + bN} \tag{A.135}$$

The first segment of the curve:

$$Q_1 = \frac{\gamma^e k(\sigma-1) + \gamma^l k(\sigma-1) + (k-\sigma+1)}{\gamma^l k(\sigma-1) + k + \gamma^e k(\sigma-1)}\mu \tag{A.136}$$

The share of population is given by:

$$b_1(\chi) = 1 - \frac{M}{N} = \left(\frac{(1+\chi)\gamma^l k(\sigma-1) + \chi(k-\sigma+1)}{(1+\chi)[(k-\sigma+1)+\gamma^l k(\sigma-1)]}\right) \tag{A.137}$$

To get the second part we add income of non-offshorers to $Q_1(b_1)$. Individuals earning less than or equal $\pi(\bar{\varphi}), \bar{\varphi} \in [\varphi^d, \varphi^o)$ receive:

$$\frac{I_2}{I} = \frac{\Pi(\bar{\varphi}) + bM(\bar{\varphi})}{wL + \bar{\pi}M + bN} \tag{A.138}$$

The second segment of the curve is given by:

$$Q_2(\mu,\chi) = \frac{[(1+\chi)\gamma^l k(\sigma-1) + \chi(k-\sigma+1)] + k\left[1 - \left[[1-\mu]\frac{(1+\chi)[(k-\sigma+1)+\gamma^l k(\sigma-1)]}{(k-\sigma+1)}\right]^{\frac{k-\sigma+1}{k}}\right] + \mu(1+\chi)\gamma^e k(\sigma-1)}{[\gamma^l k(\sigma-1) + k + \gamma^e k(\sigma-1)](1+\chi)} \tag{A.139}$$

The share of all individuals except owners of offshoring firms relative to the total population is equal to:

$$b_2(\chi) = \frac{N - \chi M}{N} = \frac{(1+\chi)\gamma^l k(\sigma-1) + k - \sigma + 1}{(1+\chi)[k - \sigma + 1 + \gamma^l k(\sigma-1)]} \tag{A.140}$$

To get the third part we add income of all offshoring firms to the previous parts: firms with productivity up to $\bar{\varphi} \in [\varphi^o, \infty)$

$$\frac{I_3}{I} = \frac{\Pi(\bar{\varphi}) - w(M(\bar{\varphi}) - M(\varphi^o)) + b(M(\bar{\varphi}) - M(\varphi^o))}{wL + \bar{\pi}M + bN} \tag{A.141}$$

The third part of curve is given by:

$$Q_3(\mu,\chi) = \frac{(1+\chi)[k + \gamma^l k(\sigma-1) + \gamma^e k(\sigma-1)] - k(1+\chi^{\frac{\sigma+1}{k}})\left[\left((1-\mu)\frac{(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1)]}{(k-\sigma+1)}\right)^{\frac{k-\sigma+1}{k}}\right] + (1-\mu)(1+\chi)[k-\sigma+1+\gamma^l k(\sigma-1) - \gamma^e k(\sigma-1)]}{[\gamma^l k(\sigma+1) + k + \gamma^e k(\sigma-1)](1+\chi)} \tag{A.142}$$

Figure 2 depicts the source country's Lorenz Curve for each share μ of the population. The Lorenz Curve in the Open Economy ($\chi > 0$) is based on the derived income segments Q_1, Q_2 and Q_3 for workers, managers of purely domestic firms and managers of offshoring firms, respectively. Note that the Lorenz Curve in Autarky only consists of two segments, as the income segment Q_3 for offshoring managers collapses to zero at $\chi = 0$.

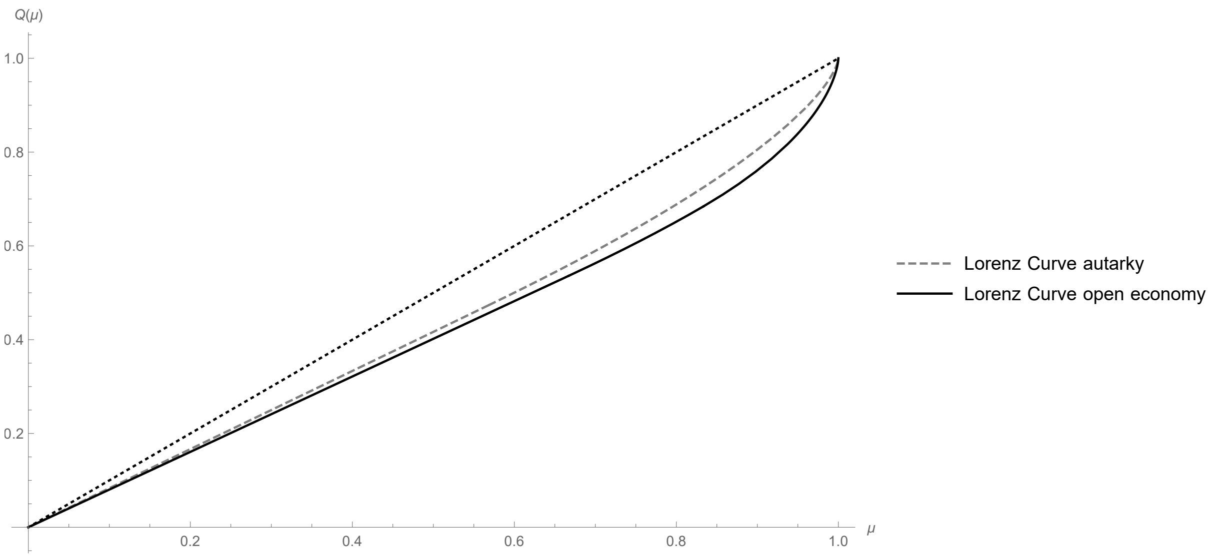

Figure 2: Source Country Lorenz Curve in Autarky and in the Open Economy

Note: The assumed parameter values are $\sigma = 2$, $k = 3$, $\alpha = 0.3$, $\eta = 0.6$, $(N/N^*) = 1$, with $\chi = 0$ under autarky and $\chi = 0.5$ in the open economy.

It can be easily seen that inequality in the source country with offshoring is strictly larger than under autarky.

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S Online Appendix

Online Appendix for

Offshoring and Environmental Policy:
Firm Selection and Distributional Effects

by Simon J. Bolz, Fabrice Naumann, and Philipp M. Richter
February 28, 2023

S.1 Autarky

production technology is identical to open economy hence optimization leads to the same cost function as a domestic firm

$$c_a = \left[y(v) \frac{w}{\alpha} \left(\left(\frac{t}{w} \right)^{\alpha} \right)^{1-\eta} \right] \tag{S.1}$$

$$p_a = \frac{\sigma}{\sigma - 1} \frac{w}{\varphi} \left(\left(\frac{t}{w} \right)^{\alpha} \right)^{1-\eta} \tag{S.2}$$

Occupational choice

$$\pi_a(\varphi^d) = w \tag{S.3}$$

$$\bar{\pi}_a = \pi_a(\varphi^d) \frac{k}{k - \sigma + 1} \tag{S.4}$$

using $Y/M = \sigma\bar{\pi}$ to solve for RHS in marginal firm indifference condition

$$\pi_a(\varphi^d) = \frac{k - \sigma + 1}{k} \frac{1}{\sigma} \frac{Y_a}{M_a} \tag{S.5}$$

wage income is a constant fraction $\frac{\sigma-1}{\sigma}(1 - \alpha(1 - \eta))$ of firms revenue

$$w_a L_a = \frac{\sigma - 1}{\sigma}(1 - \alpha(1 - \eta))Y_a \tag{S.6}$$

using (S.5) and (S.6) in (S.3) to solve for L

$$L_a = \frac{k(\sigma - 1)}{k - \sigma + 1}(1 - \alpha(1 - \eta))M_a \tag{S.7}$$

resource constraint

$$L_a = N - M_a \tag{S.8}$$

combine both to get equilibrium factor allocation

$$L_a = \frac{k(\sigma - 1)(1 - \alpha(1 - \eta))}{k - \sigma + 1 + k(\sigma - 1)(1 - \alpha(1 - \eta))} N \tag{S.9}$$

$$M_a = \frac{k - \sigma + 1}{k - \sigma + 1 + k(\sigma - 1)(1 - \alpha(1 - \eta))} N \tag{S.10}$$

using $M_a = (1 - G(\varphi^d))N$ we get the cutoff productivity of the marginal firm

$$\varphi_a^d = \left[\frac{k - \sigma + 1 + k(\sigma - 1)(1 - \alpha(1 - \eta))}{(k - \sigma + 1)} \right]^{\frac{1}{k}} \tag{S.11}$$

Aggregate Emissions

$$t_a E_a = Y_a \frac{\sigma-1}{\sigma} \alpha(1-\eta) \tag{S.12}$$

To get a closed form solution we must derive Y. We start with $Y = M^{\frac{\sigma}{\sigma-1}} q(\bar{\varphi})$. We can use pareto and insert $q(\bar{\varphi}) = (\frac{\bar{\varphi}}{\varphi^d})^{\sigma} q(\varphi^d)$. Solve it for $q(\varphi^d)$ and insert into $q(\varphi^d) = Y/Pp^{-\sigma}/P$ with $P = 1$.

$$\frac{Y}{M^{\frac{\sigma}{\sigma-1}}} \left(\frac{\bar{\varphi}}{\varphi^d}\right)^{-\sigma} = Yp(\varphi^d)^{-\sigma} \tag{S.13}$$

Solve it for the price and insert the price equation

$$\frac{\sigma}{\sigma-1} \frac{w}{\varphi^d} \left(\left(\frac{t}{w}\right)^{\alpha}\right)^{1-\eta} = \left(\frac{\bar{\varphi}}{\varphi^d}\right) M^{\frac{1}{\sigma-1}} \tag{S.14}$$

We can now use pareto for average productivity

$$\frac{\sigma}{\sigma-1} \frac{w}{\varphi^d} \left(\left(\frac{t}{w}\right)^{\alpha}\right)^{1-\eta} = \left(\frac{k}{k-\sigma+1}\right)^{\frac{1}{\sigma-1}} M^{\frac{1}{\sigma-1}} \tag{S.15}$$

Next, we solve it for the wage rate

$$w = \left[\frac{\sigma-1}{\sigma} \varphi^d \left(M \frac{k}{k-\sigma+1}\right)^{\frac{1}{\sigma-1}} \left(\frac{1}{t}\right)^{\alpha(1-\eta)}\right]^{\frac{1}{1-\alpha(1-\eta)}} \tag{S.16}$$

We now use the marginal firm indifference condition (S.3) and insert the profits of the marginal firm into (S.5). Solve it for Y:

$$Y_a = \left[\frac{\sigma-1}{\sigma} \varphi^d \left(M \frac{k}{k-\sigma+1}\right)^{\frac{1}{\sigma-1}} \left(\frac{1}{t}\right)^{\alpha(1-\eta)}\right]^{\frac{1}{1-\alpha(1-\eta)}} M \frac{k}{k-\sigma+1} \sigma \tag{S.17}$$

$$Y_a = \sigma \left[M \frac{k}{k-\sigma+1}\right]^{\frac{(\sigma-1)(1-\alpha(1-\eta))+1}{(\sigma-1)(1-\alpha(1-\eta))}} \left[\frac{1}{t}\right]^{\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}} \left[\frac{\sigma-1}{\sigma} \varphi^d\right]^{\frac{1}{1-\alpha(1-\eta)}} \tag{S.18}$$

Use it in aggregate emissions

$$E_a = (\sigma-1)\alpha(1-\eta) \left[M \frac{k}{k-\sigma+1}\right]^{\frac{(\sigma-1)(1-\alpha(1-\eta))+1}{(\sigma-1)(1-\alpha(1-\eta))}} \left[\frac{1}{t} \frac{\sigma-1}{\sigma} \varphi^d\right]^{\frac{1}{1-\alpha(1-\eta)}} \tag{S.19}$$

S.1.1 Autarky - Comparative Statics

$$\frac{\partial Y_a}{\partial t} = \sigma \left[M \frac{k}{k-\sigma+1}\right]^{\frac{(\sigma-1)(1-\alpha(1-\eta))+1}{(\sigma-1)(1-\alpha(1-\eta))}} \left(-\frac{1}{t^2}\right) \frac{\alpha(1-\eta)}{1-\alpha(1-\eta)} \left[\frac{1}{t}\right]^{\frac{\alpha(1-\eta)}{1-\alpha(1-\eta)}-1} \left[\frac{\sigma-1}{\sigma} \varphi^d\right]^{\frac{1}{1-\alpha(1-\eta)}} < 0 \tag{S.20}$$

A change of emission tax affects the aggregate emissions:

$$\frac{\partial E_a}{\partial t} = -\frac{1}{1-\alpha(1-\eta)} \left(\frac{1}{t}\right)^{\frac{1}{1-\alpha(1-\eta)}-1} (\sigma-1)\alpha(1-\eta) \left[M \frac{k}{k-\sigma+1}\right]^{\frac{(\sigma-1)(1-\alpha(1-\eta))+1}{(\sigma-1)(1-\alpha(1-\eta))}} \left[\frac{\sigma-1}{\sigma} \varphi^d\right]^{\frac{1}{1-\alpha(1-\eta)}} < 0 \tag{S.21}$$

S.2 Comparative Statics: Change in transport costs τ

S.2.1 Effects on offshoring

To model marginal trade liberalization we look at effects of a change in the variable transport costs τ. For that, we have to solve

$$\frac{d\chi}{d\tau} = -\frac{\partial F/\partial \tau}{\partial F/\partial \chi}. \tag{S.22}$$

The effect of τ is:

$$\begin{aligned}\frac{\partial F}{\partial \tau} &= (1-\eta)\left(\frac{1}{\tau}\left(\frac{t}{t^*}\right)^{\alpha}\left(\frac{(k-\sigma+1)+\gamma^l k(\sigma-1)}{1-\gamma^l-\alpha(1-\eta)}\frac{N^*}{N}\right)^{1-\alpha}\right)^{-\eta} \\ &\times\left(-\left(\frac{t}{t^*}\right)^{\alpha}\left(\frac{(k-\sigma+1)+\gamma^l k(\sigma-1)}{1-\gamma^l-\alpha(1-\eta)}\frac{N^*}{N}\right)^{1-\alpha}\right)\frac{1}{\tau^2} < 0\end{aligned} \tag{S.23}$$

Inserted jointly with (A.38) into (S.22) our total effect is:

$$\frac{d\chi}{d\tau} = -\underbrace{\frac{\partial F/\partial \tau}{\partial F/\partial \chi}}_{\frac{\leq 0}{<0}} < 0. \tag{S.24}$$

Accordingly, an increase of the variable transport costs reduces the marginal cost savings factor for every level of offshoring making offshoring less attractive.

S.2.2 Factor allocation

$$\frac{dM}{d\tau} = \underbrace{\left[\underbrace{\frac{\partial M}{\partial \chi}}_{<0} + \underbrace{\frac{\partial M}{\partial \gamma^l}}_{<0}\underbrace{\frac{\partial \gamma^l}{\partial \chi}}_{<0}\right]}_{\gtrless 0}\underbrace{\frac{d\chi}{d\tau}}_{<0} \tag{S.25}$$

For low levels of χ, an increase in τ leads to a decrease in the mass of managers in the source country and vice versa if we have high levels of offshoring.

$$\frac{dL}{d\tau} = \underbrace{\left[\frac{\partial L}{\partial \gamma^l}\frac{\partial \gamma^l}{\partial \chi}\right]}_{<0}\underbrace{\frac{d\chi}{d\tau}}_{<0} > 0 \tag{S.26}$$

An increase in τ leads to an increase in the mass of workers. A higher τ makes offshoring less attractive leading to higher labor demand in the source country which increases the mass of workers in the source country.

$$\frac{d\Xi}{d\tau} = \underbrace{\frac{\partial \Xi}{\partial \gamma}}_{>0}\underbrace{\frac{\partial \gamma}{\partial \chi}}_{<0}\underbrace{\frac{d\chi}{d\tau}}_{<0} > 0 \tag{S.27}$$

S.3 Comparative Statics: Change host country's emissions tax t^*

S.3.1 Effects on offshoring

Finally, we analyse the effect on the foreign country's emissions tax on the share of offshoring firms:

$$\frac{d\chi}{dt^*} = -\frac{\partial F/\partial t^*}{\partial F/\partial \chi} \tag{S.28}$$

$$\begin{aligned} \frac{\partial F}{\partial t^*} &= (1-\eta)\left(\frac{1}{\tau}\left(\frac{t}{t^*}\right)^{\alpha}\left(\frac{(k-\sigma+1)+\gamma^l k(\sigma-1)}{1-\gamma^l-\alpha(1-\eta)}\frac{N^*}{N}\right)^{1-\alpha}\right)^{-\eta} \\ &\times \frac{1}{\tau}\left(\frac{(k-\sigma+1)+\gamma^l k(\sigma-1)}{1-\gamma^l-\alpha(1-\eta)}\frac{N^*}{N}\right)^{1-\alpha}\alpha\left(\frac{t}{t^*}\right)^{\alpha-1}\left(-\frac{t}{t^{*2}}\right) < 0. \end{aligned} \tag{S.29}$$

We already know $\partial F/\partial \chi$, hence:

$$\frac{d\chi}{dt^*} = -\underbrace{\frac{\partial F/\partial t^*}{\partial F/\partial \chi}}_{\frac{\leq 0}{<0}} < 0 \tag{S.30}$$

An increase of the host country emission tax increases the cost of production in the host country and therefore decreases the marginal cost savings factor making offshoring less attractive. It is intuitive that host country emission tax rate and transport costs are going in the same direction when it comes to their effect on the share of offshoring firms, since they make offshoring production more costly relative to source country production. They shift the $\kappa - \chi$-function B (16) downwards. The source country emission tax rate acts in the opposite direction and shifts B upwards.

S.3.2 Factor allocation

$$\frac{dM}{dt^*} = \underbrace{\left[\underbrace{\frac{\partial M}{\partial \chi}}_{<0} + \underbrace{\frac{\partial M}{\partial \gamma^l}}_{<0}\underbrace{\frac{\partial \gamma^l}{\partial \chi}}_{<0}\right]}_{\gtrless 0}\underbrace{\frac{d\chi}{dt^*}}_{<0} \tag{S.31}$$

For low levels of χ, an increase in the host country's emissions tax leads to a decrease in the mass of managers in the source country and vice versa if we have high levels of offshoring.

$$\frac{dL}{dt^*} = \underbrace{\left[\frac{\partial L}{\partial \gamma^l}\frac{\partial \gamma^l}{\partial \chi}\right]}_{<0}\underbrace{\frac{d\chi}{dt^*}}_{<0} > 0 \tag{S.32}$$

$$\frac{\partial \frac{E}{E^*}}{\partial t^*} = \underbrace{\frac{\partial \frac{E}{E^*}}{\partial t^*}}_{>0} + \underbrace{\frac{\partial \frac{E}{E^*}}{\partial \chi}}_{<0}\underbrace{\frac{d\chi}{dt^*}}_{<0} > 0 \tag{S.33}$$