INTERNAL CARBON PRICING IN THE MULTIDIVISIONAL FIRM

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Internal Carbon Pricing in the Multidivisional Firm*

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Abstract

In response to environmental concerns, big corporations, which largely allocate resources through so-called 'internal markets', often seek to have the associated internal (or transfer) prices incorporate their social cost of pollution. We develop a theoretical rationale and framework to analyze this phenomenon. Our model involves two vertically related subsidiaries located in different jurisdictions. We examine how transfer prices would convey the mandatory carbon fares holding in each jurisdiction, consider the impact on each subsidiary's production and emissions abatement, and point out the ramifications for the organization of the firm and public policy. Thereby, we also capture how the firm's internal carbon pricing interacts with fiscal compliance. Through transfer pricing, finally, a carbon fare in one jurisdiction can have an incidence on the other jurisdiction's subsidiary; implications for environmental governance are briefly discussed.

Keywords: Greening value chains; Firm internal markets failures; Transfer pricing; Fiscal compliance and the environment; environmental governance

JEL Codes: D21, M21, Q53

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Most production in modern economies occurs within organizations, and this production is regulated only to a limited extent by [market] prices. (Stiglitz, 1991, p.15)

[Market] Carbon pricing by itself may not be sufficient to induce change at the pace and on the scale required for the Paris target to be met, and may need to be complemented by other well-designed policies tackling various market and government failures, as well as other imperfections. (Stern and Stiglitz, 2017, p.3)

1 Introduction

Economists attribute the depletion of environmental resources primarily to market failures. As Stiglitz (1991) and Stern and Stiglitz (2017) have observed, though, natural resources are allocated not only through markets, but also within organizations, and the latter too are subject to malfunction. Numerous stylized facts and case studies tend indeed to corroborate organizational failures. Wright and Nyberg (2017)'s five cases, for instance, show companies struggling to integrate climate change considerations into business-as-usual practices. DeCanio (1993, 1998), Reinhardt (2000), Johnstone (2007), and the empirical literature on the Porter Hypothesis (covered notably by Ambec and Lanoie, 2008) provide further evidence of firms' inefficiencies in managing natural capital.

Since the 1990s, many researchers have thus been also looking at some organizational remedies which, together with the appropriate market ones, could help overcome environmental externalities (surveys of earlier contributions include Gabel and Sinclair-Desgagné, 2000; Johnstone, 2007). One such organizational remedy, mentioned early on by Gabel and Sinclair-Desgagné (1994), has to do with the internal - so-called 'transfer' - prices which apply to transactions between subsidiaries in multidivisional firms. In response to more stringent public policies and growing social demands, large corporations are indeed relying increasingly on this instrument, adjusting internal prices (as public policy makers do with market prices) so they incorporate the social cost of greenhouse gases emissions (Aldy & Gianfrate, 2019). Since 2012, for example, Microsoft sets an internal carbon fee on transactions between its departments which holds across more than 100 countries. Thanks to imposing a 5 US$ charge per tCO_2 on its business groups' operating expenses (targeting travel emissions, the energy consumption of datacenters, etc.), the company succeeded in the first three years to reduce its CO2 emissions by 7.5 million metric tons (DiCaprio, 2015). Similarly, Ben & Jerry's applies a carbon fee across its value chain to incentivize emissions-reducing projects. In response, its dairy suppliers have been led to develop new technologies for the management of manure, which initially accounted for 42% of their overall carbon footprint (Chang, 2017). All in all, the Carbon Disclosure Project reports that, as of 2017, more than 1,200 companies had adopted an internal carbon pricing strategy or were planning to do so (CDP, 2016). This paper's raison d'être is to analyze, from an applied economic theory standpoint, this rapidly spreading practice.

How would a multidivisional firm then amend its internal prices in response to external pressures to deal with climate change? And what are the implications for the environment, the firm's organization, public policy, and environmental governance? We begin addressing these questions using a stylized model involving two vertically related firm subsidiaries located in separate jurisdictions. We first show that the internal carbon price will be a weighted sum of the jurisdictions' respective carbon fares, the weights being functions of the respective taxes on profit. This result highlights the trade-off that goes on in corporations between fiscal and environmental compliance. It also constitutes a straightforward validation of the above Stiglitz quote: indeed, the subsidiaries' managers will not make decisions based on external (market) emissions taxes but rather on these taxes' translation in the 'green' transfer price. The exercise next conveys insights on the amount of coordination that should take place within corporations between tax accountants (who set transfer prices to minimize the taxes paid on profit) and people implementing environmental strategy (who seek to reduce the firm's carbon footprint): our results suggest that the profit-maximizing firm may let these employees work independently only under specific conditions. We finally examine the impact of internal carbon pricing on the firm's overall production and the subsidiaries' respective emissions and abatement effort. Our results have implications for the carbon tax that will be set in each jurisdiction, which we successively study assuming that jurisdictions do not cooperate and assuming that they do. A consistent upshot is that fiscal discrepancies make carbon fares less effective; this constitutes an additional argument for the harmonization of fiscal policies across jurisdictions. The analysis finally draws attention to the diffusion, via transfer prices, of local environmental regulations across jurisdictions; we briefly discuss the implications for global environmental governance.

The paper unfolds as follows. The related literature is reviewed, and our specific contribution further delineated, in Section 2. Section 3 develops a benchmark model. This model is put to work in section 4, where we show how carbon fares would be incorporated into transfer prices, along with taxes on profit. Section 5 explores the impact of such modified transfer prices on the subsidiaries' respective production and polluting emissions, under every fiscal scenarios. Section 6 considers two direct extensions from the benchmark model: one is the emissions tax that will be respectively set by each jurisdiction under competition or cooperation, the other is the case where subsidiaries can expend effort on pollution abatement. Section 7 checks the robustness of the benchmark model's implications to amending the assumed vertical structure, changing the timing of abatement decisions, or allowing other market structures. Section 8 contains concluding remarks – particularly on the diffusion of local carbon fares across jurisdictions, owing to the multidivisional firm's internal carbon pricing – and sketches some directions for future research.

2 Related literature

There is a fast-growing literature on internal carbon pricing (ICP). Contributions include descriptions and assessments of current practices (for a recent account from an empirical perspective, see Gorbach et al., 2022; Hansen, 2023), empirical analyses of the internal and external drivers/incentives for firms to implement ICP (Bento & Gianfrate, 2020; Chang, 2017; Trinks et al., 2022), and appraisals of ICP's impact on the firm's environmental performance (Zhu et al., 2022) or financial results (Ma & Kuo, 2021). We add to these respective streams a theoretical framework for developing and assessing the use of ICP. In their article, Ma and Kuo (2021) also proposed a theoretical account of ICP in which the firm is modelled as a production function. Our approach is complementary to theirs, in the sense that it explicitly acknowledges the firm's internal structure and transactions between subsidiaries.

This paper primarily builds on the vast literature on firms' internal markets and transfer pricing.[1] In this literature, the central role ascribed to transfer pricing is to reduce a corporation's overall taxes on profits (Beer et al., 2020; Clausing, 2003; Cristea & Nguyen, 2016; Davies et al., 2018). This has raised a number of research and policy issues. A prominent one, as expected, is international taxation and the regulation of profit shifting (Brauner, 2020; Zinn et al., 2014). Dealing with the matter has lead to consider, notably, international tax competition and coordination (Choi et al., 2020; Keen & Konrad, 2013), geographic arbitrage and multinationals' location decisions (Kato & Okoshi, 2022), cross border licensing (Choi et al., 2024), and especially some principles, rules and guidelines for establishing transfer prices (Lang et al., 2019; OECD, 2022a).[2] Another key set of issues has to do with corporate management: for instance, the firm's organizational structure (see, e.g., Baldenius et al., 2004; Bond, 1980; Holmstrom and Tirole, 1991), competitive strategy (Göx, 2000; Matsui, 2011; Narayanan & Smith, 2000), or relationships with stakeholders (Baker et al., 2002; Shor & Chen, 2009). A few authors, finally, have considered the environmental impact of international taxation in the presence of transfer pricing. In a pioneering article, Fischer (2006) shows how differences in corporate taxation across countries might weigh on a multinational's allocation of abatement efforts and transfer of emissions permits across subsidiaries; to limit the ensuing inefficiency, she argues for "an international permit trading system with transparent, enforceable transfer-pricing rules." More recently, Pirlot (2014, 2020) successively illustrated some negative effects that international tax provisions can have on environmental protection, notably in the aviation sector, and discussed the opportunity of establishing 'green' transfer pricing rules. Our paper adds to these literature streams a theoretical study of transfer pricing as an instrument of the multidivisional firm's environmental strategy (to be modulated by fiscal compliance), and a first formal derivation of 'green' transfer prices

[1] See, e.g., Göx and Schiller (2006), Padhi (2019), and Kumar et al. (2021) for surveys.

[2] These guidelines, notably the so-called 'arm's length principle', are briefly discussed in the next section, as we lay out our modelling assumptions.

and their main attributes.

Another related research area is the one studying environmental regulation when it takes into account its impact on vertical production structures. In the presence of strategic international trade policy and intranational contractual relationships, Hamilton and Requate (2004) established that the optimal measure towards a polluting input under both quantity and price competition is the Pigouvian tax. Sugeta and Matsumoto (2007), on the other hand, compared the efficiency of an input tax on a monopolistic upstream division versus that of an emissions tax on a duopolistic downstream division; they found that the upstream division will price-discriminate less (more) as the input (emissions) tax increases. While these two contributions considered vertical structures respectively ruled by contractual or market relationships, we assume this time around that the vertical structure is governed by transfer pricing. And while they respectively took on key contextual elements such as strategic trade or market concentration, we emphasize fiscal policies. Some developments concerning emissions taxes are also shown in Section 6. It is beyond the scope of this paper, however, to provide a complete analysis of the emissions fare and tax on profit each jurisdiction should set. Yet, the present exercise should lay the ground for further studying the optimal emissions fares a multidivisional firm's subsidiaries adjusting to different fiscal regimes via transfer pricing would respectively face.[3]

An additional related stream is environmental taxation in the presence of other taxes (see, e.g., Bovenberg and de Mooij, 1994; Bovenberg and Goulder, 1996; Fullerton and Metcalf, 2001; Lai, 2013). Previous studies have considered the impact of (distortionary) labor and capital taxes on optimal pollution taxes, while modelling the firm as a production function. In this paper, the firm is a vertical structure, and local carbon fares are applied in the presence of taxes on profits.

This paper finally stands at the junction of the literatures on greening global value chains (e.g., Sinclair-Desgagné, 2013), international environmental agreements and cli-

[3]Throughout this paper, the term 'fare' can either refer to a tax, the equilibrium price on an emissions permit market on which the firm's subsidiary is a price-taker, or some fee resulting from a voluntary agreement between the regulator and the firm's subsidiary.

mate change policies (e.g., Marrouch and Chaudhuri, 2016; Ritz, 2022) and the diffusion of local regulations (e.g., Hale and Urpelainen, 2015). For tractability and clarity reasons, we overlook cross-border tariffs and strategic interactions between countries. Our analysis rather fits the situation of countries forming a free-trade zone; it would apply as well to a federal state or a group of cities in the same country. Throughout the paper we shall thus speak of multidivisional instead of multi- or trans- national firms. The aim is to highlight yet another channel - transfer pricing - by which environmental measures in one jurisdiction can impact production and emissions in other jurisdictions.

3 A benchmark model

Consider a multidivisional firm made of two subsidiaries or divisions. The upstream one U - the 'producer' - delivers a quantity q of an intermediate good at a unit cost c. This good is shipped to the downstream division D - the 'seller' - at a pre-established transfer price τ per unit.

As in Hirshleifer (1956)'s first canonical model, we assume that the upstream subsidiary is not subject to a capacity constraint and produces only for the downstream division.[4] Each unit of the intermediate good generates z_U units of emissions, so the producer's total emissions are given by $e_U = z_U \cdot q$. Let the jurisdiction in which the upstream subsidiary operates apply a tax rate s_U on profit and a fare t_U on polluting emissions. The producer's after-tax profit function π_U is then given by

$$\pi_U = (1 - s_U) \cdot [\tau - c - T_U] \cdot q, \tag{1}$$

where $T_U = z_U \cdot t_U$ stands for the upstream division's carbon fee.

The downstream subsidiary uses one unit of the intermediate good to supply one unit of the final good with constant marginal cost normalized at 0. It is a local monopoly in

[4] Hirshleifer (1956, p. 173) provides the following example of such a setting: "(...) imagine an integrated steel mill, with two divisions exchanging molten iron. Shipping excess iron out of the mill could involve high handling cost to the selling division, and purchasing iron outside could involve high reheating costs to the buying division so that trading on the external market might rationally occur only under very unusual conditions."

its jurisdiction, facing the linear inverse demand function $p(q) = a - q$.[5] Its activities (assembly, delivery, consumer services) also generate polluting emissions at rate z_D, so the overall pollution from selling q items is given by $e_D = z_D \cdot q$. Let the downstream jurisdiction tax profit at rate s_D and apply a carbon fare t_D. The seller's after-tax profit function π_D can be written as follows

$$\pi_D = (1 - s_D) \cdot [a - q - \tau - T_D] \cdot q \tag{2}$$

where $T_D = z_D \cdot t_D$ is the downstream subsidiary's carbon fee.

The multidivisional firm's overall after-tax profit function π is the sum of each division's after-tax profits, that is

$$\pi = (1 - s_D) \cdot [a - q - \tau - T_D] \cdot q + (1 - s_U) \cdot [\tau - c - T_U] \cdot q \tag{3}$$

As long as taxes on profit are different across jurisdictions, the transfer price τ will appear in the expression for π, hence figure explicitly as another decision variable in profit maximization.

This is of course a simplified account of how transfer pricing goes on in reality. Transfer prices are notably subject to national and supranational tax regulations. One key requirement, set forth by the OECD and applied across major free-trade areas such as the European Union, is the so-called 'Arm's Length Principle': prices in firms' internal markets should mirror the prices that independent trading enterprises would pay in an open market for similar products or services.[6] In practice, due to methodological and informational issues, this desideratum often takes the form of a wanted range rather than a single price (Holtzman & Nagel, 2014). One way to incorporate it in the present model would thus be to maximize the profit function shown in (3) subject to the following constraint on the transfer price τ:

$$\underline{\tau} \leq \tau \leq \underline{\underline{\tau}} \tag{4}$$

[5]More general market structures are allowed in Section 7.

[6]Further precisions about the Arm's Length Principle can be found in the Appendix.

where $\underline{\tau}$ and $\underline{\underline{\tau}}$ are the observed lowest and highest relevant market prices.

In the present setting, we submit that the difference between $\underline{\tau}$ and $\underline{\underline{\tau}}$ should be rather large, though. First, in agreement with the above modelling assumptions, there might be no market at all for the intermediate product or there might be a strong idiosyncratic technological relationship between the two divisions (Hirshleifer 1956, p. 173); this would make external comparisons quite approximate. Second, quoting Choi et al. (2020, p. 5)'s recent work: "Even if similar inputs are transacted in the market by other firms for different purposes, a firm may argue that the available inputs are not suitable to meet its specifications, (...) what constitutes a similar input may not be clear-cut and could be subject to dispute unless comparable inputs are identical." This argument should hold particularly strongly if the input is designed and made to meet the firm's specific environmental strategy (Pirlot, 2014). Third, as firms in free-trade areas (which is the case here) must usually comply with the same accounting standards, DeSimone (2016)'s empirical study of the EU reveals that the arm's length range of reported profits (which correlates with firms' latitude in transfer pricing) actually increases. For all these reasons, we will presume throughout this paper that the bracket set by expression (4) is big enough so these constraints never bind at an optimum and we can ignore corner conditions.

To further guarantee interior solutions to profit maximization, we will also posit that there is a limited fiscal gap between jurisdictions.

Assumption (limited fiscal gap). *The fiscal discrepancy between jurisdictions satisfies the inequality* $s_U - s_D < \frac{1-s_D}{2}$.

Empirically, this seems consistent with the fact that the worldwide statutory corporate income tax rate averages 23.45% in 2023, with a standard deviation of 8.97% across 232 countries (Enache, 2023).

The various outcomes to be considered below will be assumed to follow the timeline depicted in Fig. 1: taking each jurisdiction's respective profit tax rates s_D , s_U (or fiscal policy) and fares t_D, t_U on emissions (or environmental policy) as given, the multidivisional firm sets the transfer price τ, and the downstream subsidiary then selects the quantity q to be ordered from the upstream manufacturing division; the firm and its divisions finally receive their respective profits π, π_D , π_U.[7] Using backward induction, our analysis will start by computing the seller's selected quantity $q(\tau)$, then proceed with deriving the firm's optimal transfer price under given emissions fares and profit taxes.

Figure 1: The decisions timeline

4 Green transfer pricing - A closed-form expression

To begin with, let's consider, as a benchmark case, the customary situation where there are positive but different taxes on profit and no fares on polluting emissions, i.e. $s_D \neq s_U$ and $t_U = t_D = 0$.

The seller's optimal quantity at transfer price τ should satisfy the first-order condition

$$\frac{\partial \pi_D}{\partial q}|_{t_D=0} = (1 - s_D) \cdot (a - 2q - \tau) = 0 \ ,$$

which implies that $\overline{q} = \frac{a-\tau}{2}$. Taking this behavior into account, the multidivisional firm will in turn set a transfer price that meets the first-order condition

$$\frac{\partial \pi}{\partial \tau}|_{t_D=0} = \frac{\tau[(1 - s_D) - 2(1 - s_U)]}{2} - \frac{(1 - s_D)a - (1 - s_U)(a + c)}{2} = 0$$

[7]Having the quantity set instead at the firm's headquarters - which is the centralized case - is examined in Section 7.

Doing some algebra yields the following output and internal pricing expressions

$$\begin{cases} \overline{\tau} = \dfrac{(1-s_U)(a+c)-(1-s_D)a}{2(1-s_U)-(1-s_D)} \\ \overline{q} = \dfrac{a-\overline{\tau}}{2} = \dfrac{1}{2} \cdot \dfrac{(1-s_U)(a-c)}{2(1-s_U)-(1-s_D)} \end{cases} \tag{5}$$

One upshot of this exercise is that, since $\frac{\partial \overline{\tau}}{\partial s_D} > 0$, an increase of the tax on profit imposed by the downstream jurisdiction leads the multidivisional firm to raise its transfer price; on the other hand, since $\frac{\partial \overline{\tau}}{\partial s_U} < 0$, an increase of the tax on profit occurring in the upstream jurisdiction makes the firm decrease τ. This is consistent with one of the main prediction of the transfer pricing literature: a multidivisional firm will use transfer prices to shift revenue from higher-taxes to lower-taxes jurisdictions, thereby increasing its overall after-tax profit (Clausing, 2003; Cristea & Nguyen, 2016; Davies et al., 2018).

Suppose now that, in addition to taxing business profits, each jurisdiction raises a positive fare on polluting emissions.

Using expression (2), the first-order condition for the seller's quantity order is now

$$\frac{\partial \pi_D}{\partial q} = (1-s_D) \cdot (a - 2q - \tau - T_D) = 0$$

The seller thus reacts to the transfer price and the local carbon fare as follows:

$$\frac{\partial q}{\partial \tau} = \frac{\partial q}{\partial T_D} = -\frac{1}{2} < 0$$

Lemma. *The seller's ordered quantity decreases with a higher transfer price or a larger carbon fare in the downstream jurisdiction.*

And the firm's optimal transfer price must then satisfy the first-order condition

$$\frac{\partial \pi}{\partial \tau} = [(1-s_D)-(1-s_U)] \cdot \frac{a-\tau-T_D}{2} - (1-s_U) \cdot \frac{\tau-c-T_D}{2} = 0$$

The above equations yield the following production and transfer pricing formulas:

$$\begin{cases} \tau^* = \overline{\tau} + \dfrac{(1-s_U)(T_U - T_D) + (1-s_D)T_D}{2(1-s_U)-(1-s_D)} = \overline{\tau} + \dfrac{(s_U - s_D)T_D + (1-s_U)T_U}{2(1-s_U)-(1-s_D)} \\ q^* = \overline{q} - \dfrac{1}{2} \cdot \dfrac{(1-s_U)(T_D + T_U)}{2(1-s_U)-(1-s_D)} \end{cases} \tag{6}$$

Through their respective right-hand term, the latter expressions highlight the corrections that transfer prices and quantity orders will respectively incur, as the multidivisional firm wants its transfer pricing to internalize the emissions fares.

Formula (6) entails, moreover, that

$$\frac{\partial \tau^*}{\partial T_U} = \frac{1-s_U}{2(1-s_U)-(1-s_D)} > 0 \text{ and } \frac{\partial \tau^*}{\partial T_D} = \frac{s_U - s_D}{2(1-s_U)-(1-s_D)}$$

Note that the denominator $2(1-s_U)-(1-s_D)$ is positive by the above assumption. The transfer price will then always increase in the presence of an emissions tax applied to the producer. The outcome is not straightforward when considering a carbon fare in the downstream jurisdiction, though. These results are restated in the following central proposition.

Proposition 1.

(i) *Internal carbon pricing by the multidivisional firm leads to amend its current transfer prices according to formula (6), i.e. by adding those prices a weighted sum of the jurisdictions' emissions taxes, the weights being functions of the jurisdictions' taxes on profits.*

(ii) *The transfer price would increase following a larger upstream carbon fare. On the other hand, the impact on the transfer price of a change in the downstream carbon fare depends on the two jurisdictions' respective fiscal policy.*

In accordance with Stiglitz's quote which begins this paper, one can see here that emissions fares only imperfectly regulate the multidivisional firm's subsidiaries. The latter will actually behave, not according to the market or external fares the firm is facing, but rather according to the *internal* transfer prices they are presented. Whether these transfer prices, and the firm's ensuing production and total emissions, should go up or down depends not only on the social costs of pollution (which mandatory fares on emissions should somehow reflect), but also on the fiscal context which the multidivisional firm is facing.

Through transfer prices, the incidence of emissions fares on consumers is also mitigated by fiscal policies. Indeed, when the firm's subsidiaries are subject to some fares on their polluting emissions, formula (6) indicates that the market price of the firm's end-product increases by the amount

$$\frac{1 - s_U}{1 + s_D - 2s_U} \cdot \frac{(T_D + T_U)}{2}$$

When the two jurisdictions harbor different profit taxes (i.e. $s_D \neq s_U$), consumers will then pay a proportion of the emissions fares which depends not only on the elasticity of demand, but which also includes a positive factor $K(s_U, s_D) = \frac{1-s_U}{1+s_D-2s_U}$ based on these profit taxes. Since $\frac{\partial K}{\partial s_D} < 0$, this factor decreases with downstream profit taxes (but a greater s_D is actually passed on to consumers via the component $\overline{\tau}$ of the transfer price). As $\frac{\partial K}{\partial s_U} > 0$, a raise in upstream profit taxes makes the factor K bigger.

The next section will now discuss the firm's transfer prices and their impact on emissions under every fiscal scenario.

5 Fiscal scenarios

From formula (6), one cannot infer a definite relationship between carbon fares, transfer prices, the firm's production and total polluting emissions. Much actually depends on the jurisdictions' respective/relative fiscal policy, hence on the absolute rates s_D, s_U, and their divergence. This section will successively consider the three possible scenarios: (i) when profit taxes are the same across jurisdictions ($s_D = s_U$), (ii) when the seller's jurisdiction imposes relatively higher taxes on profit ($s_D > s_U$), and (iii) when a relatively more stringent fiscal policy holds in the producer's jurisdiction ($s_D < s_U$).

5.1 Both jurisdictions are fiscally similar

When $s_D = s_U$, formula (6) predicts that the multidivisional firm will set the transfer price at $\tau^* = \overline{\tau} + T_U = c + T_U$. The upstream jurisdiction's carbon fare T_U is then passed on entirely to the downstream subsidiary via τ^*. In other words, the selling division, which decides on the firm's output, will internalize the producer's emissions fare. This is consistent with a pure 'cost-based transfer pricing approach' (see, e.g., Hirshleifer 1956). It also corroborates some organizational practices regarding internal carbon pricing: when discrepancies in the fiscal landscape of the multidivisional firm do not exist (or are not taken into account), one way to go with ICP is to enforce on the firm's subsidiaries a fee based only on the social cost of carbon (as Microsoft actually does).

The derivatives of the transfer price regarding emissions fares are thus

$$\frac{\partial \tau^*}{\partial T_D} = 0 \quad \text{and} \quad \frac{\partial \tau^*}{\partial T_U} > 0$$

The transfer price will not be affected by the presence of an emissions fare applied to the downstream subsidiary. Furthermore, we have that

$$\frac{\partial e_i^*}{\partial t_j} = -\frac{1}{2} \cdot z_i^2 < 0 \quad \text{and} \quad \frac{\partial e_i^*}{\partial t_i} = -\frac{1}{2} \cdot z_i \cdot z_j < 0 \quad \text{for} \quad i, j = U, D$$

All this yields a first corollary to Proposition 1.

Corollary 1. *When profit tax rates are equal across jurisdictions,*

(i) *the firm's internal carbon price is the upstream jurisdiction's emissions fare.*

(ii) *the firm's internal carbon price will increase following a larger upstream carbon fare; it will not be affected by the downstream carbon fare.*

(iii) *a higher carbon fare in* ***any*** *jurisdiction leads to lower polluting emissions throughout the firm's supply chain.*

The upshot is that the downstream subsidiary's ordered quantity q^* will internalize the carbon fares over the entire vertical structure, since this subsidiary is already subject to the emissions fee T_D in its own jurisdiction.

Under similar fiscal policies, finally, the implementation of an internal carbon price makes a local carbon fare impact the whole supply chain, thereby reducing its overall environmental footprint. This agrees with some MNE's practices, as stated in their environmental reports on internal carbon pricing (e.g. Chang, 2017; DiCaprio, 2015).

5.2 The downstream jurisdiction is fiscally more stringent

Consider now the situation where $s_D > s_U$, so the seller's profits are taxed more heavily than the producer's ones in their respective jurisdictions.

From the above hypothesis, the firm's internal price of carbon, which is formula (6)'s additive correction term for the benchmark transfer price $\overline{\tau}$, has a positive denominator $2(1 - s_U) - (1 - s_D)$. This term's numerator has two components. One is the upstream jurisdiction's carbon fee T_U multiplied by a positive factor $(1 - s_U)$. As in the previous case, the firm thereby makes the seller internalize (yet partially, here) the carbon fare imposed on the producer. This scheme, however, is now tempered by the numerator's other component, $(s_U - s_D) \cdot T_D$, which is negative. The latter takes into account the fiscal gap $(s_U - s_D)$ between the two jurisdictions and the downstream jurisdiction's carbon fee T_D. With this second component, the firm has the fiscally-advantaged producer 'subsidize', so to speak, the 'overtaxed' seller by pushing down the former's revenue per unit made and shipped. This has two effects: first, it avoids having the seller reduce too much its quantity order in response to the emissions fare; second, the producer thereby internalizes the carbon fare set on the seller in proportion to its fiscal advantage. The derivatives from formula (6) are in line with this intuition:

$$\frac{\partial \tau^*}{\partial T_D} < 0 \quad \text{and} \quad \frac{\partial \tau^*}{\partial T_U} > 0$$

If the fiscal gap $(s_U - s_D)$ times the emissions fee T_D is big enough compared with $(1 - s_U) \cdot T_U$ (a trivial case being $T_U = 0$, so there is no fare on emissions in the upstream jurisdiction), the correction term will turn negative, rendering the resulting transfer price τ^* *smaller* than the benchmark one $\overline{\tau}$.

As formula (6) shows, moreover, whatever the transfer price, the qualitative effect of a larger carbon fare in *any* jurisdiction is still to bring all subsidiaries' emissions down since

$$\frac{\partial e_i^*}{\partial t_i} = -\frac{1}{2} \cdot \frac{(1-s_U)}{2(1-s_U)-(1-s_D)} \cdot z_i^2 < 0 \ \text{ and}$$
$$\frac{\partial e_i^*}{\partial t_j} = -\frac{1}{2} \cdot \frac{(1-s_U)}{2(1-s_U)-(1-s_D)} \cdot z_i \cdot z_j < 0 \ \text{ for } \ i,j = U,D$$

This discussion is summarized in the following corollary.

Corollary 2. *When the downstream jurisdiction applies a higher tax rate on profit,*

(i) *the firm's internal carbon price is proportional to the producer's carbon fare minus an adjustment for the producer's tax advantage. The internal carbon price will be negative if this adjustment - being the difference between profit taxation rates times the downstream jurisdiction's carbon fee - is big enough.*

(ii) *the firm's internal carbon price will increase following a larger upstream carbon fare; it will decrease following a larger downstream carbon fare.*

(iii) *a higher carbon fare in* ***any*** *jurisdiction leads to lower polluting emissions throughout the firm's supply chain.*

5.3 The upstream jurisdiction is fiscally more stringent

Finally, let $s_D < s_U$, so it is now the producer that faces higher taxes on profits.

In this case, the numerator in formula (6)'s correction term, $(s_U - s_D)T_D + (1-s_U) \cdot T_U$, is positive. The internal carbon price is then a weighted sum of the emissions taxes in *both* jurisdictions. Greater weight is given to the upstream jurisdiction's tax, and we have

$$\frac{\partial \tau^*}{\partial T_U} > \frac{\partial \tau^*}{\partial T_D} > 0$$

The expected relationship between emissions and emissions taxes holds, as shown by the following derivatives

$$\frac{\partial e_i^*}{\partial t_i} = -\frac{1}{2} \cdot \frac{(1-s_U)}{2(1-s_U)-(1-s_D)} \cdot z_i^2 < 0 \quad \text{and}$$
$$\frac{\partial e_i^*}{\partial t_j} = -\frac{1}{2} \cdot \frac{(1-s_U)}{2(1-s_U)-(1-s_D)} \cdot z_i \cdot z_j < 0 \quad \text{for} \quad i,j = U,D$$

This leads to a last corollary.

Corollary 3. *When the upstream jurisdiction applies a higher tax rate on profit,*

(i) *the firm's internal carbon price is proportional to the two jurisdictions' carbon fares.*

(ii) *the firm's internal carbon price gives more weight and is more sensitive to the upstream jurisdiction's emissions tax. Sensitivity to the downstream emissions tax increases with the fiscal gap.*

(iii) *a higher carbon fare in* ***any*** *jurisdiction leads to lower polluting emissions throughout the firm's supply chain.*

****

Due to fiscal discrepancies across jurisdictions, the firm's subsidiaries will again only imperfectly internalize their respective carbon fares. All in all, this section's results might provide an additional rationale - the effectiveness and efficiency of environmental policy, namely - for coordinating fiscal and environmental policies (see also Liu, 2013), and for fostering fiscal harmonization (as envisioned by the recent OECD International Tax Agreement).

6 Extensions

This section will now consider two immediate extensions of the above. First, we will look at the situation where both jurisdictions implement a carbon tax. This will have policy implications. Next, we will allow the firm's divisions to invest in pollution abatement. This will have organizational implications.

6.1 Endogenous emissions taxes

We successively consider the cases where the jurisdictions do not cooperate, and cooperate. It is assumed throughout that profits are taxed more heavily in the seller's jurisdiction, so $s_D > s_U$.[8]

Suppose that both regulators are benevolent, so they seek to maximize social welfare. In the upstream jurisdiction, the regulator's total revenue is $TR_U = s_U \cdot \frac{\pi_U}{1-s_U} + T_U \cdot q$, the producer's surplus is equal to π_U, the local consumer surplus is zero since all that is produced goes to the upstream division, and environmental damage is given by $ED_U = \psi_U \cdot e_{tot}^2$ where $e_{tot} = (z_U + z_D) \cdot q$. The upstream regulator's social welfare function is thus given by

$$\begin{aligned} W_U = \pi_U + TR_U - ED_U \\ \Leftrightarrow W_U = (\tau - c) \cdot q - \psi_U \cdot (z_U + z_D)^2 \cdot q^2 \end{aligned} \tag{7}$$

In the downstream jurisdiction, the regulator's total revenue is $TR_D = s_D \cdot \frac{\pi_D}{1-s_D} + T_D \cdot q$, the seller's surplus is its profit π_D, and the environmental damage is $ED_D = \psi_D \cdot e_{tot}^2$.[9] Consumer surplus is given by

$$CS = \int_0^q [P(Q) - P(q)] \cdot dQ = \frac{1}{2} \cdot q^2$$

The downstream regulators' social welfare function can then be written as

$$\begin{aligned} W_D = \pi_D + TR_D + CS - ED_D \\ \Leftrightarrow W_D = (a - q - \tau) \cdot q + \frac{1}{2} \cdot q^2 - \psi_D \cdot (z_U + z_D)^2 \cdot q^2 \end{aligned} \tag{8}$$

[8] Several stylized facts might support this assumption. For example, in its environmental strategy report, Renault Group - a French company operating in the car industry - stated they will engage the supply chain by implementing an internal carbon price (Renault Group, 2021). One of its downstream subsidiaries is Dacia Group, which sells self-branded cars in France. The upstream subsidiaries of Renault Group producing Dacia cars are based in Romania and Morocco. Romania is taxing less than France, and Morocco does not always apply a profit tax thanks to its industrial policy.

[9] While environmental damages must always depend on global emissions, this formulation allows such damages to differ locally.

The overall social welfare is then

$$W = W_U + W_D = (a - c) \cdot q - \frac{1}{2} \cdot [1 + (\psi_U + \psi_D)(z_U + z_D)^2] \cdot q^2 \tag{9}$$

6.1.1 The non-cooperative case

First, let both jurisdictions implement an emissions tax without cooperation. When an internal carbon price applies throughout the value chain, the upstream and downstream regulators will mutually adjust their emissions tax according to the following respective reaction functions

$$\begin{cases} R_U(t_D) = \dfrac{(1 - s_U)\psi_U(z_U + z_D)^2 + (1 - s_D)}{(1 - s_U)[2 + \psi_U(z_U + z_D)^2]z_U} \cdot (a - c - z_D \cdot t_D) \\ R_D(t_U) = \dfrac{(1 - s_U)[1 + 2\psi_D(z_U + z_D)^2] - 2(1 - s_D)}{[(1 - s_U)[5 + 2\psi_D(z_U + z_D)^2] - 4(1 - s_D)]z_D} \cdot (a - c - z_U \cdot t_U) \end{cases} \tag{10}$$

At equilibrium (where these reaction functions meet), the upstream and downstream emissions taxes are respectively

$$\begin{cases} t_U^* = \dfrac{2[(1 - s_U)\psi_U(z_U + z_D)^2 + (1 - s_D)]}{[(1 - s_U)[5 + 2(\psi_U + \psi_D)(z_U + z_D)^2] - 2(1 - s_D)]z_U} \cdot (a - c) \\ t_D^* = \dfrac{(1 - s_U)[1 + 2\psi_D(z_U + z_D)^2] - 2(1 - s_D)}{[(1 - s_U)[3 + 2(\psi_U - \psi_D)(z_U + z_D)^2] - 2(1 - s_D)]z_D} \cdot (a - c) \end{cases} \tag{11}$$

From these expressions, one may conclude that taking global value chains and their internal carbon prices into account in setting carbon taxes would make the latter differ across countries. This finding is stated as a proposition.

Proposition 2. *When regulators do not cooperate in setting a carbon fare, a different fare will be set in each jurisdiction.*

This result coincides with the conclusion that Ritz (2022) had already reached considering other contextual features (namely, international trade, firm heterogeneity, and market power).

6.1.2 The cooperative case

The IMF (2022) recommends cooperation between countries to deal with fiscal arbitrage and also to cope with climate change. For the former, the objective is to reduce tax discrepancies between countries. For climate change, the IMF (2022) advocates a global consensus on a carbon price floor which might then be adapted to local peculiarities. In accordance with the latter, we shall let our cooperating jurisdictions seek a uniform tax on emissions, namely $t = t_U = t_D$ (to possibly act as a yardstick).

Thanks to the first-order condition on the overall social welfare function (9), we obtain the following optimal emissions tax:

$$t^* = \frac{2(1 - s_D) - (1 - s_U)[3 + 2(\psi_U + \psi_D)(z_U + z_D)^2]}{(1 - s_U)(z_U + z_D)[1 + 2(\psi_U + \psi_D)(z_U + z_D)^2]} \cdot (a - c) \tag{12}$$

The above expression shows that this benchmark carbon tax should be set given the fiscal policy in each jurisdiction. The following cross-derivative

$$\frac{\partial^2 t^*}{\partial s_U \partial s_D} = \frac{2(a - c)}{(1 - s_U)^2(z_U + z_D)[1 + 2(\psi_U + \psi_D)(z_U + z_D)^2]} > 0$$

now supports a new statement.

Proposition 3. *When regulators cooperate in setting a uniform carbon tax, the latter is more sensitive to a higher downstream profits tax when there is an increase in the upstream profits tax.*

In other words, the jurisdictions' respective taxes on profit are complementary in influencing the carbon price: the latter's increase following a raise of the profit tax in one jurisdiction will be more pronounced if the other jurisdiction also augments its tax on profit. This prediction is consistent with the stylized fact that firms are less sensitive to environmental concerns (so they therefore necessitate greater pressure) when certain key constituents of their business landscape (fiscal stringency in this case) tend to impair their profitability.

6.2 Abatement efforts

Firms operating internal markets will normally treat their business units as profit (instead of cost) centers. Investment and production decisions are thereby largely decentralized. In this context, drawing from several stylized facts, Lee and Choi (2021) consider the situation where each supply chain member is subject to an emissions cap set at the firm's headquarter. We shall deal here with the alternative case where the divisions set their respective abatement efforts in response to an internal carbon fee. A widely-held belief is that setting such a fee will encourage abatement efforts and cleaner technology investments in the targeted business units (Ahluwalia, 2017).

To investigate this point, let's assume that each subsidiary $i = U, D$ can expend an effort r_i at a cost $\frac{1}{2}\gamma \cdot r_i^2$ to reduce its emissions by $R_i = r_i \cdot q$. The quadratic cost function captures decreasing returns to effort. For tractability reasons, we suppose that the positive technical parameter γ is the same across subsidiaries, and that the endogenous values r_i^2, $i = U, D$, fall within the interval $[0, 2\gamma)$.

Figure 2 describes the timing of abatement efforts in the multidivisional firm: investments in cleaner technology happen simultaneously in both divisions, ahead of production decisions.[10]

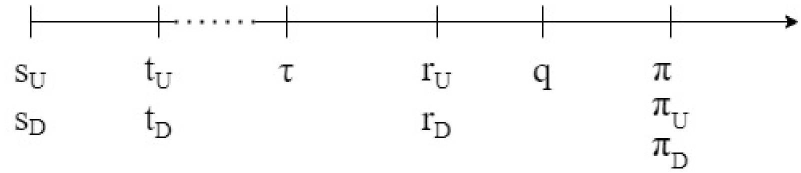

Figure 2: The timing of abatement efforts

The downstream and upstream subsidiaries' after-tax profit functions are now respectively

$$\begin{cases} \pi_{D,R} = (1 - s_D) \cdot [(a - q - \tau)q - t_D(z_D - r_D)q - \frac{1}{2}\gamma \cdot r_D^2] \\ \pi_{U,R} = (1 - s_U) \cdot [(\tau - c)q - t_U(z_U - r_U)q - \frac{1}{2}\gamma \cdot r_U^2] \end{cases} \quad (13)$$

[10]An alternative scenario is treated in Section 7.

When there are no fares on emissions, there will naturally be no abatement efforts so $r_U = r_D = 0$, while the transfer price and the quantity delivered are again respectively $\overline{\tau}_R = \overline{\tau}$ and $\overline{q}_R = \overline{q}$.

In the presence of emissions fares, production is set at

$$q_R^* = (1 + \frac{t_D^2}{2\gamma - t_D^2}).\frac{a - \tau - T_D}{2} \ ,$$

As expected, the optimal quantity q_R^* is greater than the quantity q^* when there is no abatement effort. The downstream and upstream subsidiaries respectively contribute the following investments to abate CO_2 emissions:

$$\begin{cases} r_D^* = \dfrac{2t_D}{2\gamma - t_D^2} \cdot \dfrac{a - \tau - T_D}{2} \\ r_U^* = \dfrac{t_U}{\gamma}(1 + \dfrac{t_D^2}{2\gamma - t_D^2}) \cdot \dfrac{a - \tau - T_D}{2} \end{cases} \quad (14)$$

From (14), one can readily infer that the producer's and the seller's respective efforts will be coordinated through the transfer price. Straightforward algebra actually delivers the following relationship

$$r_U^* = \frac{t_U}{2\gamma}[a - \tau - T_D + t_D \cdot r_D^*]$$

The upstream firm's investment in abatement will thus be directly proportional to the downstream firm's abatement effort. Moreover, $t_U > \frac{2\gamma}{t_D}$ will lead to $r_U^* > r_D^*$; this fact makes for another proposition.

Proposition 4. *Suppose that a fare is applied to emissions in both jurisdictions. Then, if the product of the emissions fares is large compared to the marginal cost of abatement, the producer will always invest more in abatement than the seller.*

Meeting the first-order condition for profit maximization now yields the following production and transfer pricing formulas:

$$
\begin{cases}
\tau_R^* = \dfrac{(1-s_U)[(1-\upsilon)a+c]-(1-s_D)a}{(2-\upsilon)(1-s_U)-(1-s_D)} + \dfrac{(1-s_U)[T_U-(1-\upsilon)T_D]+(1-s_D)T_D}{(2-\upsilon)(1-s_U)-(1-s_D)} \\
q_R^* = \dfrac{1}{2}\cdot\beta\cdot\left[\dfrac{(1-s_U)(a-c)}{(2-\upsilon)(1-s_U)-(1-s_D)} - \dfrac{(1-s_U)(T_D+T_U)}{(2-\upsilon)(1-s_U)-(1-s_D)}\right]
\end{cases}
\tag{15}
$$

where $\beta = 1+\frac{t_D^2}{2\gamma-t_D^2}$ and $\upsilon = \frac{t_U^2 \cdot t_D^2}{2\gamma-t_D^2}$. Comparing (15) with (6), a primary difference is the inclusion of the term υ - which depends on the emissions fares and the abatement cost parameter - in the benchmark transfer price $\overline{\tau}$. This supports our next proposition.

Proposition 5. *Suppose that a fare is applied to emissions in both jurisdictions. Then, when the firm's subsidiaries can invest in pollution abatement, internal carbon pricing does not make for a separate component of the transfer price.*

This result has organizational ramifications. In most firms, fiscal and environmental matters are usually handled by specialized employees working in distinct business units. Expression (6) allows these employees to work separately: on the one hand, tax accountants would set the internal price $\overline{\tau}$ based on current profit taxes; on the other hand, people implementing the firm's environmental strategy might add an internal carbon price based on profit and emissions fares; both prices would then combine into the green transfer price τ^*. When the firm's subsidiaries can invest in pollution abatement, however, tax accountants dealing with transfer pricing must take into account the environmental policy which holds in each jurisdiction. Some information exchange from the environmental managers to the firm's fiscal compliance unit is thus necessary. This agrees with some tax experts' recent recommendations: according to Solgaard (2022), for instance, enhanced communication between the environmental and tax departments should take place when a company implements its corporate social responsibility policy.

Note that expression (15)'s common denominator $(2-\upsilon)(1-s_U)-(1-s_D)$ is positive when $0 < \upsilon < 2$, so we have that $q_R^* > q^*$. This brings forth a last proposition.

Proposition 6. *Suppose that a fare is applied to emissions in both jurisdictions. Under certain profit and emissions fares configurations, allowing the firm's subsidiaries to invest in cleaner technologies can lead to greater production.*

Proposition 6 points out a situation in which the producer's profit would go further up as a consequence of environmental policy. This is in line with the Porter hypothesis,[11] particularly the empirical works studying the spillovers from a regulated downstream subsidiary on an upstream division's innovation and productivity (see, e.g., Greaker and Rosendahl, 2008; Leiter et al., 2011).

7 Robustness

This paper has so far built on three peculiar assumptions: a partly decentralized vertical structure (the firm's headquarter sets the transfer price, then leaves the production and abatement effort decisions to the divisions), abatement decisions made by managers after transfer pricing are set, and a linear demand for the final product. This section will now check what remains of the above results when these assumptions are relaxed.

7.1 An alternative vertical structure

Let's assume that all decisions are centralized, i.e. both the production and the transfer price decisions are made at the headquarters of the multidivisional firm. The following section successively discusses the cases without and with abatements efforts.

[11]For an initial statement of the Porter Hypothesis, the reader is referred to Porter and Van der Linde (1995)'s seminal article. Different versions of the hypothesis are discussed in Jaffe and Palmer (1997).

7.1.1 The basic centralized case

First, let's consider the situation when there are no emissions taxes applied to the subsidiaries. The first-order condition on total profit delivers the following optimal quantity:

$$\overline{q_c} = \frac{a-\tau}{2} + \frac{1-s_U}{2(1-s_D)} \cdot (\tau - c) = \overline{q} + \frac{1-s_U}{2(1-s_D)} \cdot (\tau - c)$$

Taking this into account, the multidivisional firm will then set a transfer price that meets the first-order condition on total profit.[12] This leads to the following output and transfer pricing expressions

$$\begin{cases} \overline{\tau_c} = \dfrac{(1-s_U)(a+c)-(1-s_D)a}{s_D - s_U} \\ \overline{q_c} = \dfrac{(1-s_U)a}{2(1-s_D)} \end{cases} \tag{16}$$

Formula (16) shows that the production decision under decentralization must be corrected by a positive additive term, making the production decision under centralization greater than under decentralization. The same result is found for the transfer price, i.e. $\overline{\tau_c} > \overline{\tau}$, as the denominator is now smaller.

Let each jurisdiction apply a different carbon fare, so $t_D, t_U \neq 0$. In that case, the centralized output and transfer pricing decisions would be

$$\begin{cases} \tau_c^* = \overline{\tau_c} + \dfrac{(1-s_U)(T_U - T_D) + (1-s_D)T_D}{s_D - s_U} \\ \quad\; = \overline{\tau_c} + \dfrac{(s_U - s_D)T_D + (1-s_U)T_U}{s_D - s_U} \\ q_c^* = \overline{q_c} - \dfrac{(1-s_U)T_D}{2(1-s_D)} \end{cases} \tag{17}$$

The expressions in (17) are comparable to those in (6), with the difference that the denominator is adjusted by an additive term $-(1-s_U)$. They are thus consistent with the first assertion of Proposition 1.

One divergence, though, is that $\frac{\partial \tau_c^*}{\partial T_D} < 0$, so an increase of any carbon fee will lead to a lower internal carbon price. Moreover, we have that $\frac{\partial \tau_c^*}{\partial T_U} = \frac{1-s_U}{s_D - s_U}$. When $s_D > s_U$,

[12] We are using here the fact that, for any function $f : \mathbb{R}^2 \to \mathbb{R}^2$ that has a maximum, $max_{x,y} f(x,y) = max_x max_y f(x,y)$.

$\frac{\partial \tau_c^*}{\partial T_U} > 0$, so the findings in Section 5.2 hold. But when $s_D < s_U$, $\frac{\partial \tau_c^*}{\partial T_U} < 0$, so an increase of any emissions tax will lead to a lower internal carbon price. The straightforward conclusion is that the organizational structure matters to figure out how emissions taxes are passed on to the different divisions.

7.1.2 Abatement efforts under centralization

Let's now assume that, while the output and the transfer price decisions are made by the headquarters, each subsidiary $i = U, D$ expend an effort $r_{i,c}$ at a cost $-\frac{1}{2} \cdot \gamma r_{i,c}^2$. In this situation, the optimal production decision is

$$q_{R,c}^* = (1 + \frac{t_D^2}{2\gamma - t_D^2}) \cdot (1 + \frac{(1 - s_U)t_U^2}{2\Lambda}) \cdot \frac{a - \tau - T_D}{2} + \frac{(1 - s_D)\gamma}{2\Lambda} \cdot (\tau - c - t_U z_U)$$

where $\Lambda = (1 - s_D)\gamma - (1 - s_U)t_U^2$. The quantity produced under centralization is greater than under decentralization, i.e. $q_{R,c}^* > q_R^*$, if $\gamma > \frac{1-s_U}{1-s_D} \cdot t_U^2$. This result corroborates Proposition 6.

Both divisions respectively choose to abate at respective levels

$$\begin{cases} r_{D,c}^* = \dfrac{2t_D}{2\gamma - t_D^2} \cdot \dfrac{a - \tau - t_D z_D}{2} \\ r_{U,c}^* = \dfrac{t_U}{\Lambda}[(1 - s_D)(1 + \dfrac{t_D^2}{2\gamma - t_D^2}) \cdot \dfrac{a - \tau - t_D z_D}{2} + (1 - s_U)(\tau - c - t_U z_U)] \end{cases} \quad (18)$$

If $t_U > \frac{2\Lambda}{(1-S_D)t_D}$, then the upstream division will deploy greater efforts on abatement than the downstream division, and the conclusion of Proposition 4 will stand.

The first order condition for profit leads to the transfer price

$$
\begin{aligned}
\tau^*_{R,c} = \cdot\, & [(1-s_D)(a-z_D t_D)[2\gamma^2(2\gamma-t_D^2)(1-s_D)(s_U-s_D)+t_U^4(1-s_U)^2(\gamma-2t_D^2) \\
& +(1-s_U)\gamma t_U^2[6\gamma(s_D-s_U)+t_D^2(1-4s_D+3s_U)]] \\
& +(1-s_U)(2\gamma-t_D^2)(c+t_U z_U)[(1-s_D)\gamma[2\gamma(s_D-s_U)-t_D^2(1-s_U)] \\
& \frac{-(1-s_U)t_U^2[\gamma(1+3s_D-4s_U)-2t_D^2(1-s_U)]]]}{[(1-s_D)\gamma(2\gamma-t_D^2)[2\gamma(s_D-s_U)^2-(1-s_U)^2 t_D^2]} \\
& -(1-s_D)(2t_D^2-\gamma)t_U^4(1-s_U)^2 \\
& -2(1-s_U)t_U^2[(1-s_U)^2 t_D^4 \\
& +\gamma t_D^2(s_D+5s_U+3s_D s_U-2s_D^2-4s_U^2-3) \\
& +\gamma^2(1-2s_U-6s_D s_U+3s_D^2+4s_U^2)]
\end{aligned}
\tag{19}
$$

The above expression being non additively separable (unlike formula (6) in the benchmark model), one can infer again that the fiscal and environmental departments of the firm will have to coordinate to decide on the transfer pricing decision. Proposition 5 remains therefore valid.

7.2 Ex-ante abatement efforts

Abatement efforts may correspond to long-term investments in R&D or cleaner technology. In this situation, commitment to making such efforts would occur prior to the determination of the transfer price. The optimal quantity and transfer price would then be adjusted as follows

$$
\begin{cases}
q^*_R = \overline{q} - \dfrac{1}{2}\cdot\dfrac{(1-s_U)[(z_D-r_D)t_D+(z_U-r_U)t_U]}{2(1-s_U)-(1-s_D)} \\
\tau^*_R = \overline{\tau} + \dfrac{(s_U-s_D)(z_D-r_D)t_D+(1-s_U)(z_U-r_U)t_U}{2(1-s_U)-(1-s_D)}
\end{cases}
$$

Once more, the optimal quantity is found to be greater with abatement than without it, i.e. $q^*_R > q^*$, corroborating the literature on the Porter hypothesis.

Regarding the influence of emissions fares on the transfer price, we have that

$$\frac{\partial \tau_R^*}{\partial t_U} = \frac{(1-s_U)(z_U - r_U)}{2(1-s_U)-(1-s_D)} > 0 \quad \text{and} \quad \frac{\partial \tau_R^*}{\partial t_D} = \frac{(s_U - s_D)(z_D - r_D)}{2(1-s_U)-(1-s_D)}$$

Hence, the results found in Section 5 hold.

In comparison to the benchmark model, however, one can see that

$$\left|\frac{\partial \tau^*}{\partial t_D}\right| > \left|\frac{\partial \tau_R^*}{\partial t_D}\right| \quad \text{and} \quad \frac{\partial \tau^*}{\partial t_U} > \frac{\partial \tau_R^*}{\partial t_U} > 0$$

The transfer price is thus more sensitive to the upstream carbon fare in the absence of abatement effort. In other words, when long term investments in abatement technologies are allowed, transfer prices become less responsive to environmental regulation. In other words, if a multidivisional firm decides to invest in greener technologies for its upstream subsidiary, the fiscal department will be able to take less account of the upstream emissions fare.

Considering the abatement efforts in this timeline, they are respectively given by

$$\begin{cases} r_U^* = \dfrac{(1-s_U)(s_D-s_U)[2\gamma[2(1-s_U)-(1-s_D)]^2 + (1-s_U)(1-s_D)(1-t_D)t_D]}{\eta} \\ \quad \cdot (a-c-T_U-T_D) \\ r_D^* = \dfrac{(1-s_U)(1-s_D)[\gamma[2(1-s_U)-(1-s_D)]^2 + (1-s_U)(s_D-s_U)(1-t_U)t_U]}{\eta} \\ \quad \cdot (a-c-T_U-T_D) \end{cases}$$

where $\eta = [\gamma[2(1-s_U)-(1-s_D)]^2 - (1-s_U)(s_D-s_U)t_U^2][2\gamma[2(1-s_U)-(1-s_D)]^2 - (1-s_U)(1-s_D)t_D^2] - (1-s_U)^2(1-s_D)(s_D-s_U)t_D t_U$. Fiscal discrepancies will still matter, as they did in Section 6.2 through the transfer price.

7.3 General market structures

Let the downstream division face demand for its product captured by a twice continuously differentiable function $D(q;\eta)$, $D : \mathbb{R}_+ \times \mathbb{R}^n \to \mathbb{R}_+$, where the vector $\eta \in \mathbb{R}^n$ might include the quantities and/or prices set by the firm's competitors, some macroeconomic indices, parameters characterizing consumer behavior, and so on. This subsidiary's profit function would now be written as

$$\pi_D = (1 - s_D) \cdot [D(q;\eta) - \tau - T_D] \cdot q \tag{20}$$

Assume that, at any given η, the function $\Phi(q;\eta) = D(q;\eta) \cdot q$ is strictly concave in q. To maximize profit, the seller will then order a quantity $q(\tau;\eta, s_D, T_D)$ that solves the following first-order condition

$$\frac{d\pi_D}{dq} = (1 - s_D) \cdot \{\frac{\partial}{\partial q} D(q;\eta) \cdot q + D(q;\eta) - \tau - T_D\} = 0$$

Applying the Implicit Function Theorem to this expression yields

$$\frac{\partial q}{\partial \tau} = \frac{\partial q}{\partial T_D} = \frac{1}{\frac{\partial^2}{\partial q^2}\Phi} < 0 \tag{21}$$

The lemma's statement still holds, therefore: the seller reduces the ordered quantity following a raise in the transfer price or a higher carbon fare in the downstream jurisdiction.

Taking this behavior into account, and the upstream subsidiary's profit function still being the same, i.e. $\pi_U = (1 - s_U) \cdot [\tau - c - T_U] \cdot q$, the multidivisional firm will want to set a transfer price that maximizes overall profits given by

$$\pi = \{(1 - s_D) \cdot [D(q(\tau;\eta, s_D, T_D)) - \tau - T_D] + (1 - s_U) \cdot [\tau - c - T_U]\} \cdot q(\tau;\eta, s_D, T_D) \tag{22}$$

Using the Envelope Theorem, this transfer price τ_g^* will satisfy the first-order condition

$$\frac{d\pi}{d\tau} = (s_D - s_U) \cdot q(\tau;\eta, s_D, T_D) + (1 - s_U) \cdot [\tau - c - T_U]\} \cdot \frac{\partial}{\partial \tau} q(\tau;\eta, s_D, T_D) = 0 \ .$$

Without being more specific concerning the demand function $D(q;\eta)$, it is not possible to obtain a closed-form expression for the chosen transfer price using the latter equation. Yet, thanks to the Implicit Function Theorem, one can compute the derivatives of τ_g^* with respect to the carbon fares. These are respectively

$$\begin{aligned}\frac{\partial \tau_g^*}{\partial T_D} &= -\frac{(s_D - s_U)\frac{\partial q}{\partial T_D} + (1-s_U)\cdot[\tau - c - T_U]\}\cdot\frac{\partial}{\partial\tau\partial T_D}q(\tau;\eta,s_D,T_D)}{(1+s_D-2s_U)\frac{\partial q}{\partial\tau} + (1-s_U)\cdot[\tau-c-T_U]\}\cdot\frac{\partial^2}{\partial\tau^2}q(\tau;\eta,s_D,T_D)}\\ \frac{\partial \tau_g^*}{\partial T_U} &= -\frac{-(1-s_U)\frac{\partial q}{\partial\tau}}{(1+s_D-2s_U)\frac{\partial q}{\partial\tau} + (1-s_U)\cdot[\tau-c-T_U]\}\cdot\frac{\partial^2}{\partial\tau^2}q(\tau;\eta,s_D,T_D)}\end{aligned}$$

Since expression (21) implies that $\frac{\partial^2 q}{\partial\tau^2} = \frac{\partial^2 q}{\partial\tau T_D} = 0$, the latter derivatives simplify into

$$\begin{aligned}\frac{\partial \tau_g^*}{\partial T_D} &= \frac{(s_U - s_D)\frac{\partial q}{\partial T_D}}{(1+s_D-2s_U)\frac{\partial q}{\partial\tau}}\\ \frac{\partial \tau_g^*}{\partial T_U} &= \frac{(1-s_U)}{(1+s_D-2s_U)} > 0\end{aligned}$$

The upshot is that the comparative statics statements made in Proposition 1 (ii) remain valid.

8 Conclusion

This paper considered internal carbon pricing (ICP), a modus operandi which is spreading fast across multidivisional firms and global value chains to curb greenhouse-gases emissions. Our analysis has both organizational and policy implications. On the organizational side, it revealed that: (i) along with the emissions fare imposed in each jurisdiction, the taxes set on the subsidiaries' respective profits also matter in establishing internal carbon prices, (ii) through ICP, an emissions fare aimed at a given subsidiary has an incidence on the other subsidiaries, (iii) allowing the firm's divisions to invest in pollution abatement raises the need to coordinate tax accounting with environmental strategy. On the public policy part, we found, notably, that: (a) corroborating the above assertion by Stiglitz, public emissions fares do not literally apply to a multidivisional firm's business units; these fares can be strongly distorted in the firm's transfer prices, (b) fiscal discrepancies between jurisdictions will result in non-uniform carbon taxes being implemented within global value chains, (c) the desire to make climate policy more effective brings additional pressure to harmonize fiscal policies.

Result (ii) suggests that a multidivisional firm's deployment of green transfer prices to manage its production and emissions can make local environmental policies resonate across jurisdictions. In other words, thanks to ICP, a given jurisdiction's emissions fare will not only impact the targeted subsidiary's pollution, it will also affect that of the subsidiary located in the other jurisdiction. This has implications for global environmental governance that deserve a few extra remarks.

Since GHG emissions have the same impact on global warming wherever they come from, a common approach to regulate them seeks to engage as many national jurisdictions as possible. While there are success stories in multilateral commitment (e.g., the 1987 Montreal Protocol on substances that deplete the ozone layer), reaching a global consensus on how to abate GHG emissions has proved so far to be hardly achievable. Indeed, abating such emissions is exposed to free-riding, and a greater number of engaged parties would negatively affect the effectiveness of an agreement (Barrett, 1994). This suggests a 'race to the bottom' (e.g. Wellisch, 2000; Wilson, 1996); i.e. the fact that the production of pollution-intensive goods could move to 'pollution havens' where environmental policies are more permissive (Candau et al., 2017; Grether et al., 2012) might lead certain jurisdictions to lower their environmental standards in order to attract investments.[13] To overcome this behavior, some researchers have proposed the creation of 'coalitions of the willing' and 'climate clubs', i.e. to constitute some relatively small groups of jurisdictions in which parties could possibly impose penalties (notably trade costs) on outsiders (Nordhaus, 2019). Our results further suggest that fostering coalitions covering the central nodes of global value chains might be essential to tackle climate change. The corresponding subsidiaries' compliance with climate policies would then have the largest impact on the abatement and emissions of the other subsidiaries located in nonparticipating jurisdictions. Recent efforts to implement the Paris Agreement on climate change seem to be heading in this direction. At the COP26, in Glasgow, decisions were made to target the five most pollution-intensive industries - energy, land transportation, steel, agriculture and hydrogen, with commitments coming only from key industry-specific coalitions of

[13]'Races to the top' have been observed in some cases, though (see, e.g., List and Gerking, 2000; Millimet, 2003).

governments and businesses (Ghosh et al., 2022).

The above model relied of course on several assumptions. First, we linked ICP to the general and well-established practice of transfer pricing. This is in line with the prescriptions of management practitioners. According to the Global Compact Network Germany (2018, p. 2), for instance, "carbon pricing within a company can only have real impact when it gains genuine recognition in the decision-making process and is integrated into internal structures and processes." Second, public emissions fares were implemented and were essential to come up with internal carbon prices. Alternative environmental policy instruments (e.g., tradeable permits, input taxes, emissions standards, subsidies) might have been deployed, however (see Fischer, 2006). Accordingly, there exist other approaches to establishing ICP, which use energy taxes or renewable energy support tariffs for instance (Ecofys et al., 2017). Considering these other cases would be valuable extensions. Third, we ignored international trade costs. But organizations that use transfer pricing often operate in an international context (Antràs & Chor, 2022). Introducing trade tariffs and other border adjustment mechanisms would be welcome at this point. Fourth, in our benchmark model the upstream subsidiary had only one client – the downstream subsidiary. Relaxing this assumption, thereby considering various upstream market structures, would be a worthy pursuit. Fifth and finally, while Section 7 showed that our results were rather robust, one might want to explicitly run the analysis under several other market and organizational structures, or more specific transfer pricing methods. One upshot would be the derivation of applicable formulas for establishing transfer prices; this might contribute to current debates in international tax regulation, notably those involving the 'Arm's Length Principle' versus 'Formulary Apportionment'.

Substantial applied research has already been devoted to the use of transfer pricing as a corporate fiscal instrument (e.g. Göx and Schiller, 2006). Business organizations have then followed up in implementing suitable transfer pricing policies (OECD, 2022a, 2022b). A timely challenge is to now convey policymakers and transfer pricing practitioners the rigorous background and appropriate tools to make transfer prices greener.

A A short primer on transfer pricing rules and methods

Transfer pricing, or internal pricing, refers to the pricing of goods, services and assets that are exchanged between affiliates of a company. As these transfer prices are set internally by the company, they are only partially subject to market forces that govern prices between independent entities. When subsidiaries are located in different tax jurisdictions, transfer pricing can become an instrument for fiscal optimitization. In order to mitigate this phenomenon, tax authorities have developed two standards, the Arm's Length Principle (ALP) and the Formulary Apportionment (FA). The former is commonly recommended by fiscal regulators and is defined by Article 9 of the OECD Model Tax Convention as follows:

> *[where] conditions are made or imposed between the two enterprises in their commercial and financial relations which differ from those which would be made between independent enterprises, then any profits which would, but for those conditions, have accrued to one of the enterprises, but, by reason of those conditions, have not so accrued, may be included in the profits of that enterprise and taxed accordingly.*
>
> *(OECD, 2022a: p.31)*

The ALP stipulates that the internal price should reflect the observed price between two independent third parties. This rule is based on a 'true allocation of income' approach, which stipulates that the transaction should mirror the location where the income has been generated (Pirlot, 2014). In order to achieve this, the company must first identify the financial and commercial relations between the related parties, including the risks borne by each. Once this has been done, the company must decide on an internal transactional price. The tax authorities will then select the most appropriate transfer pricing method to compare the transaction to what would be the same transaction in an external market. The method will be selected based on the nature of the transaction, the information available, and the degree of comparability.

The OECD (2022b) has developed three 'traditional' methods, namely the 'comparable uncontrolled price method', the 'resale-price method' and the 'cost-plus method'. The former is the most frequently employed method and represents a direct application of the ALP, whereby the transfer price is compared to the price of similar products on the market. This approach presents a significant challenge in practice though, as the internal price frequently incorporates a range of transactional elements that extend beyond the scope of a straightforward transaction between two independent entities. Another market-based method is the 'resale price method' which comprises three steps. Initially, the final selling price to the independent third party is established. Subsequently, the arm's length margin to be attributed to the affiliated party is determined. Finally, this margin is subtracted from the final selling price to the independent customer in order to obtain the transfer price. The 'cost-plus method' consists of determining the cost of the good or service sold or provided to an affiliated company, augmented by a margin derived from comparing internal and external sales costs.

The OECD (2022b) has introduced two additional methods for dealing with more complex transactions, particularly those involving intangible assets or limited information availability: the 'transactional net margin method' and the 'profit split method'. The former entails a comparison of the company's profitability with that of a comparable external entity. The latter is based on the relative value each local subsidiary contributes to the overall profit.

Although the ALP and the aforementioned methods provide a framework for addressing potential profit shifting, they are predicated on a comparison between intracompany and independent transactions, which is challenging to evaluate in practice (DeSimone, 2016) and not readily adaptable to environmental considerations (Pirlot, 2014).

An alternative rule for transfer pricing - known as Formulary Apportionment (FA) - seeks to capture in a formula a company's capability to generate profits through a range of factors. The most prevalent method is the Massachusetts formula, which is based on three key factors: sales, payrolls, and property. A primary benefit of FA would be that it provides a structured expression that can be adapted to accommodate environmental concerns. This topic is notably discuss in Pirlot (2014).

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