Combining Rate-Based and Cap-and-Trade Emissions Policies

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Abstract

Rate-based emissions policies (like tradable performance standards) fix average emissions intensity, while cap-and-trade policies fix total emissions. This paper shows that unfettered trade between rate-based and cap-and-trade programs always raises combined emissions, except when product markets are related in particular ways. Gains from trade are fully passed on to consumers in the rate-based sector, resulting in more output and greater emissions allocations. We consider a range of policy options to offset the expansion, including unilateral ones when jurisdictional differences require. The cap-and-trade jurisdiction could impose an "exchange rate" to adjust for relative permit values, but marginal abatement cost equalization is sacrificed. Still, that jurisdiction may prefer adjusted trade over tightening their own cap, which transfers away rents. Although the rate-based sector would have to implement the switch to output-based allocation of a cap, its surplus would be higher than with adjusted trade, which is also preferred to no trade. The cap-and-trade sector would also be better off. Thus, a range of combinations of tighter allocations could improve situations in both sectors with trade, while holding emissions constant.

Key Words: emissions trading, permit allocation, tradable performance standards, climate, greenhouse gases

JEL Classification Numbers: H23, H3, Q2, Q48

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1 Introduction

In the Kyoto Protocol to the United Nations Framework Convention on Climate Change, partici-
pating countries agreed to reduce their greenhouse gas emissions to target levels generally below
1990 emissions. To achieve their individual targets, the signatory countries are considering a di-
verse mix of policies, but emissions trading is expected to be a central component of overall climate
policies. Even among tradable emissions permit policies, diversity exists. Some target emissions
intensity, such as with tradable performance standards, which fix the average emissions rate for key
sectors but allow their total emissions to vary. Others fix a cap on the overall emissions for desig-
nated participants in the permit program. Although countries may initially tailor individual trading
policies for specific sectors, ultimately the hope is to take advantage of potential gains by allowing
trade across sectors and across countries. An important question then arises: What happens when a
cap-and-trade system of emissions permits is opened to trading with a system regulating emissions
intensity?

Cap-and-trade programs for CO_2 are already being prepared in several countries, and one is
being designed for the European Union overall, with the first trading period to begin in 2005.
In the EU proposal, while absolute emissions targets are required for covered sectors overall,[1]
"relative targets" of emissions intensity are allowed for individual industries, as long as they are
converted to quantities in a given period for the purposes of the trading cap (COM 2001). emissions

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All errors and opinions remain the responsibility of the author.
[1]The EU current directive proposal begins with a cap on CO_2 emissions for large sources in certain energy-
producing or energy-intensive sectors: combustion installations, refineries, metal and mineral industries, and paper
and pulp mills. Together, these sectors are estimated to account for about 46% of total CO_2 emissions in 2010.

rate targets are also already in use as part of climate policy in several countries. Alongside the Climate Change Levy in the United Kingdom are negotiated agreements that offer 80% rebates to most manufacturing sectors in exchange for specify energy-per-unit-of-output targets for the next 10 years (DEFRA 2001). Another 34 companies have accepted fixed targets; they may trade among one another and sell to the rate-based sectors, but not buy from them. The Netherlands is separating its energy-intensive sectors into trade-sensitive ones, which will be subject to a tradable performance standard, and less exposed ones, which will be subject to a cap-and-trade program (Kuik at al. 2002). Many countries also have portfolio standards for renewable energy generation, which are similar to intensity targets.[2] The United States, having rejected the Kyoto Protocol, plans to target emissions intensity instead, though in a voluntary framework.

The reasons for preferring a rate-based policy are equally diverse. The initial intent may be to mitigate cost uncertainty (Kolstadt 2002). Motivations might also be political or distributional. An emissions intensity target may be easier to negotiate with industry than a fixed allocation or an auction, since it encourages growth. And a rate-based allocation may not need special arrangements for new participants and participants that cease operation. However, if the emissions cap for the trading program is not fixed and the country (or group of countries) has an absolute emissions limit, a rate-based allocation may impose a larger reduction burden on sources outside the rate-based trading program. In general, even within a single sector, if the goal is to achieve a certain level of emissions, rate-based allocations are inefficient (Fischer 2001). Furthermore, when the incidence of the allocation subsidy to consumers and intermediate input providers is taken into account, producers may not be better off with output-based allocation than with auctioned permits (Burtraw et al. 2002). However, a rate-based allocation strategy may be justified in certain situations, such as if close competitors with similar emission profiles cannot be regulated (Bernard et al. 2002). In this case, the output support implicit in the rate-based allocation can mitigate the loss of competitiveness and subsequent emissions leakage to firms outside the regulation's juris-

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[2]These countries include Australia, Belgium, Denmark, France, Germany, Italy, Netherlands, Sweden, and the United Kingdom, as well as at least 10 states in the United States. (Source: Union of Concerned Scientists).

diction.[3] Another general equilibrium argument that favors output-allocated over "grandfathered" permits (gratis lump-sum allocations) involves the interaction with other taxes in the economy: a large body of literature indicates that environmental policies that raise the prices of goods can exacerbate preexisting distortions in the economy.[4]

In this paper, we focus on the question of integrating trading programs, evaluating the impacts of different strategies on prices, production, emissions, and rents. To remain agnostic about the specific reasons for the rate-based policy, we ignore the general equilibrium effects or political economy factors that might motivate the policy choice as beyond the scope of this paper. The intent is to outline the important component effects of integration, acknowledging that a complete welfare analysis would require specific knowledge of the underlying market failures that make the rate-based program an appropriate second-best policy response in the first place. To illustrate these effects, section 2 presents a simple, partial equilibrium model and analyzes the fundamental incentives for each of two sectors, one with an emissions cap, the other with an intensity target. Section 3 evaluates the effects of allowing free trade between the two sectors. Section 4 then weighs different policy options for holding total emissions constant under trade, taking distributional effects into consideration.

We find that allowing unfettered trade between rate-based and cap-and-trade programs always raises combined emissions—regardless of the direction of trade—when the product markets are independent. In the rate-based sector, no permit rents exist, since all cost savings are passed along to consumers. The gains from trade in the permit market then lead to lower prices and expanded production in that sector; that increased output brings with it additional permit allocations, which in turn expand the overall cap of allocated emissions. In certain situations when product markets are interrelated, however, allowing trade in permits can cause emissions to fall. An example would be if the two sectors produce substitute goods, and trade in permits lowers prices for the cap-and-trade sector; if that sector becomes relatively more competitive, causing demand for the rate-based

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[3]Kuik et al. (2002) find a significant welfare loss for the Netherlands when the trade-exposed sectors are subject to a cap rather than intensity targets because of the loss in competitiveness.

[4]See, e.g., Bovenberg and de Mooij (1994), Goulder (1995), Goulder et al. (1997), Fullerton and Metcalf (1997).

sector's products to fall, output and thereby emissions allocations to that sector could contract. Thus, a comprehensive analysis of integrating particular regulated sectors needs to account for their product market interactions.

Since total emissions rise with output in the rate-based sector, some sort of compensating policy is necessary to allow trade but hold emissions constant. If both sectors fall in the same jurisdiction, the regulator can presumably choose among tightening the cap, tightening the standard, seeking outside offsets, or some combination. However, if the cap-and-trade sector lies in a separate jurisdiction, one that holds stronger preferences about holding emissions fixed, it may need to seek unilateral adjustment actions to trade in permits. Some policy options include taxing the output of the rate-based sector to offset the change in allocation, imposing an "exchange rate" for relative permit values, or tightening its own cap. A tax on output keeps abatement incentives efficient but may be difficult to impose across borders, since it must apply to goods trade rather than to permit trade. Adjustments to permit exchanges change the ratio of emissions that a rate-based sector permit can offset for (or with) capped sector permits; they can be more easily imposed on cross-border permit transactions, but marginal abatement cost equalization is sacrificed. Tightening its own emissions cap would preserve both efficiency and constant emissions; however, the loss in rents from the lower allocation may mean that total surplus in that sector is lower than with the less efficient, adjusted permit trade. On the other hand, compared with adjusted trade, the rate-based sector would prefer to switch on its own to output-based allocation of a cap equal to its initial emissions (or, equivalently, tighten its standard to hold emissions constant). In their case, the gains from unrestrained trade outweigh the reduction in allocation, resulting in higher surplus for that sector. The cap-and-trade sector would also benefit from such a switch. Thus, this mechanism is likely to be preferred when rate-based allocation remains important for this sector, though a range of mutually beneficial adjustments to allocations exists. We conclude by noting that the specific characteristics of the sectors, the broader economic context, and the underlying motivations of the regulators will be important for understanding the full implications of the incentives created when tradable emissions permit programs with different designs are integrated.

2 Model

The simplest form that captures the main aspects of the problem is a partial equilibrium model of two sectors, each with a representative firm. Each firm is assumed to be a price taker both in product and in emissions markets, but trade between them occurs only in the latter. This situation could arise if the sectors represent different industries or are located in different countries, or both. For example, one country could set a performance standard for its energy-intensive industry, while another sets a cap on CO_2 emissions from its electricity sector.

Total emissions in each sector E_i are the product of the emissions rate μ_i and total output Q_i. Marginal costs of production for firm i, represented by $c_i(\cdot)$, are constant in output but a decreasing function of the emissions rate, up to some finite natural emissions rate μ_i^0: $c_i(\mu) > 0$, $c_i'(\mu) \leq 0$, $c_i''(\mu) > 0$, and $c_i'(\mu_i^0) = 0$. This formulation essentially represents the long-run average cost of production for the industry, recognizing that it must be higher when emissions intensity is lower.

The model is one of partial equilibrium, as each sector is assumed to face exogenous demand functions. In the base case, consumer demand in each sector is assumed to be independent of the other sector and income effects. Then demand is a simple, declining function of consumption of that sector's product price ($Q_i(P_i)$), and we can define consumer surplus as $CS_i(P_i) = \int_{P_i}^{\infty} Q(s)ds$, the main point being that it is also declining with the price. However, we will also relax the assumption of independent markets to discuss the effects of cross-price interactions when the two products are substitutes or complements.

This basic formalization is attractive in its transparency. Perfect competition ensures that prices equal marginal costs in output and emissions markets. All abatement costs are evident in the product market, in the form of increased production costs and avoided consumption. Total surplus is the sum of consumer surplus and producer profits, which in this case of constant marginal production costs will simply equal consumer surplus and lump-sum allocated emissions rents. Although these assumptions are somewhat restrictive, particularly with respect to normative welfare analysis, the main intuition regarding incentive effects will hold in a broader model.

2.1 Cap-and-Trade System

Our first system is a cap-and-trade system (CAT), in which overall industry emissions are fixed at $\bar{E}$. Each firm must buy permits to the extent its emissions exceed its fixed allocation, $\bar{A}$, and can sell any extra allowances if its emissions fall below. Let t_1 be the market price of permits. For our representative, perfectly competitive firm, profits are revenues less production costs less the value of net permit purchases:

$$\pi_1 = (P_1 - c_1(\mu_1) - t_1\mu_1)Q_1 + t_1\bar{A}. \tag{1}$$

The firm will lower its emissions rate from the natural rate until the marginal cost of emissions rate reduction equals the marginal price of emissions, arriving at the optimal emissions rate μ_1^*:

$$-c_1'(\mu_1^*) = t_1. \tag{2}$$

Meanwhile, in the competitive industry equilibrium, the output price must equal the marginal cost of another unit of output, which includes both production costs and permit costs:

$$P_1^* = c_1(\mu_1^*) + t_1\mu_1^*. \tag{3}$$

In equilibrium, supply must equal demand, so output levels are determined by the quantity demanded at the equilibrium price: $Q_1^* = Q_1(P_1^*)$. The equilibrium permit price is such that 2 and 3 hold and the cap binds: $\mu_1^* Q_1^* = \bar{E}$.

In this model, with constant marginal costs, firm profits—excluding emissions rents—are zero. Thus, producer surplus equals the value of the allocation, $t_1\bar{A}$. For simplicity, we will assume that $\bar{A} = \bar{E}$, recognizing that these rents need not necessarily be distributed to the firms, but that the total value will not be affected by changes in the lump-sum distribution. Total surplus is $TS_1 = CS_1(P_1^*) + t_1\bar{E}$. Since the allocation remains constant, the distributional effects of trade depend on the change in consumer surplus and the change in the value of the lump-sum emissions allocation via the permit price change.

2.2 Tradable Performance Standard

The second system is a tradable performance standard (TPS), also known as a rate-based emissions permit program, which fixes the average emissions intensity rather than capping total emissions. To the extent a firm produces with emissions rates below the standard, that firm creates permits that it can sell; to the extent the firm produces with above-average emissions, it must purchase permits to cover the gap. The subsequent equilibrium determines the price of emissions and total amount of emissions, such that the industry emissions rate average equals the performance standard. This policy represents a form of output-based rebating of emissions rents, combining a price on emissions (in the form of permit liabilities) with a subsidy to output (in the form of the rate-based allocation).

Let t_2 represent the price of emissions permits in the TPS program. The firm must buy permits to the extent it emits more than the standard, $\bar{\mu}$, which determines the industry's average emissions rate. In other words, the firm pays an emissions tax of $t_2 \mu_2 Q_2$ and receives a subsidy equal to the average value of emissions embodied in its output, $t_2 \bar{\mu} Q_2$.

Consider our representative, perfectly competitive firm with constant marginal costs. Its profits now equal total revenues from the sale of output less the costs of production, less emissions costs net of the rebated subsidy:

$$\pi_2 = \left(P_2 - c_2(\mu_2) - t_2(\mu_2 - \bar{\mu})\right) Q_2. \tag{4}$$

Maximizing profits, the firm lowers its emissions rate until the marginal cost per unit of output equals the marginal price of emissions, just as in the CAT case:

$$-c_2'(\mu_2^*) = t_2.$$

Similarly, the equilibrium output price must equal the marginal costs of an additional unit,

which in this case include not only production and permit costs but also the allocation subsidy:

$$P_2^* = c_2(\mu_2^*) + t_2(\mu_2^* - \bar{\mu}).\qquad(5)$$

In a closed equilibrium, compliance with the performance standard implies $\mu_2^* = \bar{\mu}$; correspondingly, the permit price equals the marginal abatement cost at that standard: $t_2 = -c_2'(\bar{\mu})$. Furthermore, the marginal permit price just equals the marginal subsidy per unit of output, so the equilibrium output price just equals marginal production costs, much as it would with no regulation. However, compliance with the performance standard raises marginal production costs compared with the no-regulation case (superscript 0); that is, $P_2 = c_2(\bar{\mu}) > c_2(\mu_2^0) = P_2^0$.

Total production in the market equilibrium is determined by consumer demand. Let $\overline{Q}_2 = Q_2(P_2^*) = Q_2(c_2(\bar{\mu}))$. The higher price resulting from the regulation corresponds to a lower level of output than in the absence of regulation; however, since the price does not include the marginal environmental cost of the emissions embodied in remaining production, output will be higher than with a cap-and-trade policy achieving the same intensity (or, equivalently in this case, emissions price). As a consequence, given an equivalent emissions rate (or permit price), total emissions will be higher than with CAT. The dual to this result is that, to achieve the same total level of emissions, the emissions rate must be lower in a rate-based system to offset the lesser conservation incentive compared with the CAT system.

The assumption of constant marginal production costs means that all cost changes—including the value of the rate-based allocation—are passed on to consumers. Thus, firm profits are always zero, no emissions rents exist, and total surplus equals consumer surplus: $TS_2 = CS_2(P_2^*)$.

3   Trade between Programs

Allowing trade between a traditional CAT program and a rate-based emissions program will provide for an equalization of marginal abatement costs, at least with respect to emissions rate reductions. If there is a difference in the permit prices without trade, the sector with the higher autarky

price will want to do less abatement and instead buy permits from the sector with the lower price, which in turn will reduce emissions to be able to sell more permits. The resulting equilibrium permit price with trade will lie somewhere in between the no-trade prices, where the marginal costs of control are equalized.

Since the allocation to the CAT sector is fixed, the change in joint emissions equals the change in the allocation of permits to the rate-based sector. The change in that allocation depends on the change in output in that sector, which in turn depends on how prices change.

Proposition 1 *Trade in emissions between a performance standard and a cap-and-trade program always lowers the output price in the sector with the performance standard.*

Proof. Let t be the market price of emissions with trade and μ'_2 be the emissions rate that satisfies $-c'_2(\mu'_2) = t$. By the definition of profit maximization, if μ'_2 is optimal, it must be that costs are lower than with $\bar{\mu}$: $c_2(\mu'_2) + t(\mu'_2 - \bar{\mu}) < c_2(\bar{\mu})$. Accordingly, product prices are lower ($P'_2 < P^*_2$). ∎

In other words, gains from trade arise from the potential for cost savings. Since no emissions rents exist in the rate-based sector, all the savings are passed on to consumers. In our base case, when demand is independent, the quantity demanded and produced increases with the price fall ($Q'_2 > \overline{Q}_2$). Correspondingly, the permit allocation and thereby total combined emissions will increase by $\bar{\mu}(Q'_2 - \overline{Q}_2)$. Thus, joint emissions always increase with permit trade, regardless of the direction of trade between the sectors.

To explore this result further, suppose first that the autarky price is higher in the TPS sector: $t_2 > t_1$. In the trading equilibrium, the rate-based sector imports permits from the capped sector. In the capped sector, emissions rates fall until marginal costs equal the new price: $-c'_1(\mu'_1) = t > t_1$. Total emissions in that sector fall by the amount sold to the rate-based sector. The higher marginal cost of control plus higher permit costs mean output prices must rise as well. However, the value of the initial permit allocation rises as well, raising overall surplus in that sector.

In the TPS sector, emissions rates rise until marginal costs equal the new price: $-c'_2(\mu'_2) = t < t_2$. With a higher emissions rate, direct production costs fall; however, the price of output now

reflects a net tax on the embodied emissions: $P_2(Q_2') = c_2(\mu_2') + t(\mu_2' - \bar{\mu})$. Still, we can be assured that this price is lower than $c_2(\bar{\mu})$, and that the corresponding increase in output expands overall emissions. Total emissions in this sector then change by $\mu_2' Q_2' - \bar{\mu}\overline{Q}_2$; however, net purchases from the capped sector equal $(\mu_2' - \bar{\mu})Q_2'$. In other words, as abatement and thereby production costs fall with trade in permits, the rate-based sector is allowed to expand. However, it is not required to purchase permits for all of its additional emissions, just those above the standard.

Suppose now that the autarky price is higher in the CAT sector: $t_2 < t_1$. In this case, the TPS sector exports permits to the capped sector. In the capped sector, emissions rates rise until marginal costs equal the new equilibrium price: $-c_1'(\mu_1'') = t < t_1$. Total emissions in that sector rise by the amount purchased from the rate-based sector. Cost savings are passed on to consumers, and the value of emissions rents falls with the market price.

In the TPS sector, emissions rates fall until marginal costs equal the new price: $-c_2'(\mu_2'') = t > t_2$. With a lower emissions rate, direct production costs rise; however, the price of output now reflects a net subsidy: $P_2(Q_2'') = c_2(\mu_2'') + t(\mu_2'' - \bar{\mu})$. The net change in emissions equals $\mu_2'' Q_2'' - \bar{\mu}\overline{Q}_2$, but net sales to the capped sector equal $(\bar{\mu} - \mu_2'')Q_2''$. Thus, total combined emissions increase by the sum $\bar{\mu}(Q_2'' - \overline{Q}_2)$.

In other words, the net subsidy from having the emissions rate below the standard must outweigh the direct cost increase. Accordingly, trade lowers costs and raises output in the rate-based sector. Total emissions in this sector may rise or fall, depending on the output effect relative to the rate reduction. However, total joint emissions necessarily increase, since the rate-based sector's allocation increases with its output, while the capped sector's allocation remains fixed.

3.1 Caveat

An important caveat to this analysis applies when demand for the two products is not independent but rather interdependent. In the case of strong substitutes (or complements), trade in permits can reduce total emissions if it makes the CAT sector product relatively more competitive (or more expensive). Since competitiveness effects are a common rationale for rate-based mechanisms, this

case merits concern. Although the justification is typically that the important competitors are less stringently regulated, it is possible that for strategic or other reasons, one sector has a TPS while its competitor (or complementary sector) has a CAT requirement. Without having to model a complete general equilibrium, we can understand under what conditions trade between a CAT and a TPS system could lower emissions. Since the change in total emissions in the two programs depends on output in the TPS sector, the question is whether quantity demanded in that sector could fall with the changes in the competitive market prices.

Consider consumer demand in the TPS sector as being a function not only of its own price, but also of the price in the CAT sector: $Q_2(P_2, P_1)$. Then we can write the change in that sector's output due to trade as

$$\frac{dQ_2}{Q} = \eta_{22}\frac{dP_2}{P_2} + \eta_{21}\frac{dP_1}{P_1}$$

where η_{22} is the own-price elasticity (assumed to be negative) and η_{21} is the cross-price elasticity. Proposition 1 showed that $dP_2 < 0$, regardless of the direction of trade. On the other hand, the sign of dP_1 depends on whether trade increases or decreases the price of permits compared with no trade. Thus, we can identify two potential cases in which Q_2 could fall, both requiring that the cross-price effects dominate the own-price effects.

First, if the goods are complements ($\eta_{21} < 0$), then if $t_2 > t > t_1$, the rise in P_1 could drive down Q_2. This case might occur if the CAT sector provides an important input to the TPS sector,[5] or if both provide inputs to another sector, such as electricity generation and steel to a manufacturing industry. For example, if the increased value of emissions under trade is fully passed forward in electricity prices, consumers of that input could also demand less of other inputs like steel, even if their prices are somewhat lower.

Second, if the goods are substitutes ($\eta_{21} > 0$), then if $t_2 < t < t_1$, the fall in P_1 could drive down Q_2. An example of this situation would be if the sectors produce similar goods in different countries. If, say, country 1 regulates its paper mills with a CAT, they are relatively less competitive in autarky than mills regulated with a TPS in country 2. If trade results in lower permit

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[5]Although in this example we should note that the costs would also be correlated.

prices for country 1 and its mills become relatively more competitive, their output could expand at the expense of output in country 2.

It is indeed possible for the cross-price effects to be bigger even if own-price elasticities are stronger, since the output price in the CAT sector is more sensitive to permit price changes than the price in the TPS sector.[6] Correspondingly, while output in the CAT sector should respond as before, in the opposite direction of its own-price change, output in the TPS sector may behave differently. Thus, to understand the implications of integrating permit trade between a CAT and a TPS system, it is important to take into account the trade relationships between the two product markets as well. This said, for the rest of the paper we will proceed with the assumption that own-price effects always dominate.

4 Equalizing Trade between Programs

Since Kyoto targets are fixed caps, policy designers might prefer to keep total combined emissions from expanding. One option would be to buy offsets outside the two programs. For example, a country with a rate-based policy could seek credits from projects within the Clean Development Mechanism. However, policy designers might prefer to keep the adjustment mechanism within the trading programs. Obviously, the most straightforward way to ensure that is for the second sector to adopt a cap. Otherwise, some tightening of the emissions standard and/or the emissions cap would be required in the new trading equilibrium. But the two sectors may fall under different regulatory jurisdictions—like different countries—with their own priorities. If the rate-based country does not wish to tighten its standard, can the cap-and-trade country design a tax that neutralizes the effects of rate-based allocations? Would this be a credible and desirable alternative to tightening its own cap? Furthermore, facing adjustments to permit trade, would the rate-based sector be better off switching to a cap with output-based allocation of emissions permits?

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[6]For example, if we consider small changes from the autarky permit price we see $dP_2/dt_1 = \mu_1^*$ while $dP_2/dt_2 = \mu_2^* - \bar{\mu} = 0$. Note that since costs are minimized with respect to emissions rates at the autarky prices, small changes in μ do not affect output prices.

4.1 Taxing Trade

One way for the CAT regulator to offset the effects of trade on emissions is by imposing a tax on the output of the TPS sector equal to the cost differential: $\tau = c_2(\bar{\mu}) - c_2(\mu_2) - t(\mu_2 - \bar{\mu})$. That would hold output, and thereby emissions, constant in sector 2. It also retains most of the output support from the rate-based allocation. However, this adjustment may be difficult if the permit trade involves separate countries. The CAT policy country could then only hope to tax the foreign output it imports itself, and even that policy is likely to be restricted by multilateral trade agreements.[7]

The other tax option would be to introduce a price wedge between the price of permits at home and abroad. Although an export or transaction tax would reduce trade and dampen the opportunities for emissions expansion, it would not affect the variability of allocation. For the same reasons as in the free-trade scenario, any worthwhile trade will allow sector 2 to expand its allocation. Thus, to ensure that trade holds emissions constant, the adjustment policy must offset the allocation effect. In other words, the tax would need to expropriate permits rather than just a fee.

A permit exchange rate would create a wedge between the number of permits traded rather than between their prices. A policy regulating trade in permits across jurisdictions could be imposed unilaterally, regardless of the direction of trade. The policymaker governing the CAT sector would make rules regarding the relative value of the permits being traded. She would make adjustments in terms of the rate of offset (or impose an expropriation rate for cross-border trade) to prevent joint emissions from expanding. However, a drawback of this regime is that marginal abatement costs will not be equalized.

With trade adjusted by an exchange rate (denoted with superscript A), the TPS sector would have to buy (or would be able to sell) α permits from the CAT sector for each unit it emits above (below) its average. With trade, its marginal costs of reducing the emissions rate will equal the adjusted price of permits: $-c_2'(\mu_2^A) = \alpha t_A$, where t_A is the market price received (or paid) by the CAT sector. Since $\alpha \neq 1$, the TPS sector has different incentives to abate under trade than the

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[7]See Fischer et al. (2002).

CAT sector, which equalizes marginal costs of emissions reduction to the unadjusted permit price. This disparity also creates room for corner solutions with respect to emissions abatement: if the adjustment factor is higher than the autarky price differential, no trade will occur.

If it does occur, trade can only lower costs compared with autarky behavior, as shown in the previous propositions. Output then rises as the price falls: $P_2(Q_2^A) = c_2(\mu_2^A) + \alpha t_A(\mu_2^A - \bar{\mu}) < c_2(\bar{\mu})$. Total emissions in this sector will then change by $\mu_2^A Q_2^A - \bar{\mu}\overline{Q}_2$. The adjustment factor must be set such that adjusted permits sold equal the change in emissions in the cap-and-trade sector, which must also equal the actual change in emissions in the rate-based sector:

$$\alpha(\mu_2^A - \bar{\mu})Q_2^A = (\mu_1 Q_1 - \mu_1^A Q_1^A) = \mu_2^A Q_2^A - \bar{\mu}\overline{Q}_2.$$

Thus, the adjustment rate that holds total combined emissions constant is

$$\alpha = \frac{\mu_2^A Q_2^A - \bar{\mu}\overline{Q}_2}{(\mu_2^A - \bar{\mu})Q_2^A}.$$

In other words, the country with the CAT sector expropriates the share $1 - \alpha$ of the $(\mu_2^A - \bar{\mu})Q_2^A$ permits traded, or $\bar{\mu}(Q_2^A - \overline{Q}_2)$ permits, representing the change in the total allocation. Since $Q_2^A > \overline{Q}_2$, regardless of the direction of trade, this amount is always positive. If $t_A > t_2$, then $\mu_2^A < \bar{\mu}$ and $\alpha < 1$. This means in turn that the TPS sector will have less incentive to abate when it is exporting permits, since $-c_2'(\mu_2^A) = \alpha t_A < -c_1'(\mu_1^A) = t_A$. If instead $t_A < t_2$, then $\mu_2^A > \bar{\mu}$ and $\alpha > 1$. This means in turn that sector 2 will have more incentive to abate when it is importing permits, since $-c_2'(\mu_2^A) = \alpha t_A > -c_1'(\mu_1^A) = t_A$. In both cases, then, some of the potential gains from trade are forgone to keep total emissions stable.

4.2   Output-Allocated Permits

Another option would be for sector 2 to switch to a fixed emissions cap but use output-based allocation (OBA) of the emissions permits. OBA is another type of rate-based allocation, but the average allocation is endogenous, rather than equal to a fixed emissions intensity. Output-based

allocations are part of the proposed CO_2 trading program designs for several countries, including France, Switzerland, and Canada. The last is particularly concerned about limiting the adverse impacts on industries that compete with firms in the neighboring United States, which has not committed to a national greenhouse gas emissions limit. Output-based allocations have also been proposed in the United States for NO_x emissions allowances within some northeastern states.

Let the OBA program be represented with superscript B. In autarky, a policy allocating fixed emissions based on output shares would be equivalent to the tradable performance standard. To illustrate, consider a cap of $\bar{\mu}\overline{Q}_2$ permits that is allocated among program participants according to output shares. The assumption of perfect competition implies that the individual firm does not perceive an impact on the industry average allocation of its own production behavior. Thus, each firm expects to get an allocation $\bar{e}$ per unit of its output. The profits for our representative firm are then revenues less production costs less the value of net permit purchases:

$$\pi_2^B = \left(P_2 - c_2(\mu) - t_B(\mu - \bar{e})\right) Q. \tag{6}$$

As with the other policies, the firm equalizes the marginal cost of emissions rate reduction with the marginal price of emissions: $-c_2'(\mu) = t_B$. And the equilibrium output price equals marginal costs plus permit costs net of the subsidy:

$$P_2(Q_2^B) = c_2(\mu_2^B) + t_B(\mu_2^B - \bar{e}). \tag{7}$$

In equilibrium, the average allocation will equal the emissions cap divided by total production in the sector:

$$\bar{e} \equiv \bar{\mu}\overline{Q}_2/Q_2^B. \tag{8}$$

If the emissions market is restricted to this sector, the average permit allocation will equal the average emissions rate, and $\bar{e} = \mu_B = \bar{\mu}$, $t_B = t_2$, and $Q_2^B = \overline{Q}_2$. However, in the case of emissions trading with other sectors, it is an important distinction that the subsidy is a function not

of the industry average emissions rate but rather of the average allocation. By definition, allowing trade between two capped markets has no impact on total emissions. It does, however, reallocate the costs and subsidies.

With trade, both sectors will equalize the marginal cost of abatement to the new market price of permits: $-c_1'(\mu_1^B) = t = -c_2'(\mu_2^B)$. As with the previous versions, trade can only lower production costs. If sector 2 chooses the autarky emissions rate, then $\bar{e} = \bar{\mu}$, and $P_2 = c(\bar{\mu})$ applies.[8] Therefore, if another emissions rate is optimal, costs must be lower. Thus, output rises with trade ($Q_2^B > \overline{Q}_2$), regardless of the direction of the exchange, and the average allocation is diluted: $\bar{e} < \bar{\mu}$.

It is also straightforward to see here that an equivalent adjustment policy would be for the rate-based regulator to tighten the performance standard from $\bar{\mu}$ to $\bar{e}$. This would lead to the equivalent allocation and equilibrium under trade. Thus, the regulator should also prefer this tighter standard to facing adjusted trade or no trade, since costs are lower. The main difference is, of course, that the OBA allocation is endogenous and ensures the cap is always met, whereas if costs are uncertain, the revised standard may not accurately adjust for changes in emissions.

From the previous analysis, we know that if trade occurs, prices in sector 2 are lower than with no trade; that is, $P_2^A < P_2^*$ and $P_2^B < P_2^*$. However, we can also show that $P_2^B < P_2^A$. Therefore, if the regulator of sector 2 is concerned with consumer surplus, he will prefer output-based allocation of a cap equal to autarky emissions over adjusted trade without a cap.

Proposition 2 *Given any t, prices are lower and output higher in sector 2 with output-based allocation than with adjusted trade.*

Proof. Suppose instead $Q_2^A = Q_2^B$. Let $\alpha = \frac{\mu_2^A Q_2^A - \bar{\mu}\overline{Q}_2}{(\mu_2^A - \bar{\mu})Q_2^A}$, the adjustment factor that holds overall

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[8] Suppose the price were lower and output higher—then $\bar{e}$ would fall and the net tax would imply the price must be higher than autarky. If the price were higher, then lower output would imply a higher average allocation and a net subsidy, which would mean the price must be lower than autarky. Therefore, if $\bar{\mu}$ is the prevailing emission rate, $\bar{e} = \bar{\mu}$ must be the average allocation.

emissions constant. Then both price equations simplify to

$$P_2 = c_2(\mu_2) + t(\mu_2 - \bar{\mu}\overline{Q}_2/Q_2^B)$$

However, the equilibrium emissions rate cannot be the same under the adjustment policy as under OBA, since for any t, the trade adjustment implies a different permit price in sector 2. Since μ_2^B is optimal under OBA, and $\mu_2^A \neq \mu_2^B$, then costs must be higher with μ_2^A: $0 > c_2(\mu_2^B) - c_2(\mu_2^A) + t(\mu_2^B - \mu_2^A) = P_2^B - P_2^A$. Thus, it must be that prices are lower and output higher in the rate-based sector with OBA than with adjusted trade. ∎

In other words, the inefficiency of the adjustment mechanism lowers gains from trade and raises costs. The incidence of the cost differential would be distributed somewhat, since (assuming α is adjusted optimally) the allocation subsidy is somewhat larger (though not enough to offset the higher costs completely), and the permit price adjusts as well.

The impact on the market price for permits depends on the net impact on emissions in sector 2. Suppose first that $t_1 > t_B > t_2$, so sector 2 would export permits to sector 1. If $t_A = t_B$, we know that $\mu_2^A > \mu_2^B$ while $Q_2^A < Q_2^B$. Let us assume, as is likely, the emissions rate effect dominates the output effect. Then emissions in sector 2 are higher with adjusted trade than with OBA, and it does not export as many permits. Consequently, sector 1 must abate more than with OBA and the equilibrium permit price must be higher: $t_A > t_B$. If, on the other hand, $t_2 > t_B > t_1$; then $\mu_2^A < \mu_2^B$ when $t_A = t_B$. Lower emissions mean less demand to import from sector 1, which drives down the market price compared with the OBA scenario, so $t_A > t_B$. In other words, the permit price will remain closer to sector 1's autarky price with adjusted trade than with OBA, since not all the gains from trade will be dissipated.

In all scenarios, no rents exist in sector 2; they are completely dissipated to consumers. The lowest prices—and thereby the highest consumer surplus— in that sector occur with OBA, then adjusted trade with TPS, then no trade. For sector 1, production costs are increasing with the permit price, but so is the value of the emissions allocation. The net effect of a change in the

permit price then depends on the extent to which sector 1 is a net importer or exporter of permits: $dTS_1/dt = -Q_1 dP_1/dt + \bar{E} = \bar{E} - \mu_1 Q_1$. If $t_1 > t_2$, then sector 1 wants to import; since $t_A > t_B$ in that case, it suffers from the higher price from adjusted trade. If $t_2 > t_1$ and sector 1 wants to export permits, the fact that $t_A < t_B$ means that it profits less from adjusted trade. Thus, sector 1 will tend to prefer that sector 2 choose OBA as well. Either form of trade, however, is preferred to no trade by both sectors.

4.3 Tightening the Cap

Finally, the CAT regulator could also offset the effects of trade on emissions by simply tightening the cap in sector 1; let us denote this equilibrium with superscript C. The new lump-sum allocation would be $\bar{E} - \bar{\mu}(Q_2^C - \overline{Q}_2)$.

The TPS sector would undoubtedly be better off in this scenario, since it retains a larger allocation than with OBA. A consequence of this bigger subsidy is that product prices will be lower in the rate-based sector, and the expansion of output implies that permit prices must be higher to compensate.

Proposition 3 *Given any t, prices are lower and output higher in sector 2 with a reduction in the cap for sector 1 than with output-based allocation for sector 2 ($P_2^C < P_2^B$).*

Proof. This follows directly from $\bar{e} < \bar{\mu}$, since $P_2^C = c(\mu) + t(\mu - \bar{\mu}) < c(\mu) + t(\mu - \bar{e}) = P_2^B$. ∎

Corollary 4 *Permit prices are higher with a reduction in the cap for sector 1 than with output-based allocation for sector 2 ($t_C > t_B$).*

Proof. Suppose $t_C = t_B$; then $\bar{e} < \bar{\mu}$ implies $Q_2 > Q_2^B$, while $\mu_1 = \mu_1^B$, $\mu_2 = \mu_2^B$, and $Q_1 = Q_1^B$. Then total emissions are greater than the cap ($\mu_1^B Q_1^B + \mu_2^B Q_2 > \mu_1^B Q_1^B + \mu_2^B Q_2^B = \bar{E} + \bar{\mu}\overline{Q}_2$), which cannot be an equilibrium. Thus, demand for permits is higher and permit prices must rise ($t_C > t_B$) to encourage more abatement and output shifting until the cap is met. ∎

In other words, part of the incidence of the larger subsidy will reveal itself in higher permit prices and lower emissions rates in both sectors, to temper the effect of greater output in sector 2. However, the CAT sector may not be better off with trade under the tighter cap than with adjusted trade with the permit exchange rate. This depends on whether the value of the reduction in the allocation is greater than the gains from unrestricted trade. Since the change in surplus depends on net exports from sector 1, and those must equal imports from sector 2 ($\bar{E} - \mu_1^C Q_1^C = (\mu_2^C - \bar{\mu})Q_2^C$), we can write the change in total surplus for sector 1 as

$$
\begin{aligned}
TS_1^C - TS_1^A &= CS_1^C - CS_1^A + (t_C - t_A)\bar{E} - t_C\bar{\mu}(Q_2^C - \overline{Q}_2) \\
&\cong (t_C - t_A)(\mu_2^C - \bar{\mu})Q_2^C - t_C\bar{\mu}(Q_2^C - \overline{Q}_2),
\end{aligned}
$$

where we can see the sign depends on the relative magnitudes of the effects on permit prices, emissions rates, and output in sector 2.

If the allocation reduction is indeed larger, proposing a permit exhange rate regime will be a credible policy threat for country 1, which would be an inducement to country 2 to accept a tightening of its own standard. The existence of gains from trade also reveals that both sectors could be made better off with some combinations of tightening both the cap and the standard.

5   Conclusion

Decisionmakers around the world are voicing commitments to formulate policies to reduce greenhouse gas emissions using market-based mechanisms. Tradable emissions permit systems have long been lauded by economists for their ability to achieve environmental goals at least cost and maximum flexibility. However, putting a price on emissions means that whoever is given the initial right to the remaining emissions has a valuable asset, and allocating that asset can be a difficult political decision. If the government owns it, it gains valuable revenues; if incumbent firms own it, they gain profitable rents; and if they are distributed in proportion to output, consumers gain, at least in part. Furthermore, the initial goal of a tradable permit system can differ: a cap-and-trade

system targets a fixed emissions goal, while a tradable performance standard targets an average emissions intensity. These issues are exemplified in the current EU climate policy proposal for European emissions trading: member countries are directed to allocate their emissions allowances gratis, though each may determine by what method, and intensity mechanisms are allowed as well as emissions caps.

When two different emissions trading programs attempt to deal with the same pollution problem, like global warming, overall costs can be lowered by allowing trade between them. However, certain problems are posed when the programs differ in their design. Without some policy of adjustment or a switch to a fixed cap, allowing trade between a rate-based emissions program and a cap-and-trade program will tend to lead to an expansion of overall emissions. This expansion occurs regardless of the direction in which trade occurs when demand for the products of the two sectors is unrelated. If the product markets are strongly related, then emissions will still expand if the output price of a CAT competitor falls with cheaper permit imports, or if the output price of a complementary producer under a CAT rises with valuable permit exports.

When a goal of integration is to keep emissions from expanding, adjustments have to be made to offset the changes in allocation in the rate-based sector. Though the allocation changes could be done in either sector, or outside the system by governing authorities, it may be that holding emissions constant under trade is the mandate of the cap-and-trade sector. Jurisdictional differences may then require a policy that can be implemented unilaterally. An indirect tax on the products of the sector with rate-based regulation could be designed to hold output, and thereby emission allocations, constant under trade. An output tax would not distort incentives to reduce emissions rates either. However, such a tax would be difficult, if not illegal, to levy across jurisdictions. A permit exchange rate could also be set to expropriate additional allocations in the rate-based sector. This policy could be set by the regulator of the cap-and-trade sector, but some of the potential gains from trade would be forgone because marginal abatement costs would not be equalized. Furthermore, like the necessary output tax, this adjustment factor would be hard to predict and therefore difficult to administer. Finally, one could merely reduce the cap by the increase in the other sector's

allocation; however, this reduction in permit assets may outweigh the additional gains from trade to the CAT sector compared with adjusted trade, and therefore may not be acceptable.

Unsurprisingly, the simplest way to hold overall emissions constant is to have the TPS sector switch to a cap. More interesting is that switching to a fixed emissions cap with output-based allocation leads to lower consumer prices in that sector than if an adjustment policy is imposed. Thus, if earmarking emissions rents to the affected sector is important, the rate-based sector should actually prefer an output-allocated cap to a performance standard with a permit exchange rate. In general, the incentives for abatement are also more efficient, since the permit price is equalized across sectors.[9] The improved efficiency and larger gains from trade lead to higher combined gains in the cap-and-trade sector as well with output-allocated permits compared with an adjustment policy.

From a true welfare standpoint, though, it will be important to understand the market failures that drive the choice of rate-based allocations in the first place. General equilibrium effects can be especially important for welfare analysis, and they would have to be modeled carefully for the problem at hand: whether affected sectors trading in permits are small or large relative to the economy, whether their product markets are interdependent, whether permit trade occurs across countries, what the scope is for leakage to unregulated polluters, what the alternative uses of the revenues would be, and whether policymakers maximize welfare or are subject to political constraints. These factors will affect the desirability of different allocation policies. However, the main result remains: allowing trade between a cap-and-trade system and a tradable performance standard program requires some form of policy adjustment to keep emissions stable.

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[9]An exception might be if output substitution opportunities are an important means of emissions reduction in sector 2, but that tends to make rate-based policies less attractive in the first place.

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