International Coordination of Trade and Green Industrial Policies*

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Abstract

Green industrial policy is often justified as a way to loosen domestic political constraints on carbon mitigation. Yet politically effective green subsidies must discriminate in favor of domestic producers. These subsidies can have negative international spillovers, as they may lead to production relocation and profit shifting. In this paper I argue that green subsidies can also have negative *political* spillovers, as they make it more difficult for foreign policymakers to implement climate policy. To study this logic I develop a two-country model in which producers can adopt a dirty or green technology and the political weight of a sector scales with the number of domestic firms. In the noncooperative equilibrium, carbon taxes are too low and one of two outcomes obtains: a subsidy race, or international specialization, in which one country implements both subsidies and mitigation while the other remains stuck in a no-mitigation equilibrium. The optimal trade-climate agreement commits countries to free trade, sets a globally efficient carbon price, and allows but caps discriminatory green subsidies when domestic constraints bind. The results imply that post-WTO rules should coordinate (rather than prohibit) green subsidies: they can be instrumentally valuable for mitigation, but their uncoordinated use generates beggar-thy-neighbor political effects.

1. Introduction

Green industrial policies have emerged in part from the need to relax political constraints to more stringent climate policies (Meckling *et al.*, 2015, 2017; Juhász and Lane, 2024). This political logic requires that policies supporting green industries or inducing the decarbonization of polluting industries be targeted to politically pivotal domestic producers. For this reason, green industrial

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policies are public goods in the international arena but, crucially, also have a zero-sum component, as they shift investment and profits from foreign countries to the domestic economy (Allcott *et al.*, 2024). The zero-sum distributive implications of green industrial policies at the international level can lead to "subsidy races" (Clausing and Wolfram, 2023; The Economist Intelligence Unit, 2023). However, we lack a theoretical understanding of the welfare and political implications of this logic: will subsidy races accelerate the green transition and increase global welfare, or will competition on subsidies lead to inefficiencies, waste of fiscal resources, and potentially a political backlash to green policies?

Domestic content requirements in green industrial policies such as the Inflation Reduction Act violate World Trade Organization rules (Charnovitz and Fischer, 2015; World Trade Organization, 2024). This raises a second question: how would a post-WTO world deal with the increase in green subsidies across both developed and developing countries? We can speculate that new forms of international cooperation could emerge to ameliorate the zero-sum effects of green subsidies. For example, countries that want to keep free trade flows and at the same time support domestic green industries could coordinate their subsidies on different parts of critical supply chains.

To answer these questions, I develop a framework that integrates a theory of domestic climate policymaking into a model of international trade and climate cooperation. The economic model is based on the partial-equilibrium version of Venables (1987) (revisited by Ossa, 2011) presented in Helpman and Krugman (1989, Ch. 7), and revisited by Bagwell and Staiger (2015). The model features two economies with two sectors, one of which has monopolistic competition with increasing returns to scale and trade costs. The main feature of this model is the "firm delocation" effect, by which tariffs induce foreign firms to relocate in the home economy, which allows home consumers to save on transport costs. I introduce two innovations. First, I introduce two technologies into the monopolistically competitive sector, one of which releases carbon emissions and thus creates a global negative externality. This allows me to study climate policy, particularly carbon taxes and green industrial policy. Second, I introduce a political economy process that shapes the incentives and constraints of the policymaker. In a departure from the standard Grossman and Helpman (1994) approach, I assume that the *number* of firms determines the political power of any coalition of producers, rather than their willingness and ability to pay for policy concessions.[1] Through this channel, the "firm delocation" effect has political consequences, relaxing political constraints imposed by domestic polluters, but reducing the power of green producers abroad.

I find that in the optimal international agreement countries commit to free trade, a carbon tax equal to the global marginal cost of carbon emissions, and to green industrial policies if domestic political constraints bind. If countries do not coordinate climate policies, in contrast, carbon taxes are too low, because policymakers do not internalize the global climate externality. The main result

[1] See, e.g., Lohmann (2023) for a critique of the Grossman-Helpman approach.

of the paper is that, in addition, governments can engage in subsidy races. The reason is that the level of the subsidy required to create a large enough coalition of green producers in one country increases with the level of green subsidies in other countries. In addition to relaxing political constraints, green subsidies have direct positive effects on economic welfare, but these effects are zero-sum, as they operate by relocating green firms from the foreign to the domestic economy. The second main result is that the subsidy race is not the only possible noncooperative outcome. Another possibility (which depends on parameters) is that one country pursues climate policy and, as a consequence, policy inaction results in other countries.

The most important conceptual takeaway of the analysis is that even though green industrial policy can be desirable due to (inter alia) its capacity to reduce domestic political opposition to more efficient climate policies, it can have negative *political* spillovers on climate mitigation in other countries. While existing research has recognized the usefulness of green subsidies to relax political constraints (e.g., Hallegatte *et al.*, 2024), and their international economic spillovers, in particular the "reverse leakage" effect (Kotchen and Maggi, 2025), the point that uncoordinated green subsidies can be ineffective has not been considered in previous work.

The immediate normative implication of the analysis is that countries should coordinate their use of green subsidies. A more subtle implication is that international trade law should allow for discriminatory green subsidies but should regulate them, since there are non-environmental (essentially protectionist) incentives to use them. Existing international trade agreements incorporate provisions on environmental regulation, particularly about leakage (Brandi and Morin, 2023), but to the best of my knowledge no trade agreement has explicitly regulated the use of green subsidies. Reducing the damages from climate change will require both free trade (Le Moigne *et al.*, 2024) and green industrial policies, so the future will require their coordination.

Literature. The main contribution of the paper is to provide a model of subsidy races, and study their implications for international cooperation, in particular for international trade law. Clausing and Wolfram (2023) discuss subsidy races informally. Here I provide an explicit model that clarifies the forces that produce the subsidy race, namely, a combination of firm delocation and domestic political constraints. I show that a subsidy race is not the only possible outcome: without international cooperation, subsidies in one country may simply deter other countries from pursuing climate policies, leading to a pattern of international specialization consistent with the argument in Kennard and Melnick (2025).

There is a large literature in economics and political science on international climate agreements, some of which studies the linkage of trade and climate policy (e.g., Nordhaus, 2015; Farrokhi and Lashkaripour, 2025). The only papers that study international cooperation on both carbon taxes and green subsidies with international trade are Kotchen and Maggi (2025) and Kay (2025). In their models green subsidies are valuable because they have a "reverse leakage" effect: a subsidy on green goods reduces world prices, including that of polluting goods, which reduces their production. Both papers find that optimal international agreements have no green subsidies (only pollution taxes), but optimal noncooperative policies involve green subsidies. In their models there is no mechanism that generates a subsidy race. In Kotchen and Maggi (2025) lobbying by green producers induces policymakers to increase green subsidies (due to a simple quid-pro-quo, and not because green subsidies relax political constraints), and can improve welfare in the noncooperative equilibrium simply because it leads to more emissions abatement. The difference with my model is that I consider market imperfections that create a non-environmental reason to use green subsidies, which is consistent with empirical studies on the effects of subsidies (Allcott *et al.*, 2024). The reverse leakage effect is not dominant in my model; in fact, green subsidies in one country can increase carbon emissions in other countries due to the green delocation effect.

The idea that industrial policy more broadly has international spillovers and may require coordination in order to be effective is not new: see Lashkaripour and Wu (2025).

Comment. I'll add all the relevant citations in the future (including all the political science I didn't cite nor discuss, sorry!), and I'll add more on the facts that motivate the question. Important questions that I plan to address include what is the best international agreement that can be enforced using WTO procedures as in Bagwell and Staiger (2001) or a "climate club" that includes subsidies as threats. I plan to extend the analysis to a Melitz-style model building on Costinot *et al.* (2020).

2. The Model

2.1. *Preliminaries*

I develop a model with the following features:

- There are two countries ("home" and "foreign").
- There is an industry with a fixed continuum of locations, each of which produces a distinct variety. Producers are monopolistic.
- There are two technologies available in each location: a polluting and a green technology.
- The green technology has a fixed cost, which creates increasing returns to scale.
- There is international trade with transport costs.
- Governments have access to carbon taxes, green industrial subsidies, tariffs, and consumption taxes.
- Governments maximize aggregate welfare, but policy changes require the approval of a certain number of locations. (This feature creates political constraints.)

The combination of love of variety, increasing returns to scale, free entry and transport costs creates a welfare rationale for the use of unilateral tariffs due to their "firm delocation" effect

(Venables, 1987; Helpman and Krugman, 1989; Ossa, 2011; Bagwell and Staiger, 2015). The intuition is as follows. Unilaterally increasing the cost of imports increases demand for domestic varieties. This increase in demand encourages the marginal producer to pay the fixed cost to reach the necessary scale and start operating, and does not increase domestic prices (which are equal to marginal cost times a fixed markup). Therefore, more varieties are produced at home, which saves consumers the transport costs and increases aggregate welfare. However, this normatively positive effect for the home economy comes at the expense of the foreign economy. Reducing domestic demand for foreign varieties induces the marginal foreign firm to exit the market. This is interpreted as the "delocation" effect: we can think of the marginal foreign producer as relocating to the home country in response to the tariff. Foreign consumers now have to pay transport costs for more products, which reduces their welfare. Because this incentive to raise tariffs is symmetric and negative-sum, both countries have a reason to sign a trade agreement. The optimal trade agreement involves no tariffs.

In my model, which features a fixed number of varieties and a technology choice that involves a fixed switching cost, asymmetric barriers to trade have a "green delocation" effect. The reason is that creating a barrier for imports increases demand for domestic varieties. This, in turn, induces the marginal polluting firm to adopt the green technology if doing this reduces marginal costs (due to technological differences or to policy, e.g., a carbon tax or a regulatory standard). Thus, more firms become green in the domestic economy, and they increase their exports due to their lower marginal cost. This, in turn, increases competition abroad, which leads the marginal green firm to become unprofitable. If foreign firms anticipate the policy, the marginal firm planning to adopt the green technology will decide to keep using the polluting technology instead. The implication of this argument is that asymmetric trade restrictions can reduce emissions at home at the expense of increasing emissions abroad.

Domestic climate policy also has a "green delocation" effect. Reducing carbon emissions requires making the green technology more profitable than the polluting technology. This leads to an increase in the number of firms using the green technology at home. Assuming, again, that these firms have lower marginal costs, increasing their number creates more competition for firms abroad, which reduces their profitability, which leads some green firms to exit (or some polluting firms to hold back costly investments in abatement). We can interpret this shift as green investments being relocated from the foreign to the domestic economy.

2.2. *Model of the Economy*

There are two countries, 1 and 2 (Home and Foreign), a continuum of varieties $v \in [0, 1]$ of a good M per country, and a numéraire good N, which is freely traded. Varieties face an iceberg trade cost $\theta > 1$, so that shipping a quantity q from i to j requires producing θq units of the good.

Consumer preferences in country j are given by

$$U_j = \log\left(\sum_{i=1}^{2}\int_0^1 m_{ij}(v)^{\frac{\sigma-1}{\sigma}}\,dv\right)^{\frac{\sigma}{\sigma-1}} + N_j - D_j,$$

where $m_{ij}(v)$ the quantity of variety v from i consumed in j, $\sigma > 1$ is the elasticity of substitution of varieties, N_j is the quantity of the numéraire consumed in j, and D_j is climate damages, defined shortly. Country i is endowed with labor L_i. Technology is the same in both countries. Each variety $v \in [0,1]$ can be produced with a green or a polluting technology. The green technology has labor cost $l = f + cq$ to produce q units, where $f > 0$ is a fixed cost and $0 < c < 1$ is the marginal cost, and the polluting technology has labor cost $l = q$. Producing q units of the numéraire requires labor $l = q$. Producers of varieties are monopolists, and the numéraire good is produced competitively. Climate damages are

$$D_i \equiv \gamma \sum_{j=1}^{2}\int_0^1 \chi_j(v) q_j(v)\,dv,$$

where $\chi_j(v) \in \{0,1\}$ is 1 iff country j produces v with the polluting technology, $q_j(v)$ is the units of variety v produced at j, and γ measures the social cost of carbon. Let $g_i = 1 - \int_0^1 \chi_i(v)\,dv$ be the share of varieties produced with the green technology. Throughout the paper I will assume that in equilibrium $0 < g_i < 1$.

Country i imposes a carbon tax $\tau_i \geqslant 0$ paid per unit of the M variety produced using the polluting technology, and a green subsidy $s_i \geqslant 0$ offered to producers that choose the green technology. In addition, it charges an ad-valorem import tariff t^i_{ji} and an export tax t^i_{ij} to M varieties. Thus, if $p_i(v)$ is the domestic price of variety v at i, j consumers pay price $p_{ij}(v) \equiv t_{ij}\theta p_i(v)$, where $t_{ij} \equiv 1 + t^i_{ij} + t^j_{ij}$ includes both i's export tax and j's import tax. We define $p_{ii}(v) \equiv p_i(v)$. The numéraire faces a consumption tax $\frac{1}{\sigma-1}$ required to compensate for the monopoly distortion in the market for M varieties.

The numéraire good is produced competitively and freely traded, so the wage is 1 in both countries. Varieties are produced by monopolists, who set ex-factory prices $p_i(v) = \frac{\sigma}{\sigma-1}c_i(v)$, where $\frac{\sigma}{\sigma-1}$ is a markup (implied by CES demand) and $c_i(v)$ is the marginal cost. Green varieties have a marginal cost $c_i(g) \equiv c$, and polluting varieties have a marginal cost $c_i(b) \equiv 1 + \tau_i$. There is a tax $\frac{1}{\sigma-1}$ on the numéraire, so demand for variety v is given by

$$m_{ij}(v) = \frac{\sigma}{\sigma-1}P_j^{\sigma-1}p_{ij}(v)^{-\sigma},$$

where $P_j = \left(\sum_{i=1}^{2} \int_0^1 p_{ij}(v)^{1-\sigma}\, dv\right)^{\frac{1}{1-\sigma}}$ is the "price index" of M. Profits are

$$\pi_i(v) = \frac{1}{\sigma - 1} c_i(v) q_i(v) - f_i(v),$$

where $f_i(v) = f - s_i$ is the fixed cost net of the green subsidy if v is produced using the green technology, and $f_i(v) = 0$ if v is produced using the polluting technology.

The indirect utility of a consumer with pre-tax income Y_i is given by

$$V_i(Y_i) \equiv -\log P_i + Y_i + T_i - D_i$$

plus a constant, where

$$T_i \equiv \tau_i(1 - g_i) q_i(b) - g_i s_i + \int_0^1 t^i_{ij} \theta p_i(v) m_{ij}(v)\, dv + \int_0^1 t^i_{ji} \theta p_j(v) m_{ji}(v)\, dv$$

is the lump-sum transfer net of the tax on the numéraire. Aggregate utility is

$$W_i \equiv -\log P_i + \int_0^1 \pi_i(v)\, dv + T_i - D_i$$

plus a constant.

2.3. *Model of the Policy Process*

The status quo policy is no carbon taxes, no green subsidies, and no trade taxes on M, i.e., $\tau_i = s_i = t^i_{ij} = t^i_{ji} = 0$. The policymaker in country i can change policies but requires the support of a fraction $n_i \in [0, 1]$ of M producers. The policymaker seeks to maximize aggregate utility W_i, and producers maximize their indirect utility $V_i(\pi_i)$. Timing of events:

1. Policymakers simultaneously choose green subsidies s_i.
2. Producers simultaneously choose technology.
3. Policymakers simultaneously choose carbon taxes τ_i and trade taxes t^i_{ij}, t^i_{ji}.
4. Production and consumption takes place.

I will consider several variations, including ones in which choices are restricted (e.g., trade taxes are not available due to a free trade agreement). The assumption that carbon and trade taxes are chosen after technology choices captures the fact that investing in green technology takes time, and policymakers cannot commit to keep carbon and trade taxes fixed once investments are made.

3. Climate Policy in Autarky

Before I analyze the full model, let's study a version of the model with only one country. We can drop subscripts.

3.1. *No Political Constraints*

Without political constraints, optimal policy consists in carbon taxes equal to marginal climate damage, $\tau = \gamma$, and no green subsidies, $s = 0$. This policy choice is time-consistent, because the optimal carbon tax does not depend on the number of firms using green technology.

We can prove this standard result by noting that $\tau = \gamma$ and $s = 0$ in fact implement the optimal allocation: given g, the planning problem consists in choosing quantities $m(v), N$ and technology $\chi(v) \in \{0, 1\}$ to maximize

$$W = \log M + N - \gamma \int_0^1 \chi(v)m(v)\, dv$$

with $M = \left(\int_0^1 m(v)^{\frac{\sigma-1}{\sigma}}\, dv\right)^{\frac{\sigma}{\sigma-1}}$ subject to the resource constraint

$$\int_0^1 (f(v) + c(v)m(v))\, dv + N = L,$$

where $f(v) = (1 - \chi(v))f$ and $c(v) = \chi(v) + (1 - \chi(v))c$. The solution has $m(v) = \tilde{P}^{\sigma-1}\tilde{p}(v)^{-\sigma}$ with $\tilde{p}(v) = c(v) + \chi(v)\gamma$ and $\tilde{P} = \left(\int_0^1 \tilde{p}(v)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$.

The decentralized allocation with $\tau = \gamma$, $s = 0$, and a tax $\frac{1}{\sigma-1}$ on the numéraire is $m(v) = \frac{\sigma}{\sigma-1}P^{\sigma-1}p(v)^{-\sigma}$ with $p(v) = \frac{\sigma}{\sigma-1}(c(v) + \chi(v)\tau)$ and $P = \left(\int_0^1 p(v)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$. Technology choices are such that firms are indifferent in equilibrium, which happens if profits are equalized:

$$\frac{1}{\sigma}p(b)m(b) = \frac{1}{\sigma}p(g)m(g) - f + s.$$

In the optimal allocation, the Lagrangian is

$$\mathcal{L} = \log M + L - \int_0^1 (f(v) + c(v)m(v))\, dv - \gamma \int_0^1 \chi(v)m(v)\, dv - \lambda\left(M^{\frac{\sigma-1}{\sigma}} - \int_0^1 m(v)^{\frac{\sigma-1}{\sigma}}\, dv\right).$$

Maximization on $m(v)$ requires $1 + \gamma = \lambda\frac{\sigma-1}{\sigma}m(b)^{-\frac{1}{\sigma}}$ and $c = \lambda\frac{\sigma-1}{\sigma}m(g)^{-\frac{1}{\sigma}}$, and the optimal technology choice requires

$$(1 + \gamma)m(b) - \lambda m(b)^{\frac{\sigma-1}{\sigma}} = f + cm(g) - \lambda m(g)^{\frac{\sigma-1}{\sigma}},$$

which using the FOCs is $\frac{1}{\sigma-1}(1+\gamma)m(b) = \frac{1}{\sigma-1}cm(g) - f$, the same as in the decentralized equilibrium setting $\tau = \gamma$ and $s = 0$.

3.2. *Political Constraints*

Profits using the polluting technology are decreasing in the carbon tax:

$$\pi(b) = \frac{1}{\sigma}p(b)m(b) = \frac{1}{\sigma-1}P^{\sigma-1}p(b)^{1-\sigma} = \frac{1}{\sigma-1}\frac{p(b)^{1-\sigma}}{gp(g)^{1-\sigma} + (1-g)p(b)^{1-\sigma}}$$

with $p(b) = \frac{\sigma}{\sigma-1}(1+\tau)$, so clearly $\frac{d\pi(b)}{d\tau} < 0$. As long as this effect dominates the positive effect due to the reduction in climate damages, which is the case if γ is not too large, polluters refuse to accept an increase in carbon taxes.

Producers who adopted the green technology, in contrast, benefit from an increase in the carbon tax, because it reduces their competition from polluting producers and increases their profits (in addition to reducing climate damages and increasing fiscal revenue).

Therefore, if the number of green producers in the optimal allocation is smaller than the size of the minimal coalition required to implement a policy change ($g^* < n$), the optimal policy cannot be implemented. Now, using the green subsidy increases the number of green producers, and therefore in equilibrium the policymaker needs to use the subsidy so that $g = n$, and then set $\tau = \gamma$. If this policy increases aggregate welfare relative to the status quo, it will be acceptable to the coalition of producers who decide to adopt the green technology, because they benefit from climate policy more than the average individual.

In other words, political constraints may force policymakers to use green subsidies, even though there isn't a welfare rationale for the subsidies in the model.

4. Analysis

4.1. *Benchmark: International Cooperation without Political Constraints*

Suppose that policymakers in both countries can choose policies without political constraints, and coordinate their policies in a negotiated international agreement. The same argument in Subsection 3.1 can be used to show that the optimal allocation can be implemented setting $\tau_i = 2\gamma$, $s_i = 0$, and no trade taxes.

International cooperation without domestic political constraints involves more ambitious climate change mitigation policies (because countries agree to internalize the externality they impose on each other) and free trade. Green subsidies are not needed: with the right carbon price, producers make the socially optimal choices regarding pollution abatement.

However, domestic political constraints can prevent policymakers from implementing their policy commitments. If the equilibrium number of green firms given $\tau_i = 2\gamma$ and $s_i = 0$ is smaller than the size of the minimal coalition, policymakers will not be able to ratify the agreement at home.

I ask two questions. First, what is the second-best international agreement subject to domestic political constraints? Second, what are equilibrium policies if countries decide climate policies unilaterally?

4.2. *International Cooperation with Binding Political Constraints*

The global optimal allocation problem is to maximize

$$\sum_{i=1}^{2} W_i = \sum_{i=1}^{2} (\log M_i + N_i - D_i)$$

subject to

$$M_i^{\frac{\sigma-1}{\sigma}} = \sum_{j=1}^{2} \int_0^1 m_{ji}(v)^{\frac{\sigma-1}{\sigma}} \, dv,$$

the aggregate resource constraint

$$\sum_{i=1}^{2} \left\{ \int_0^1 [f_i(v) + c_i(v)(m_{ii}(v) + \theta m_{ij}(v))] \, dv + N_i \right\} = \sum_{i=1}^{2} L_i,$$

and the domestic political constraints $g_i \geqslant n_i$.

The Langrangian is

$$\begin{aligned}\mathcal{L} = & \sum_{i=1}^{2} \left\{ \log M_i - \int_0^1 [f_i(v) + (c_i(v) + 2\gamma\chi_i(v))(m_{ii}(v) + \theta m_{ij}(v))] \, dv \right\} \\ & - \sum_{i=1}^{2} \frac{\sigma}{\sigma-1} \lambda_i \left(M_i^{\frac{\sigma-1}{\sigma}} - \sum_{j=1}^{2} \int_0^1 m_{ji}(v)^{\frac{\sigma-1}{\sigma}} \, dv \right) + \sum_{i=1}^{2} \mu_i (g_i - n_i),\end{aligned}$$

with $\lambda_i \in \mathbb{R}$, $\mu_i \geqslant 0$ and $\mu_i(g_i - n_i) = 0$. Taking $\frac{d\mathcal{L}}{dM_i} = 0$ we obtain $\lambda_i = M_i^{\frac{1-\sigma}{\sigma}}$. For almost every v we must have $m_{ij}(v)^{-\frac{1}{\sigma}} = M_i^{\frac{\sigma-1}{\sigma}} \theta_{ij}(c_i(v) + \gamma\chi_i(v))$, i.e., $m_{ij}(v) = M_j^{1-\sigma} \tilde{p}_{ij}(v)^{-\sigma}$, where $\tilde{p}_{ij}(v) \equiv \theta_{ij}(c_i(v) + 2\gamma\chi_i(v))$. This is equivalent to $m_{ij}(v) = \frac{\sigma}{\sigma-1} P_j^{\sigma-1} p_{ij}(v)^{-\sigma}$ with $P_j = \left(\sum_{i=1}^{2} \int_0^1 p_{ij}(v)^{1-\sigma} \, dv \right)^{\frac{1}{1-\sigma}}$ and $p_{ij}(v) = \frac{\sigma}{\sigma-1} \tilde{p}_{ij}(v)$. What is the optimal technology choice? Taking $\frac{d\mathcal{L}}{dg_i} = 0$ we obtain

$$\frac{1}{\sigma-1}(1 + 2\gamma) q_i(b) = \frac{1}{\sigma-1} c q_i(g) - (f - \mu_i),$$

where $q_i(b) = m_{ii}(v) + \theta m_{ij}(v)$ if $\chi_i(v) = 1$ and $q_i(g) = m_{ii}(v) + \theta m_{ij}(v)$ if $\chi_i(v) = 0$. This is equivalent to

$$\frac{1}{\sigma} p_i(q) q_i(b) = \frac{1}{\sigma} p_i(b) q_i(b) - (f - \mu_i),$$

where $p_i(q) = \frac{\sigma}{\sigma-1}(1+2\gamma)$ and $p_i(b) = \frac{\sigma}{\sigma-1}c$, which is a profit equality condition. By inspection it's clear that this allocation can be implemented setting $\tau_i = 2\gamma$, $s_i = \mu_i$, and no trade taxes.

In sum, the optimal international agreement subject to domestic political constraints involves carbon taxes equal to the (global) social cost of carbon, free trade, and green industrial subsidies if political constraints are binding.

4.3. *The Effect of Policies in the Decentralized Equilibrium*

Before I study optimal policies, I will show how policies affect equilibrium prices, quantities, and technology choices. First, suppose that technology choices are endogenous.

Market clearing for varieties requires

$$q_i(v) = \sum_{j=1}^{2} \theta_{ij} m_{ij}(v) = \frac{\sigma}{\sigma - 1} \sum_{j=1}^{2} P_j^{\sigma-1} \theta_{ij}^{1-\sigma} t_{ij}^{-\sigma} p_i(v)^{-\sigma}$$

at both countries i. The technology choice is such that firms are indifferent in equilibrium, and thus profits are equalized:

$$\pi_i = \frac{1}{\sigma} p_i(b) q_i(b) = \frac{1}{\sigma} p_i(g) q_i(g) - f_i^s,$$

where $q_i(b), q_i(g)$ are the quantities produced for varieties using the polluting and green technology, respectively, and $f_i^s \equiv f - s_i$. In addition, $\frac{q_i(b)}{q_i(g)} = \left(\frac{p_i(b)}{p_i(g)}\right)^{-\sigma}$, so

$$q_i(g) = \frac{p_i(g)^{-\sigma} \sigma f_i^s}{p_i(g)^{1-\sigma} - p_i(b)^{1-\sigma}}, \quad q_i(b) = \frac{p_i(b)^{-\sigma} \sigma f_i^s}{p_i(g)^{1-\sigma} - p_i(b)^{1-\sigma}}, \quad \pi_i = \frac{p_i(b)^{1-\sigma} f_i^s}{p_i(g)^{1-\sigma} - p_i(b)^{1-\sigma}}.$$

Now, equal profits implies $p_i(g) q_i(g) - p_i(b) q_i(b) = \sigma f_i^s$, so

$$\sum_{j=1}^{2} P_j^{\sigma-1} \theta_{ij}^{1-\sigma} t_{ij}^{-\sigma} = \frac{(\sigma - 1) f_i^s}{p_i(g)^{1-\sigma} - p_i(b)^{1-\sigma}}.$$

Solving, we obtain

$$P_i^{\sigma-1} = \sum_{j=1}^{2} \frac{(-1)^{i-j} \theta_{ij}^{1-\sigma} t_{ij}^{-\sigma}}{1 - \theta^{2-2\sigma} t_{ij}^{-\sigma} t_{ji}^{-\sigma}} \frac{(\sigma - 1) f_j^s}{p_j(g)^{1-\sigma} - p_j(b)^{1-\sigma}}.$$

By definition,

$$P_j^{1-\sigma} = \sum_{i=1}^{2} [g_i p_{ij}(g)^{1-\sigma} + (1-g_i) p_{ij}(b)^{1-\sigma}],$$

i.e.,

$$\sum_{i=1}^{2} g_i (p_i(g)^{1-\sigma} - p_i(b)^{1-\sigma}) \theta_{ij}^{1-\sigma} t_{ij}^{1-\sigma} = P_j^{1-\sigma} - \sum_{i=1}^{2} p_{ij}(b)^{1-\sigma},$$

so

$$g_i = \frac{1}{p_i(g)^{1-\sigma} - p_i(b)^{1-\sigma}} \sum_{j=1}^{2} \frac{(-1)^{i-j} \theta_{ji}^{1-\sigma} t_{ji}^{1-\sigma}}{1 - \theta^{2-2\sigma} t_{ij}^{-\sigma} t_{ji}^{-\sigma}} \left(P_j^{1-\sigma} - \sum_{k=1}^{2} p_{kj}(b)^{1-\sigma} \right).$$

Now, suppose that technology choices (the numbers g_i) are given. Domestic prices $p_i(v)$ are marginal cost including the carbon tax times the markup $\frac{\sigma}{\sigma-1}$, and international prices are given by $p_{ij}(v) = t_{ij}\theta p_i(v)$. Price indices are given by $P_j^{1-\sigma} = \sum_{i=1}^{2} [g_i p_{ij}(g)^{1-\sigma} + (1-g_i) p_{ij}(b)^{1-\sigma}]$, so quantities are given by $m_{ij}(v) = \frac{\sigma}{\sigma-1} P_j^{\sigma-1} p_{ij}^{-\sigma}$.

Let's consider the effect of carbon taxes and green subsidies. If technology choices are endogenous, an increase in the carbon tax or the green subsidy in country i, τ_i or s_i, increases the price of polluting varieties $p_i(b)$ and reduces the cost of green technology f_i^s, respectively, which reduces the price index of M at home P_i and increases the price index of M abroad, P_j. This is apparent from the formula

$$P_i^{\sigma-1} = \frac{1}{1 - \theta^{2-2\sigma} t_{ij}^{-\sigma} t_{ji}^{-\sigma}} \left(\frac{(\sigma-1) f_i^s}{p_i(g)^{1-\sigma} - p_i(b)^{1-\sigma}} - \theta^{1-\sigma} t_{ji}^{-\sigma} \frac{(\sigma-1) f_j^s}{p_j(g)^{1-\sigma} - p_j(b)^{1-\sigma}} \right).$$

This implies that $\frac{dg_i}{d\tau_i} > 0$, $\frac{dg_i}{ds_i} > 0$, $\frac{dg_j}{d\tau_i} < 0$ and $\frac{dg_j}{ds_j} < 0$ by looking at the formula $P_j^{1-\sigma} = \sum_{i=1}^{2} [g_i p_{ij}(g)^{1-\sigma} + (1-g_i) p_{ij}(b)^{1-\sigma}]$, i.e., a carbon tax or a green subsidy at i increases the number of green varieties at home and reduces the number of green varieties abroad. In other words, both carbon taxes and green subsidies have a “green delocation” effect, which increases aggregate welfare, even ignoring climate damages. However, they reduce profits at home, so their net effect is ambiguous. Without international trade and climate damages climate policy is simply distortionary, and so the optimal policies are $\tau_i = 0$ and $s_i = 0$, but for that reason the efficiency effect of a small carbon tax or a small green subsidy is second order. With international trade, however, a small carbon tax or a small green subsidy have a positive net effect, because the efficiency effect is second order but the green delocation effect is positive and first order.

The important implication is that international trade creates an effect of climate policies on welfare that is distinct from the reduction in climate damages. This is because both carbon taxes and green subsidies produce green delocation, which is beneficial for the domestic economy. Now, while carbon taxes are the best policy instrument to reduce carbon emissions, green industrial subsidies are the better instrument to induce green delocation.

If technology choices are fixed, however, the only effect of carbon taxes is to raise prices, which hurts consumers in both countries, and to reduce profits, which hurts domestic producers. Therefore, in this case the only motivation for a policymaker to use carbon taxes is to correct the climate externality. The implication of this result is that, absent political constraints, countries can decouple trade and climate agreements. A trade agreement that commits countries to free trade and prohibits subsidies leaves countries with the right incentives and the right instruments to cooperate on climate change mitigation.

(Notice, however, that absent climate cooperation countries have a legitimate reason to use trade policy for climate mitigation. This is because a carbon tax at home increases demand for polluting foreign varieties, i.e., it has the well-known leakage effect.)

4.4. *Subsidy Races and Asymmetric Inaction*

I haven't yet found an analytical characterization of the noncooperative optimal policies (I'm working on it). But I have run some numerical simulations. Suppose that countries are committed to free trade, so $t_{ij} = 1$.

I take $\sigma = 8$, $\theta = 1.25$, $c = 0.8$, and f such that without any climate policy we have $g = 0.3$. Even without climate damages (i.e., $\gamma = 0$) the optimal unilateral policy involves a positive green subsidy, $s_i \approx 0.03$, which increases the number of domestic green firms to $g_i \approx 0.42$, and reduces the number of foreign green firms to $g_j \approx 0.25$. Carbon emissions at home are reduced by 27% relative to no climate policies, and they increase abroad by 7%. Notice that the green delocation effect dominates the "reverse leakage" effect of green subsidies.

With climate damages $\gamma = 0.04$, the optimal unilateral policy involves a carbon tax $\tau_i \approx 0.0271$ (notice: $\tau_i < \gamma$ due to the leakage effect) and a green subsidy $s_i \approx 0.027$ (notice: it's smaller than without a climate mitigation objective!). The number of domestic green firms is $g_i \approx 0.49$, and the number of foreign green firms is $g_j \approx 0.24$. If we impose a political constraint $g_i \geqslant n_i = 0.5$, both the subsidy and the carbon tax increase (to $s_i \approx 0.029$ and $\tau_i \approx 0.0274$); carbon emissions go down at home but increase abroad (they go down globally).

The Nash equilibrium policies with $\gamma = 0$ are $s_i = s_j \approx 0.034$, with $g_i = g_j \approx 0.39$. This shows that the subsidy race occurs even without climate mitigation objectives. With $\gamma = 0.04$, the Nash equilibrium policies are $\tau_i = \tau_j \approx 0.021$ and $s_i = s_j \approx 0.038$. We see the subsidy race: both countries increase their subsidies from 0.027 to 0.038, and reduce their carbon taxes from 0.027 to 0.021, as a response to each other's unilateral policies. The number of green firms is $g_i = g_j \approx 0.44$.

If we impose a political constraint $n_i = n_j = 0.5$, the Nash equilibrium is $s_i = s_j \approx 0.054$ and $\tau_i = \tau_j \approx 0.0213$. Political constraints intensify the subsidy race, and reduce carbon emissions by 17% at the expense of reducing aggregate welfare (account for climate damages) by 1.5%. In contrast, an optimal international agreement subject to the same political constraints reduces carbon emissions by 44% while increasing aggregate welfare by 1.5%. It achieves this by imposing the optimal carbon tax $\tau_i = \tau_j = 2\gamma$ and capping the subsidies at $s_i = s_j \approx 0.03$.

Now, suppose that $n_j = 0.75$. Then the Nash equilibrium is $(s_i, \tau_i) \approx (0.029, 0.027)$ and $s_j = \tau_j = 0$. The level of subsidies needed to implement climate policy in the second country is so large that the policymaker gives up, and prefers not to implement climate policies. With $n_j = 0.72$ country j would implement climate policy $(s_j, \tau_j) \approx (0.06, 0.032)$ if i is inactive, but i's best response is to implement $(s_i, \tau_i) \approx (0.06, 0.02)$. But in that case j's best response is not to implement any climate policy. This is not an equilibrium, however: if j is inactive, i's best response is to implement $(s_i, \tau_i) \approx (0.03, 0.027)$. This is also not an equilibrium, because with such a low subsidy from i, j can again implement a climate policy. As it turns out, there is no pure-strategy Nash equilibrium: country i has to choose a large subsidy with some probability in order to deter j, who, in turn, must implement positive subsidies with some probability.

This example illustrates that subsidy races are not the only possible outcome: asymmetric inaction (or, in other words, international specialization) can occur, and countries may use large subsidies to deter other countries from developing their own climate policies.

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