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## Green subsidies as strategic trade policy tools

Domenico Buccella, Luciano Fanti and Luca Gori\*

**Abstract** In a three-country model in which export countries adopt environmental policies, this note analyses how abatement (“green”) subsidy can become a potential strategic trade policy tool. When governments set the optimal policy tool considering their local environmental damages, a rich set of equilibria arise. In contrast to the standard result, it is shown that subsidising pollution abatement can 1) emerge as a Pareto-efficient equilibrium of the game; and 2) be the only feasible environmental policy when environmental awareness is low, irrespective of the technological efficiency. Therefore, “green” subsidies can lead to a win-win situation.

**Keywords** Abatement subsidy; Exports; International duopoly

**JEL Classification** H23; F13; L13

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## 1. Introduction

The provision of cost-reducing subsidies for exporting firms is a keystone of the public intervention in several manufacturing sectors. As WTO rules generally forbid subsidies, in recent decades governments have adopted well-designed industrial policies (The Economist, 2013), and in the recent months (The Economist, 2023a,b) environmental policies as pseudo-strategic trade policy tools.

Consider, for instance, the “architecture of subsidies”, included in the Inflation Reduction Act (IRA) of the Biden Administration, in the US, related to clean energy and “green” transition, \$400bn for green tech in ten years. On surface, the official motivation for introducing those subsidies is the need to fight climate change, which predominantly stems from greenhouses gas emissions from the combustion of fossil fuels for manufacturing and services production. Deep down, it seems that those measures are mainly designed to harm Chinese exports.

Nonetheless, they have also generated harsh reactions in the EU and among US “alleys” Asian countries like Japan and South Korea. French and German ministers have declared that they want “a new green industrial policy”; European Commission president Ursula von der Leyen has called for “our European IRA” (Financial Times, 2023). The Economist (2023a) reports that a senior Asian diplomat in Washington declared that “Free trade is dead. It’s a basic game theory. When one side breaks the rule, other soon break the rules, too. If you stand still, you will lose the most”.

Indeed, this is the results of the standard model of strategic trade policy due to Brander and Spencer (1985): in the case of quantity competition, to provide subsidies create a competitive advantage when other rival countries do nothing; if the other country counter-react with a subsidy policy, the outcome is a prisoner dilemma in which both countries would have been better off without policy intervention policy (see Krugman, 1986, Helpman and Krugman, 1989, and Brander, 1995 for earlier surveys of classical issues in this strand of the literature, and Fanti and Buccella, 2023 and the works quoted therein for recent developments).

Commentators at The Economist (2023a, b) seems to share those concerns; on the other hand, observers at Financial Times (2023) have a more cautious and optimistic approach because, in their opinion, “Climate change is the biggest market failure the world has ever known and a subsidy race in green-tech and carbon-free energy would be a race to the top not the bottom.” Aim of this note is to provide a first insight on the use of “green” subsidies as a tool of strategic trade policy and launch a discussion on this renewed debate on the use of environmental policies to improve the national welfares of countries involved in international trade.

In doing so, a basic two-stage game, three-country model is developed. In the first stage, a social welfare maximizing government optimally chooses the environmental policy tool for the exporting polluting firm: either an emissions tax or an abatement subsidy. In the second stage, Cournot duopolists compete in the third market, choosing simultaneously output and abatement levels. The key result of the analysis is as follows.

Depending on the societal awareness toward the environment and the available abatement technology, a rich set of equilibria arise. However, contrary to the standard result with cost-reducing subsidy per unit of output, it is found that to subsidise pollution abatement can emerge as a Pareto-efficient equilibrium for low environmental awareness. Moreover, abatement subsidy is the only feasible policy when the environmental awareness is low, irrespective of the available technology. Therefore, if governments consider the impact of the environmental damage in the design of the environmental policy for exporting sectors, the provision of “green” subsidies can lead to a win-win situation. Our results offer novel and interesting policy implications.

The reminder of this note proceeds as follows. Section 2 develops the model and presents the main results. Section 3 closes launching a discussion about “green” strategic trade policy and outlining potential routes for further investigation.

## 2. The model and the results

We consider a single polluting industry consisting of two firms, 1 and 2, located in two exporting countries, which produce homogeneous goods,  $q_1$  and  $q_2$ , sold to a third country, an importing country, competing à la Cournot. Firm  $i$  uses a linear technology to produce  $q_i$  units of the goods, leading to constant (marginal) cost set equal to zero for analytical tractability, and without loss of generality.

Production generates  $e_i$  units of pollution, with  $e_i = q_i - k_i$  (Ulph, 1996), where  $k_i \in [0, q_i)$  is the abatement level to reduce the environment impact, deriving from the adoption of an *end-of-pipe* cleaning technology available on the market.<sup>1</sup> The cost function of the emissions abatement technology is  $CA_i(k_i) = \frac{z}{2}k_i^2$ , with  $z > 0$  an exogenous index of technological progress: a lower  $z$  reflects a technology improvement which makes abatement less costly. However, to abate emissions, firms sustain costs with decreasing returns to investment.

The index  $ED_i = \frac{g}{2}(e_i)^2$  measures the environmental damage industrial production generates in each country, and it is a convex function of total pollution. The parameter  $g > 0$ , identical in the two countries, is the weight the government attributes to the environmental damage, i.e., the society's awareness towards the environment: increasing values  $g$  imply, *ceteris paribus*, that the society is more concerned about the environment. The (inverse) market demand is linear, whose expression is normalized to  $p = 1 - Q$ , where  $Q = q_1 + q_2$  is total supply.

### 2.1 Environmental tax

Consider the case in which governments incentivise firms' abatement activities via an optimal emissions tax per each unit of polluting output,  $t \in (0, 1]$ , with the aim of maximizing social welfare. The tax base of firm  $i$  is  $q_i - k_i$ ; the government's tax revenue per firm is  $t(q_i - k_i)$ . Thus, firm  $i$  profit function is:

$$\pi_i^{ET} = (1 - q_i - q_j)q_i - t_i(q_i - k_i) - \frac{zk_i^2}{2}, \quad i = 1, 2, \quad (1)$$

where the upper script ET stands for "emissions tax". At stage two of the game, firms simultaneously choose output and the abatement level. By cutting emissions, firms decrease their costs of an amount equal to the reduced tax burden. Maximisation of (1) with respect to  $q_i$  and  $k_i$  leads to the following first-order conditions:

$$(i) \quad q_i = \frac{1 - q_j - t_i}{2}; \quad (ii) \quad k_i = \frac{t_i}{z}, \quad i = 1, 2; \quad i \neq j,$$

and from the Hessian matrix, one gets that the successive principal minors are  $|H_1| < 0$ , and  $|H_2| > 0$  revealing that it is negative definite, i.e., the stationary point is a maximum. Solving the system of reaction functions (i), one gets that, in equilibrium, output is

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<sup>1</sup> See Buccella et al. (2021, Appendix A) for analytical details supporting the assumption of an abatement technology that does not allow to eliminate pollution entirely. This assumption is different from Asproudis and Gil-Moltó (2015) in which emissions are a fraction of total production.

$q_i = \frac{1-2t_i+t_j}{3}$ , with the standard comparative statics  $\frac{\partial q_i}{\partial t_i} < 0$  and  $\frac{\partial q_i}{\partial t_j} > 0$ . Making use

of (3) equilibrium output and condition (ii), one obtains the expressions for the producer surplus ( $PS$ ), the government's budget ( $GB$ ), and the environmental damage ( $ED$ ) under ET, which enters the social welfare expression,

$$\begin{aligned} SW_i^{ET} &= PS_i^{ET} + GB_i^{ET} - ED_i^{ET} \\ &= \frac{-4z^2(t_i - .5t_j - .5)[(1+g)t_i - .5(1+t_j)(g-2)] - 12zt_i[(g+.75)t_i - .5(1+t_j)] - 9gt_i^2}{18z^2}. \end{aligned} \quad (2)$$

At stage one, the government sets the emissions tax that maximizes (2), that is:

$$\frac{\partial SW_i^{ET}}{\partial t_i} = 0 \Rightarrow t_i^{ET}(t_j) = \frac{z[(2zg + 3g - z)(1+t_j)]}{4z^2(1+g) + 3z(3+4g) + 9g}. \quad (3)$$

Equation (3) represents the reaction function of government  $i$ . Solving the system of reaction functions in (3) one gets  $t^{*ET} = \frac{z(2gz + 3g - z)}{2gz^2 + 9gz + 5z^2 + 9g + 9z} > 0 \Rightarrow g^{ET} \geq \frac{z}{2z+3}$ . Direct inspection reveals that, for  $g > g^{ET}(z)$ ,  $\frac{\partial t_i^{ET}}{\partial t_j} > 0$ : the environmental policy game among governments is

in strategic complements. The second-order condition for a maximum  $\frac{\partial^2 SW_i^{ET}}{\partial t_i^2} < 0$  is satisfied.

One can also verify that if  $g > g^{ET}(z)$ , then the conditions  $q_i^{ET} > 0$ ,  $k_i^{ET} > 0$ , and  $e_i^{ET} = q_i^{ET} - k_i^{ET} > 0$  are always satisfied. Making use of (3), after substitutions, the equilibrium social welfare under ET is obtained, summarized in Table 1.

## 2.2 Environmental subsidy

Consider now that social welfare maximizing governments incentivise cutting emissions providing firms an optimal subsidy per each unit of pollution abatement,  $s \in (0,1]$  (see, e.g., Lee and Park, 2021). Governments incur an expenditure per firm of  $s_i k_i$ . The profit function of firm  $i$  is now:

$$\pi_i^{AS} = (1 - q_i - q_j)q_i + s_i k_i - \frac{zk_i^2}{2}, \quad i = 1, 2, \quad (4)$$

where the upper script AS stands for ‘‘abatement subsidy’’. At stage two of the game, firms simultaneously choose output and the abatement level. By cutting emissions, firms now decrease their cost of the cleaning technology. Maximising (4) with respect to  $q_i$  and  $k_i$  yields the following first-order conditions:

$$(iii) \quad q_i = \frac{1 - q_j}{2}; \quad (iv) \quad k_i = \frac{s_i}{z}, \quad i = 1, 2; \quad i \neq j.$$

and from the Hessian matrix, one obtains that the successive principal minors are  $|H_1| < 0$ , and  $|H_2| > 0$ , revealing that it is negative definite, i.e., the stationary point is a maximum. The system of reaction functions (iii) leads to the equilibrium output  $q_i = \frac{1}{3}$ , and

together with condition (iv), one gets the producer surplus, the government's budget, and the environmental damage needed for the expression of social welfare:

$$SW_i^{AS} = PS_i^{AS} + GB_i^{AS} - ED_i^{AS} = \frac{1}{9} - \frac{s_i^2}{2z} - \frac{g}{2} \left( \frac{1}{3} - \frac{s_i}{z} \right)^2. \quad (5)$$

At stage one, the government fixes the subsidy to maximise (5), that is:

$$\frac{\partial SW_i^{AS}}{\partial s_i^{AS}} = 0 \Rightarrow s_i^{*AS} = \frac{gz}{3(z+g)}. \quad (6)$$

Direct inspection reveals that, when the environmental policy is a subsidy, its amount depends only on technology and societal awareness, i.e. there is no strategic interaction with the rival government. This is because the abatement decision of firms is not linked to output. The second-order condition for a maximum  $\frac{\partial^2 SW_i^{AS}}{\partial s_i^2} < 0$  is satisfied. From (6), one gets that an optimal feasible abatement subsidy exists (i.e.,  $s_i^{*AS} \leq 1$ ) if the social environmental awareness is not large, that is,  $g < -\frac{3z}{3-z} := g^{AS}(z)$ . Analytical inspection of (18) shows that, if  $g < g^{AS}(z)$ , then  $q_i^{AS} > 0$ ,  $k_i^{AS} > 0$ , and  $e_i^{AS} = q_i^{AS} - k_i^{AS} > 0$  are always satisfied. Using (6), after the standard substitutions, one gets the equilibrium social welfare under AS, reported in Table 1.

### 2.3 Asymmetric policies

Consider now that one governments provides an abatement subsidy, let us say, country  $i$ , while the rival country  $j$  levies an emission tax. The firms profit functions are (1) and (4), respectively, from which first order conditions are (i) and (ii) for firm in country  $i$  and (iii) and for firm in country  $j$ . However, solving the system of reaction function, one gets that the

equilibrium output are  $q_i = \frac{1+t_j}{3}$  and  $q_j = \frac{1-2t_j}{3}$ : the higher the environmental tax levied in

country  $j$ , the higher the costs of the exporter in that country which leads to output expansion of the firm in the rival country  $i$ . Given the equilibrium outputs, together with conditions (ii) and (iv), one gets the producer surplus, the government's budget, and the environmental damage included into the social welfares:

$$SW_i^{AS/ET} = \left( \frac{1+t_j}{3} \right)^2 - \frac{s_i^2}{2z} - \frac{g}{2} \left( \frac{1+t_j}{3} - \frac{s_i}{z} \right)^2. \quad (7)$$

$$SW_j^{AS/ET} = \frac{8z(t_j - .5)^2 + 9t_j^2}{18z} - t_j \left( \frac{1-2t_j}{3} - \frac{t_j}{z} \right) - \frac{g}{2} \left( \frac{1-2t_j}{3} - \frac{t_j}{z} \right)^2 \quad (8)$$

At stage one, government's maximization of social welfares leads to:

$$\frac{\partial SW_i^{AS/ET}}{\partial s_i^{AS/ET}} = 0 \Rightarrow s_i^{*AS/ET} = \frac{(1+t_j)gz}{3(z+g)}, \quad (9a)$$

$$\frac{\partial SW_j^{AS/ET}}{\partial t_j^{AS/ET}} = 0 \Rightarrow t_j^{*AS/ET} = \frac{z(2gz+3g-z)}{(1+g)4z^2+12gz+9g+9z} > 0 \Rightarrow g^{ET} \geq \frac{z}{2z+3} \quad (9b)$$

	ET	AS
ET	$SW_1^{ET} = \frac{(g+z)(2+z)[(1+g)4z^2 + 12gz + 9g + 9z]}{(2gz^2 + 9gz + 5z^2 + 9g + 9z)^2}$ $SW_2^{ET} = \frac{(g+z)(2+z)[(1+g)4z^2 + 12gz + 9g + 9z]}{(2gz^2 + 9gz + 5z^2 + 9g + 9z)^2}$	$SW_1^{ET/AS} = \frac{(g+z)(2+z)}{8z^2(1+g) + 6z(4g+3) + 18g}$ $SW_2^{ET/AS} = \frac{(2g+2z-gz)(2gz^2 + 5gz + z^2 + 3g + 3z)^2}{(g+z)[(1+g)4z^2 + 12gz + 9g + 9z]^2}$
AS	$SW_1^{AS/ET} = \frac{(2g+2z-gz)(2gz^2 + 5gz + z^2 + 3g + 3z)^2}{(g+z)[(1+g)4z^2 + 12gz + 9g + 9z]^2}$ $SW_2^{AS/ET} = \frac{(g+z)(2+z)}{8z^2(1+g) + 6z(4g+3) + 18g}$	$SW_1^{AS} = \frac{(2-z)g + 2z}{18(g+z)}$ $SW_2^{AS} = \frac{(2-z)g + 2z}{18(g+z)}$

Direct inspection reveals that  $\frac{\partial s_i^{*AS/ET}}{\partial t_j^{AS/ET}} > 0$ : if country  $j$  levies an environmental tax, the competitive advantage of country  $i$  increases, which allows its government to set higher subsidies. Substituting (9b) into (9a) one gets  $s_i^{*AS/ET} = \frac{gz(2gz^2 + 5gz + z^2 + 3g + 3z)}{[(1+g)4z^2 + 12gz + 9g + 9z](z+g)}$ , from which it is obtained that the abatement subsidy is feasible if  $g < \frac{z(3z^2 + 13z + 18 + z\sqrt{41z^2 + 166z + 169})}{2(2z^3 + z^2 - 9z - 9)} := g^{AS/ET}(z)$ . Analytical inspection reveals that all non-negativity constraints as well as the second-order conditions for a maximum for both countries are satisfied if  $g \geq g^{ET}$ , and  $g < g^{AS/ET}(z)$ . Using (9a) and (9b), the standard substitutions leads to the equilibrium social welfares under AS/ET, reported in Table 1.

#### 2.4 The strategic game played by national Governments.

Now we can derive the endogenous equilibrium regime of the game among governments. The countries' benefits of the different environmental policy regimes are summarised in the Governments pay-off matrix in Table 1. The strategies for each government are an environmental tax, ET, or abatement subsidy, AS. The first element in each entry represents the payoff of country 1, while the second element represent that of country 2. On the top, government 2's strategies are listed; on the left, those of government 1.

Preliminary, analytical inspection of  $SW_i^{AS}$  and  $SW_i^{AS/ET}$  reveals the following results.

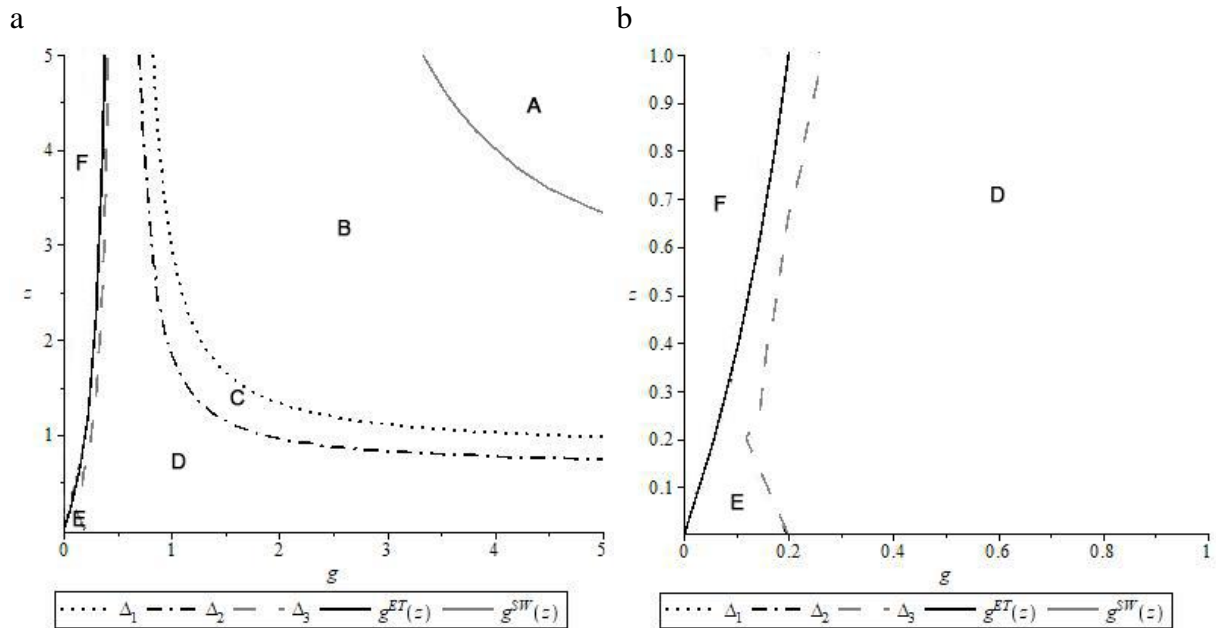
**Lemma 1.**  $SW_i^{AS} \geq 0, SW_i^{AS/ET} \geq 0$  if  $g < \frac{2z}{z-2} \equiv g^{SW}(z)$ . Proof: the proof follows from the condition of positivity of the denominator of  $SW_i^{AS}$  and  $SW_i^{AS/ET}$ .

**Lemma 2.**  $g^{SW}(z) < g^{AS/ET}(z) < g^{AS}(z)$ . Proof: the proof follows from direct comparison.

**Table 1.** Pay-offs matrix of the game between Governments.

Let us define the following social welfare differentials,  $\Delta_1 = SW_1^{AS/ET} - SW^{ET}$ ;  $\Delta_2 = SW_2^{AS/ET} - SW^{AS}$ ;  $\Delta_3 = SW^{AS} - SW^{ET}$ . The first differential reveals when a government has an incentive to abandon an environmental tax and adopt an abatement subsidy policy. The second differential defines when a government has an incentive to deviate from mutual subsidization towards taxation. The third differential inform us about the Pareto-efficiency properties of the equilibria. Their analytical expressions, the feasibility condition of the tax and the non-negativity condition on social welfare under subsidization allow us to build Figure 1 (Panel a and b), whose graphical and analytical inspection leads to the core result.

**Result 1.** The social welfare differentials  $\Delta_1, \Delta_2, \Delta_3$  and the condition  $g < g^{AS}(z)$  generate six regions in Figure 1 whose characteristics are: 1) Region A: economically unfeasible; 2) Region B:  $\Delta_1 < 0, \Delta_2 > 0, \Delta_3 < 0$ : emission tax unique Pareto-efficient equilibrium; 3) Region C:  $\Delta_1 > 0, \Delta_2 > 0, \Delta_3 < 0$ : multiple symmetric equilibria, emission tax Pareto-dominant equilibrium; 4) Region D:  $\Delta_1 > 0, \Delta_2 < 0, \Delta_3 < 0$ : abatement subsidy unique Pareto-inefficient equilibrium; 5) Region E:  $\Delta_1 > 0, \Delta_2 < 0, \Delta_3 > 0$  abatement subsidy unique Pareto-efficient equilibrium; 6) Region F: abatement subsidy unique feasible policy.



**Figure 1.** Game equilibria and their efficiency properties. Panel a: extended graphical representation. Panel b: snapshot for lower values of societal awareness and technological index

Therefore, if the societal awareness is significantly low, the government can nudge abatement activities only via subsidization, and in a context of international trade with governments engaged in environmental policies, those subsidies can lead, though in a limited parametric area, to a Pareto-efficient equilibrium. Of course, if the environmental awareness is high enough, the standard result that mutual subsidization leads to a Pareto-inefficient equilibrium appears. Nonetheless, those results seem to suggest that there is room from the provision of “green” subsidies in a context of international trade because can be beneficial for governments to start pushing the “green” transition.

### 3. Conclusion

Using a basic two-stage game, three-country model, in which at the first stage, social welfare maximizing governments optimally chooses the environmental policy tool for exporting polluting firms, and at the second stage, firms compete in quantity (choosing concurrently abatement levels), this note gives a first insight on the use of “green” subsidies as a tool of strategic trade policy. The key result of the analysis is that, depending on the societal awareness toward the environment and the abatement technology efficiency, a rich set of equilibria emerges. Subsidization can emerge as Pareto-inefficient equilibrium. However, for low environmental awareness, to subsidize pollution abatement can 1) either emerge as a Pareto-efficient equilibrium; or 2) be the only feasible environmental policy. Based on this note, both the concerns of The Economist and the optimistic views of The Financial Times observers are worth to be considered. This note aims at launching a provocative discussion on the current debate on the use of environmental policies as a tool to improve national welfares of countries



involved in international trade. Even so, further investigation and more articulated models are needed. For example, extensions with segmented markets/reciprocal trade models that embeds consumer welfare when designing the policy, and “green” R&D investments that abate emissions and improve production processes are suitable routes for further research. Moreover, also the case in which environmental pollution may spillover to trading partners (transboundary pollution) represents a possible future extension.

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