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Can policies backfire? The impact of uncoordinated domestic policies on global pollution

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Abstract

In this paper, we take into account that different types of pollutants (both local pollutants like SPM and global pollutants like CO2) are generated during a production process. We consider a two-country framework with one firm in each country and strategic interaction between them A dirty good beings produced by both the firms generates both local and global pollutants during production. The dirty good is a quality-differentiated product with the quality being determined by the cleanliness of the good, which in turn depends on the abatement technology used. We analyse the impact of an environmental standard imposed by one country to curb local pollution there. We show that such unilateral policy adopted by the high-quality country aimed at lowering domestic pollution may not be a step in the right direction as they may raise global pollution. However, in the presence of consumer awareness regarding global pollution, a standard imposed by the high-quality country will lower global pollution while one imposed by the low-quality country may raise it if awareness is too low. thus creating awareness about global pollution should be undertaken before adopting any policy.

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1. Introduction

As environmental problems assume paramount importance, many policies, both unilateral and coordinated, are being adopted across the world. Countries have realized the need for coordination in tackling global environmental problems and international treaties on environment now have more participation than before. While everyone accepts that policy coordination is imperative for reducing global pollution, there has been some debate on whether unilateral policies are also effective tools or not. Though most economists feel that they are at least a step in the right direction, if not the best solution, some contend this view. Hoel (1991) observes that in the presence of transboundary pollution, a unilateral reduction in emission by one country may increase the emissions by the other country. Also, when there is a possibility of negotiations between them, and a country pre-commits itself to unilateral reductions, then it weakens its position. The outcome of negotiations may then result in emissions that are higher than what they would have been if the two countries had chosen selfishly.

In the absence of transboundary pollution, the standard view is that domestic policies are optimum and no international cooperation is needed. However, Kox and Van der Tak (1996) show that even in these cases, non-coordinated domestic policies are not always the most efficient. They argue that in the presence of discrete technologies, set up costs and increasing returns to scale, international cooperation increases efficiency even when pollution is local in nature. In this paper, we go one step further and show that un-coordinated domestic policy aimed at reducing local pollution may actually end up increasing global pollution levels.

Almost all papers deal with pollution as a negative externality to either production or consumption and treat it as homogeneous in nature. Here we take into account the fact that different types of pollutants generated during the production process create different types of environmental hazards. While some emissions like SPM cause only local environmental hazards like smog, others like CO_2 have a much wider impact on the global environment like the greenhouse effect and climate change. We show that in certain cases a unilateral domestic policy aimed at lowering local pollution may trigger off reactions in other countries and may actually raise global pollution. Thus, uncoordinated domestic policies might not always be a wise move.

2. The Model

To demonstrate the impact of domestic standards on global pollution when there is strategic interaction between two countries, we take a two-country framework with identical sets of heterogeneous consumers having different taste parameters. This is assumed in order to focus only on the effects of national quality standards on the scale of production of both countries. There are two firms, one in each country producing a dirty good X, which generates various harmful gases and particles during production. While the local pollution generated can be checked by installing a cleansing device, e.g. filters and other end-of-pipe devices, *and* by curbing production, global pollution can be checked only by phasing out the good or by curbing production. (Missfeldt,1999). This is because global pollutants like CO_2 are generally generated by the energy sectors and cannot be curbed by abatement technology unless some new fuel efficient technology is adopted, and that is not possible in the short run. The quality of X is characterised by local pollution generated during production which in turn depends on the standard of the cleansing device used. A cleaner variety of X uses a more sophisticated cleansing device and generates less local pollution. The quality of X is indexed by $A \in [0, \bar{A}]$ with $\bar{A}$ being the quality of the cleanest good that can be produced by the present state of technology[1]. Such characterisation has been done previously by Arora and Gangopadhyay (1995) and Sen and Acharyya (2012). The cleansing device has no impact whatsoever on the global pollution, which essentially varies with the scale of production. The *technique effect* on local pollution, is thus, captured by the environmental-quality parameter A in this model.

Suppose that the two firms have identical cost structures. The cost of quality improvement, in this case the cost of installing the cleansing device, is incurred in the first stage before the actual production. This cost increases with the environmental-quality chosen, but is fixed in the sense that it remains invariant with the output levels. That is, the cost of quality depends on how sophisticated or effective a cleansing device is, and not on the actual volume of production that is made using this technology. Such a fixed cost structure has been analysed in Shaked and Sutton (1982, 1983, 1984) and Motta (1993). We assume for the sake of simplicity, that there are no further costs of production or transport costs. Since there is free trade between the two countries, the firms have access to the markets in both the countries and compete with each other for market share in both. The firms play a two-stage game. In the first stage, they choose the environmental-quality (or the standard of the cleansing device) of the good and in the second stage they choose quantities. As demonstrated by Motta (1993) in the context of endogenous quality choice, the two firms will offer two distinct qualities to relax competition between them. Suppose the environmental quality supplied by the firm *i* in country *j* is A_{ij}. Also, for simplicity, $A_{1j} > A_{2j}$. That is, firm 1 (in country 1) is the higher quality firm and supplies a cleaner X to the consumers of both the countries. The equilibrium price of firm 1 p_{1j} will, naturally, be more than that of firm 2, p_{2j}.

We assume that each consumer buys, if at all, only one unit of X and that she derives utility from the cleanliness of the good. That is, a cleaner variety (higher quality) gives her a greater satisfaction. At this, stage, we do not take into account the fact that there is also a disutility as her consumption adds to the global pollution. This is dealt with in Section 4. The net utility derived by a consumer from consuming one unit of X of quality A is then, $U = \nu A - p$, where ν is the taste parameter which depends on her environmental consciousness. ν is uniformly distributed in country *j* with a unit density and $\nu \in [0,1]$. The consumers in each country make a two-fold decision. They decide whether to buy the good and then choose the most desirable price-quality pair between the alternatives offered by the two firms. A consumer will buy if she derives at least her reservation utility, which in this case is zero, from consuming the good. That is, she will buy if $U = \nu(A) - p \geq 0$. Also, she will purchase the cleaner and costlier variety, A_{1j} if 'net' utility from it is at least as large as that from the dirtier and cheaper variety, A_{2j}. That is, if $\nu(A_{1j}) - p_{1j} \geq \nu(A_{2j}) - p_{2j}$. In both these decisions, that of market participation and selection of environmental quality, it is assumed that the consumer indifferent between purchasing or not,

[1] An improvement in technology is possible with R&D, but that can take place only in the long run.

actually purchases, and the one indifferent between the qualities A_{1j} and A_{2j} selects the higher quality A_{1j}.

Similar to that shown by Motta (1993), the consumers who have a taste parameter $\nu < \nu_2$ (where .$\nu_2 = p_{2j} / A_{2j}$) do not buy X at all, those with ν such that $\nu_2 \leq \nu < \nu_1$ (where $\nu_1 = (p_{1j} - p_{2j})/(A_{1j} - A_{2j})$) buy the low quality good A_{2j} from the firm 2 while those with $\nu \geq \nu_1$ buy the high quality good A_{1j}. The amount of X that is demanded in Country j is then,

$$q_{1j} = 1 - \nu_1 = 1 - \frac{p_{1j} - p_{2j}}{A_{1j} - A_{2j}} \tag{1a}$$

$$q_{2j} = \nu_1 - \nu_2 = \frac{p_{1j} - p_{2j}}{A_{1j} - A_{2j}} - \frac{p_{2j}}{A_{2j}} \tag{1b}$$

where q_{ij} is the quantity of X demanded by consumers of the jth country from the ith firm. The equilibrium price and quantity chosen by the *i*th firm for the *j*th country by maximizing $\pi_i = \sum_j p_{ij} q_{ij}$ in the second stage are,

$$q^*_{1j} = \frac{(2A_{1j} - A_{2j})}{4A_{1j} - A_{2j}} = q^*_1; \qquad q^*_{2j} = \frac{A_{1j}}{4A_{1j} - A_{2j}} = q^*_2; \quad j=1,2 \tag{2a}$$

$$p^*_{1j} = \frac{(2A_{1j} - A_{2j})A_{1j}}{4A_{1j} - A_{2j}} = p^*_1; \qquad p^*_{2j} = \frac{A_{1j} A_{2j}}{4A_{1j} - A_{2j}} = p^*_2 \tag{2b}$$

Note, $\partial q_1 / \partial A_1 = 2A_2 / (4A_1 - A_2)^2 > 0 \;\; and \;\; \partial q_2 / \partial A_2 = A_1 / (4A_1 - A_2)^2 > 0$

That is, a firm will raise its output levels (thus raising pollution, specially global pollution) if it chooses a cleaner quality in order to maximize their profits. Thus, there is an intrinsic tradeoff between the local pollutant (captured in this model by the quality improvement) and the global pollution which depends on the scale of production. Let a firm's investment on environmental quality be $\max(A^2_{i1}, A^2_{i2})$. That is, the cost of quality is determined by the cleaner variety one produces (in case a firm produces two different qualities for the consumers in the two countries). So, in the first stage each firm maximizes $\Pi_i = \sum_j \left(p^*_{ij} q^*_{ij} - \max(A^2_{i1}, A^2_{i2}) \right)$ and the reaction functions in environmental-quality in country *j* are (See Figure 1) [2]

$$\frac{(2A_{1j} - A_{2j})(8A^2_{1j} - 2A_{1j}A_{2j} - A^2_{2j})}{(4A_{1j} - A_{2j})^3} - A_{1j} = 0 \tag{3a}$$

$$\frac{A^2_{1j}(4A_{1j} + A_{2j})}{(4A_{1j} - A_{2j} - 3\alpha)^3} - A_{2j} = 0 \tag{3b}$$

[2] The reaction functions have been drawn with the help of Mathematica 4.

As shown by Motta (1993), these yield the Nash equilibrium quality levels, [3]

$$A_{1j}^* = A_1^* = 0.2519$$

$$A_{2j}^* = A_2^* = 0.0902 \quad \forall\ j = 1,2$$

Note that $A_{i1} = A_{i2}$ and $q_{i1} = q_{i2}$ as the consumers in the two countries are identical.
The quantity of goods produced is then,

$$q_{1j}^* = q_1^* = 0.4509, \quad q_{2j}^* = q_2^* = 0.2746 \quad \forall j = 1,2 \tag{4a}$$

$$Q_1^* = 2q_1^* = 0.9017\ ; \tag{4b}$$

$$Q^* = Q_1^* + Q_2^* \tag{4c}$$

where Q_j^* is the total output produced in country j; $Q*$ is the global output. Since the local pollution decreases with a cleaner technology but increases with the scale of production in a country, it can be expressed as:

$$L_j = L_j(Q_j, A_j)\ ;\ \partial L_j / \partial Q_j > 0\ ,\ \partial L_j / \partial A_j < 0 \tag{5}$$

The global pollution, on the other hand, depends only on the total world production

$$GP = \beta\left(\sum Q_j\right) \quad ; \quad 0 < \beta < 1 \tag{6}$$

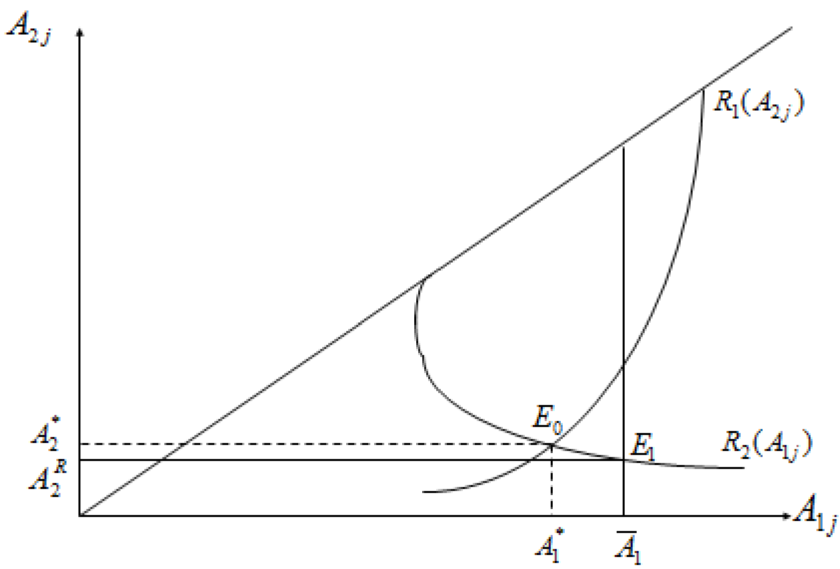

Figure 1: Unilateral Environmental Standards in Country 1

3. Unilateral Domestic Standards

Suppose Country 1 imposes a minimum standard $\overline{A}_1$ on environmental-quality in its own country. Firm 1 is then bound to produce goods of that minimum quality for domestic sale and export. As there is no regulation in country 2, firm 2 may produce any environmental-quality and

[3] The calculation of the equilibrium values of A and q has been done with the help of Mathematica 4.

it chooses it by maximising its profit. With firm 1 now selling goods of quality $\overline{A}_1$ in both the countries, it is no longer optimum for firm 2 to continue producing A_2^*, as is evident from the reaction functions. Firm 2 responds to the regulation in Country 1 by lowering the quality of its own products to A_2^R. That is, the new equilibrium moves along $R_2(A_1)$ to $E_1(\overline{A}_1, A_2^R)$. (Figure 1). Thus, the minimum standard in country 1 drives producers in country 2 to produce dirtier goods.

Proposition 1: *An environmental standard in Country 1 set above* A_1^* *prompts the low-quality firm in Country 2 to lower the environmental-quality of its goods further.*

Proof: The standard in Country 1 raises the environmental-quality of goods produced by firm 1 to $\overline{A}_1 > A_1^*$. Since $\left.\frac{dA_2}{dA_1}\right|_{R2} = \frac{2A_{1j}A_{2j}(8A_{1j}+A_{2j})}{2A_{1j}^2(8A_{1j}+A_{2j})-(4A_{1j}-A_{2j})^4} < 0$ in the neighbourhood of the original equilibrium, $A_2^R = R_2(\overline{A}_1) < A_2^*$. ■

Thus, the minimum standard in Country 1 raises the environmental-quality of X produced there but lowers that in country 2. The *technique effect* lowers domestic pollution in one country but raises that in the other. The change in the environmental-quality produced triggers off a change in outputs by both firms. In fact,

Proposition 2: *The minimum environmental standard actually increases global pollution even when local pollution in both countries fall.*

Proof: The change in local pollution in country *j* is,

$$dL_j = (\partial L_j / \partial Q_j)dQ_j + (\partial L_j / \partial A_j)dA_j \tag{7}$$

where $$dQ_1 = \frac{4}{(4A_1 - A_2)^2}\left[A_2 - A_2 \left.\frac{dA_2}{dA_1}\right|_{R2}\right]dA_1 > 0$$

$$dQ_2 = \frac{2}{(4A_1 - A_2)^2}\left[-A_2 + A_1 \left.\frac{dA_2}{dA_1}\right|_{R2}\right]dA_1 < 0$$

As the output of firm 1 increase, the technique effect is offset at least to some extent. In country 2, the volume of output declines and so, local pollution falls due to the scale effect. Thus in both countries, the scale and technique effects work in opposite directions. Local pollution may fall in both countries.

$$\hat{L}_1 = [s_1\varepsilon_{11} + t_1]\hat{A}_1 < 0 \qquad \text{when} \qquad \varepsilon_{11} < |t_1| / s_1 \tag{8a}$$

$$\hat{L}_2 = [s_2\varepsilon_{12} + t_2\gamma_{12}]\hat{A}_1 < 0 \qquad \text{when} \qquad |\varepsilon_{12}| < t_2\gamma_{12} / s_2 \tag{8b}$$

where $s_j = \frac{\partial LP_j / LP_j}{\partial Q_j / Q_j} > 0$: the scale effect in country *j*

$$t_j = \frac{\partial LP_j / LP_j}{\partial A_j / A_j} < 0 \quad \text{: the technique effect in country } j$$

$$\varepsilon_{1j} = \frac{\partial Q_j / Q_j}{\partial A_1 / A_1} \quad \text{: the scale elasticity of environmental - quality of the firm 1 in country } j$$

$$\gamma_{12} = \left.\frac{dA_2}{dA_1}\right|_{R_2} \frac{A_1}{A_2}$$

That is, a minimum standard may lower local pollution in country 1 if dirty good is so scale-inelastic that the technique effect outweighs the scale effect. In Country 2 the scale elasticity is negative and pollution may fall if its magnitude is large enough to outweigh the impact of the technique effect. However, even when domestic pollution in both countries falls, global pollution rises as the total global production of X increases.

$$d(GP) = d(\beta \sum Q_i) = \frac{4\beta}{(4A_1 - A_2)^2}\left[A_2 - A_1 \left.\frac{dA_2}{dA_1}\right|_{R2}\right] dA_1$$

$$= \left[\frac{-2\beta A_2 (4A_1 - A_2)^2}{2A_1^2(8A_1 + A_2) - (4A_1 - A_2)^4}\right] dA_1 > 0 \tag{9}$$

as $2A_1^2(8A_1 + A_2) - (4A_1 - A_2)^4 < 0$ in the neighbourhood of equilibrium

■

Thus, it is not certain whether a unilateral domestic policy adopted by the high-quality country always succeeds in reducing local pollution. However, even when local pollution falls, global pollution rises due to the increase in global output.

4. Awareness about Global Pollution

In this section, we take into account the fact that consumption of X gives the consumer a negative feeling as she knows that she is adding to the global pollution. However, as she buys only one unit of the good, her contribution to global pollution is constant once she decides to buy. Then the net utility derived by a consumer from consuming one unit of X of quality A is $U = \nu(A - \alpha) - p$, where α is sufficiently low to ensure positive values of A_1 and A_2.[4] So, though a higher quality gives greater utility, there is a scaling down as consumption adds to global pollution. The consumer who is indifferent between buying and not, now has a taste parameter $\nu_2' = p_{2j} / (A_{2j} - \alpha)$). While ν_2' rises as α rises, ν_1 remains unchanged. That is, if concern for global pollution increases, more people decide not to buy the dirty good, but the decision on the quality remains unaffected as quality has no bearing on the global pollution. The amount of low-quality X that is demanded in Country j is then,

$$q_{2j} = \nu_1 - \nu_2' = \frac{p_{1j} - p_{2j}}{A_{1j} - A_{2j}} - \frac{p_{2j}}{A_{2j} - \alpha} \tag{10}$$

[4] See Table 1

The reaction functions in environmental-quality in country *j* are

$$\frac{(2A_{1j}-A_{2j}-\alpha)\{8(A_{1j}-\alpha)^2-(2A_{1j}-A_{2j}-\alpha)(A_{2j}-\alpha)\}}{(4A_{1j}-A_{2j}-3\alpha)^3}-A_{1j}=0 \tag{11a}$$

$$\frac{(A_{1j}-\alpha)^2(4A_{1j}+A_{2j}-5\alpha)}{(4A_{1j}-A_{2j}-3\alpha)^3}-A_{2j}=0 \tag{11b}$$

These reaction functions yield the Nash equilibrium quality levels as

$$A_{1j}^*=A_1^*=f(\alpha);\quad f'(\alpha)<0 \tag{12a}$$ [5]

$$A_{2j}^*=A_2^*=g(\alpha);\quad g'(\alpha)<0\quad \forall\ j=1,2 \tag{12b}$$

Proposition 3: *In the presence of consumer awareness about global pollution, a minimum standard imposed by Country 1 reduces global pollution while one imposed by Country 2 may increase it if awareness is not sufficiently high.*

Proof: As shown in Table 1, for $0<\alpha<0.2545$,[6] the slopes of the reaction functions of the two firms in qualities is positive. Hence, a minimum standard introduced by any country will induce the other country to increase the environmental-quality of its product. As the environmental – quality of the goods produced in both the countries improve, the firms change their output level as a strategic response to the change in quality. Again, as shown in Table 1,

$$d(Q_1+Q_2)/dA_1<0\quad \forall\,\alpha<0.2545 \text{ and } d(Q_1+Q_2)/dA_2>0\ \forall\ \alpha<0.2$$

Thus, the total world production, and hence global pollution, falls when country 1 imposes the standard, whatever be the awareness levels. But global pollution may rise when the Country 2 imposes a standard when the consumer awareness regarding global pollution is not sufficiently high. ■

5. Conclusion

In this paper we have shown that a domestic standard imposed in the high-quality country to curb local pollution may actually backfire and raise global pollution in the absence of consumer awareness about global pollution. Even when there is awareness, a standard imposed by the low-quality country may raise pollution if that awareness is not sufficiently high. So, uncoordinated policies may not be a good idea, even at the national level. A dialogue may be necessary between countries even when the issue is pollution at the domestic level and steps should be taken to increase the awareness of consumers regarding global pollution as some amount of global pollutants are emitted by almost all production activities.

[5] See Table 1.

[6] The optimum environmental-qualities chosen by the firms are negative for greater values of $\propto$.

Table 1

α	A1	A2	slope of R2	d(Q1+Q2)/dA1	slope of R1	d(Q1+Q2)/dA2
0	0.2519	0.0902	-0.2168825			
0.0001	0.2332	0.3479	2.9021	-0.9617	1.4902	0.0008
0.0010	0.2324	0.3464	2.8803	-0.9538	1.4910	0.0007
0.0100	0.2248	0.3329	2.6800	-0.8788	1.5023	0.0006
0.0200	0.2163	0.3180	2.4932	-0.8064	1.5178	0.0004
0.0500	0.1903	0.2737	2.1112	-0.6362	1.5952	0.0001
0.1000	0.1456	0.2020	2.2850	-0.3475	2.2357	0.0000
0.2000	0.0524	0.0679	0.5053	-0.2738	0.8949	-0.0001
0.2500	0.0043	0.0054	0.4711	-0.2364	0.9954	0.0000
0.2510	0.0033	0.0042	0.4700	-0.2356	0.9965	0.0000
0.2520	0.0023	0.0029	0.4689	-0.2349	0.9976	0.0000
0.2530	0.0014	0.0017	0.4678	-0.2342	0.9986	0.0000
0.2540	0.0004	0.0005	0.4667	-0.2334	0.9996	0.0000
0.2544	0.0000	0.0000	0.4662	-0.2331	1.0000	0.0000
0.2545	negative	negative				
0.2550	negative	negative				
0.2600	negative	negative				

References

Arora, S. and Gangopadhyay, S. (1995) "Toward a Theoretical Model of Voluntary Overcompliance" *Journal of Economic Behaviour and Organisation* 28, 289-309.

Hoel, M. (1991) "Pollution Problems: The Effects of Unilateral Actions Taken by One Country" *Journal of Environmental Economics and Management* 20, 55-70.

Kox, H.M.L and Van der Tak, C.M. (1996) "Non-transboundary Pollution and the Efficiency of International Environmental Cooperation" *Ecological Economics* 19, 247-259.

Missfeldt F. (1999). "Game-Theoretic Modelling of Transboundary Pollution" *Journal of Economic Surveys* 13(3), 287-321.

Motta M. (1993). "Endogenous Quality Choice: Price Vs. Quantity Competition" *The Journal of Industrial Economics* XLI, 113-131.

Sen A. and Acharyya R. (2012). "Environmental Standard and Employment: Impact of the Productivity Effect" *Environment and Development Economics* 17(2), 187-206.

Shaked A. and Sutton J. (1982). "Re laxing Price Competition Through Product Differentiation" *Review of Economic Studies 49,* 3-14.

Shaked A. and Sutton J. (1983). "Natural Oligopolies" *Econometrica 51,* 1469-1483.

Shaked A. and Sutton J. (1984). "Natural Oligopolies and International Trade" in H. Kierkowszki ed. *Monopolistic Competition and international Trade* (Claredon, Oxford).