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Subsidy to environmental industry in a North-South model of trans-boundary pollution, trade and migration.

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Abstract

Differences in environmental regulation between rich and poor countries have caused a geographical relocation of polluting industry from the former to the latter. In several cases the reduction in domestic emissions is at least partly compensated by an increase in trans-boundary pollution which is detrimental to the productivity of environmental sensitive sectors (such as agriculture) industry in a developed country. Can a government in a rich country try to correct the negative consequences of trans-boundary pollution when mechanisms such as binding international agreements are difficult to implement? In this paper we build a simple North-South model of trade where the manufacturing plants are completely outsourced in a developing country and we analyze the effects of a subsidy program to pollution abatement industry located in the North. We find that, contrarily to common intuition, the subsidy to the pollution abatement equipment industry might reduce welfare in the North when the efficiency of the pollution abatement technology is already relatively high and when the wage gap between the North and South is high. In addition we find that international migration might have a positive impact on improving the environmental stock and welfare in the North and might be a more efficient and less distortive way to address the trans-boundary externality.

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1. Introduction

Strict environmental regulations in rich countries accompanied by a substantial decrease in the cost of international outsourcing strategies have induced a relocation of polluting industries in poor countries where production costs are lower and regulations (including environmental ones) less rigorous.[1]

For many rich countries it is often the case that a large amount of man-made pollution which "exit from the door" through relocation of polluting industries re-enters "through the windows" via trans-boundary pollution. The case of Japan is emblematic in this respect: notwithstanding a reduction in the emission in the atmosphere of pollutant the quality of air and phenomena such as acid rain or photochemical smog are on the rise mainly as a consequence of trans-boundary pollution form mainland China.[2]

One way of attempting a correction of the international externality caused by trans-boundary pollution is the move toward and international enforcement of environment protection (for instance the Kyoto protocol). Strong asymmetries in country preferences for the degree of environmental regulation – in particular between rich and poor countries – make this road quite hard to follow as the history of the Kyoto protocol (and similar agreements) seems to suggest. Existing international regulation (WTO agreements) makes also difficult to use trade policy as a way to correct (at least partly) the effect of trans-boundary pollution externalities (Copeland 1996).

In the present paper we analyze the possibility for a rich country affected by trans-boundary pollution to neutralize the negative externality by subsidizing a pollution abatement industry in which the country has a ricardian comparative advantage.

Markets for pollution abatement equipment, and more in general for environmental products, have developed mostly in rich countries for reasons related both to the demand and supply sides. The willingness to pay for a cleaner environment is a positive function of income per capita; as a consequence also policy regulations are relatively stricter in richer countries since firms face higher costs if they introduce harmful or poisonous substances in the environment. On the other side, technologies for pollution control and abatement of toxic emissions are developed with an intensive use of R&D

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[1] This process has been extensively documented and analyzed within the existing literature and is known as the Pollution Heaven Effect (PHE) based on the early contribution of Copeland and Taylor (1994). For a recent empirical analysis on the PHE see Kellenberg (2009).

[2] Ohara (2008) indicates that frequency of serious photochemical smog in Japan has been increasing recently because of Chinese emission of NOx.

investments and hence rich countries have a natural comparative advantage in this sector. Brunnermeier and Cohen (2003) find evidence that environmental innovation in the US is driven by pollution abatement expenditure, a proxy of regulatory burden.

Marinova and McAleer (2006) compute an international ranking in anti-pollution technologies using data on patents application in the US over the period 1975-2002. Excluding domestic inventors from the US, the results show that the leadership in pollution control technologies is held by rich OECD countries such as Japan (23% of total anti-pollution patents applications), Germany (5,9%), France (5,2%), Canada (2,4%) and Taiwan (1,7%).

A recent report on the competitiveness of EU Eco-industries[3] (Ecorys 2009) highlights the importance of the Environmental Goods and Service sector which in 2008 produced an estimated turnover of 300 billion € and employed 3,4 million workers. Trade flows in this sector are also substantial; according to the above-mentioned report, EU-27 total export[4] of eco-industries products to China amounted to 3,7 billion €, while the export of the US and Japan toward the Chinese market in the same year amounted to respectively 920 million € and 585 million €. Stricter environmental regulations in many emerging and developing countries have contributed to the expansion of the global market for environmental industries[5].

The environmental sector is heavily subsidized in most rich country. The ratio of such policy interventions reside in the market failures associated with the (at least partial) public good nature of environmental technologies once discovered. More recently interventions are aimed also at promoting the global competitiveness of national environmental industry as demonstrated by large public subsidies granted by the US, Japan and several EU governments to the domestic automotive sectors for developing new ecological cars.

In this paper we build a simple North-South model of trade where the manufacturing plants are completely outsourced in a developing country and we analyze the effects of a subsidy program to pollution abatement industry located in the North. Our main aim is

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[3] Eco-industries are defined using the following OECD definition as "*those [identifiable] sectors within which the main – or a substantial part of – activities are undertaken with the primary purpose of the production of goods and services to measure, prevent, limit, minimize or correct environmental damage to water, air and soil, as well as problems related to waste, noise and eco-systems.*". The definition includes sectors such as air pollution control, waste management equipment, renewable energy.

[4] Export figures are likely to be under-estimated given that part of the trade might take the form of service trade or FDI which are difficult to capture in trade data.

[5] The scale of environmental industry is estimated around 300 billion USD in 2000. World export of environmental goods (OECD definition) is almost five times larger than that of 1990. See OECD (1996) (2001) (2005).

to analyse the potential for a government in a rich country to correct the negative consequences of trans-boundary pollution when mechanisms such as binding international agreements are difficult to implement. We find that, contrarily to common intuition, the subsidy to the pollution abatement equipment industry might reduce welfare in the North when the efficiency of the pollution abatement technology is already relatively high and when the wage gap between the North and South is high. In fact, the policy intervention generates a trade-off. On one side the subsidy gives an incentive to reduce total emission in the South with a positive impact on environmental stock in the North. On the other side, the subsidy generates costly market distortion which might dominate the positive effects when pollution abatement technologies are already sufficiently efficient. The results highlight the importance of targeting subsidies toward pollution abatement technologies that are in their infancy stage rather than granting general forms of support. In addition we find that international migration might have a positive impact on improving the environmental stock and welfare in the North. Under some hypothesis a less restrictive migration policy might be a more efficient and less distortive way to address the trans-boundary externality.

Our paper is related to Greaker and Rosentdahl (2008) who consider a model where the government might influence a upstream non-competitive abatement technology sector using environmental policy or through subsidy to environmental R&D. The policy variables by affecting competition in the upstream industry affects the abatement costs faced by the downstream polluting industry with a direct influence on total pollution. Differently from our paper, Greaker and Rosentdahl (2008) employ a reciprocal-dumping model with two (rich) countries who trade in pollution abatement equipments and with no trade in downstream manufacturing. Hence their focus, contrarily to our paper, is on the international competitiveness of pollution abatement equipment in a context with no trans-boundary pollution.

Several theoretical studies deal with environmental topics in an international trade model. With regard to the environmental industry, Merrifield (1988) analyzes the effects of equipment standards on trade and capital mobility. Copeland (1991) studies the trade of waste disposal services. Chua (2003) examines the effects of an emission tax on the trade pattern in a three- sector model, in which one sector is the non-tradable pollution abatement service sector. Sugiyama (2003) also studies the effects of environmental policies in a two-sector model, in which one sector is the production sector of pollution abatement equipment. Abe and Sugiyama (2008) analyse the structure of comparative advantage determined by the international differences in environmental policies in a model with the pollution abatement equipment and examine the effects of an environmental policy in an open economy. In a related paper, Kondoh (2009) analyzes the welfare effects of international migration in the presence of pollution abatement industry by using a simplified version of the Copeland and Taylor (1999) two-country model. As in this paper, Kondoh (2009) shows that migration has positive effects on the wage rate, the stock of the environmental and welfare of the worker in at least one country. Moreover he shows the possibility that both countries gain from international migration. Finally our paper is also related to Kohn (2001) which develops a two asymmetric-country Heckscher-Ohlin-Samuleson framework with trans-boundary pollution. The author investigates under which condition is optimal for the capital intensive North to unilaterally transfer abatement capital to the South. The author assumes that both countries abate and reduce emission in the same proportion (same environmental policy) while we consider a Ricardian framework where countries are completely specialized and hence the polluting manufacturing industry is located only in the South.

In section 2, we present the baseline model. In Section 3 we present the analysis on the effects of environmental subsidy policy and immigration policy. Concluding remarks are in section 4.

2. The Model

We assume that the world comprises two countries H (home, developed like Japan or Hong Kong, with small population) and F (foreign, developing like China with large population). Three goods are produced in this stylized world economy, a polluting manufacturing industry, an environment-sensitive agricultural sector and a pollution abatement industry. The two primary factors of production are labor and environmental capital; the latter is the specific factor in the production of the agricultural good.

Let consider for simplicity that the smokestack manufacturing industry of country H has completely been relocated to country F through an FDI outflow [6]. We assume this manufactured good is consumed only in country H, therefore all of the production will be exported to country H. In each country there exists environmentally sensitive agricultural sector, which suffers from the environmental damage due to pollution (domestic pollution in country F and trans-boundary pollution in country H).

[6] We may reasonably assume that country F has a strong comparative advantage in the industrial sector because of a substantially low wage rate (due to the large population assumption). Alternatively, the assumption might reflect a situation where relocation is due to the well-known pollution heaven hypothesis .

We assume that country H is specialized in the production of the pollution abatement equipment industry due to a technological advantage; hence this hi-tech industry is located in the rich country H and exported in the poor country F. We assume that this equipment is just like a filter, which helps to purify polluted air or water. This equipment is a kind of intermediate good and improves the pollution abatement technology of the manufacturing industry. The assumed comparative advantages in production implies that country H exports pollution abatement equipment while country F exports manufacturing final good; trade of agricultural good also exists.

The production functions of the agricultural and pollution abatement equipment industries in country H are:

$$A = \sqrt{E} L_A, \tag{1a}$$

$$B = f(L_B), \tag{1b}$$

where E is the stock of environmental capital; A and L_A are respectively output and labor input of the agricultural sector, B and L_B are those of the pollution abatement equipment industry. We assume $f' > 0$ and $f'' < 0$.

The production function of manufacturing industry in country F is

$$M^* = g(L_M^*), \tag{1c}$$

where M^* denotes the output and L_M^* the labor input of this industry. We also assume $g' > 0$ and $g'' < 0$.

Production activity in the manufacturing industry in country F, by degrading the quality of the environment, causes both domestic (in country F) and trans-boundary (in country H) pollution. Since distance from the pollution source might significantly affect the degree of environmental degradation we allow for an heterogeneous effect in the two countries. The following expression measure total pollution respectively in country F and country H:

$$Z = (\lambda - \mu B) M^*. \tag{2a}$$

$$Z^* = \delta(\lambda - \mu B) M^* \tag{2b}$$

where λ measure the emission of pollutant per unit of product in the absence of pollution abatement equipment; μ is the efficiency of a pollution abatement equipment B employed by manufacturing firms and δ is the parameter that reflects the difference between domestic pollution and trans-boundary pollution. In usual case, trans-boundary pollution is weakened because of a larger distance from the polluting source, therefore it is reasonable to consider $\delta > 1$. We assume that pollution abatement technology improves proportionally with the number of equipments.[7]

We assume that the stock of environmental capital in country H decreases with the amount of emission Z by trans-boundary pollution. Therefore, the quantity of productive environmental capital is:

$$E = \bar{E} - Z \,, \tag{3}$$

where $\bar{E}$ is the natural stock level of environmental capital before damages.

The manufacturing industry is characterized by perfect competition with free entry. Let $\pi_M{}^*$ be the total profit of this sector and it can be expressed as follows:,

$$\pi_M{}^* = p_M M^* - \underline{w} L_M{}^* - pB - \gamma Z^* \,, \tag{4}$$

where p_M is the price of the manufacturing product; $\underline{w}$ is the wage rate in country F, for simplicity and without loss of generality we assume that wage is fixed and much smaller than that of country H; p is the price of pollution abatement equipment and γ is the penalty cost per unit of pollution. We assume the sign of $d\pi_M{}^*/dB$ should be positive which implies the motivation of introducing pollution abatement equipment.

Profit maximization condition of the representative firm in this sector yields

$$\frac{\partial \pi_M{}^*}{\partial L_M{}^*} = [p_M - \gamma\delta(\lambda - \mu f(L_B)]g'(L_M{}^*) - \underline{w} = 0 \tag{5}$$

Perfect competition with free entry characterizes also both the agricultural and pollution abatement equipment industry in country H.[8] Let π_A and π_B be the total profits of the agricultural sector and pollution abatement equipment industry, respectively, and those can be expressed as follows:

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[7] Given that our focus is on the effects of environmental policy on welfare of representative workers in country H, we abstract from the effects of pollution in the poor country F.

[8] In a companion paper Coniglio and Kondoh (2010) we introduce imperfect competition in the pollution abatement industry.

$$\pi_A = A - wL_A, \tag{6}$$
$$\pi_B = (p+s)B - wL_B, \tag{7}$$

where the price of agricultural good is the numeraire, w is the competitive wage rate. The government financially supports pollution abatement equipment industry and the subsidy per unit of output is denoted s.[9] Then the profit maximization condition of both industries yield to:

$$\frac{\partial \pi_A}{\partial L_A} = \sqrt{E} - w = 0, \tag{8}$$
$$\frac{\partial \pi_B}{\partial L_B} = (p+s) f'(L_B) - w = 0. \tag{9}$$

The full employment condition of country H is:

$$L_A + L_B = L, \tag{10}$$

where L is the labor endowment of country H.

The subsidy is financed by tariff revenue. The government of country H impose tariff t per unit of import of manufactured good. Thus fiscal balance condition of the government is given by the following expression:

$$tM^* = sB. \tag{11}$$

On the demand side, we specify the following social utility function:

$$U = (D_M)^{\alpha}(D_A)^{1-\alpha}, \quad 0 < \alpha < 1 \tag{12}$$

where D_M and D_A are, respectively, aggregate consumption levels of the manufactured and agricultural good. Because of the zero profit of domestic firms and the government budget constraint, the GDP of country H is equal to labor income, wL.

[9] Subsidies to the "green" sector are very common in most OECD countries and take different forms (R&D subsidies, production subsidies, cheap loans, public procurements, regulation etc.). In this paper we model government intervention simply as a per unit production subsidies; the qualitative results of the paper are confirmed in alternative settings.

Demand for each good is obtained by solving utility maximization problem, subject to the following budget constraint:

$$D_A + (p_M + t)D_M = wL . \qquad (13)$$

Thus, we have

$$(p_M + t)D_M = \alpha wL , \qquad (14a)$$
$$D_A = (1-\alpha)wL . \qquad (14b)$$

Finally, under the assumption of perfect competition of manufacturing sector in country *F*, the aggregate profit of this sector is also null.

$$p_M M^* - \underline{w}L_M{}^* - pB - \gamma Z^* = 0 \qquad (15)$$

The above condition also denotes the trade balance between two countries. The value of agricultural good that is exported from country *H* is equal to $\underline{w}L_M{}^* + \gamma Z^*$. It follows that – under balanced international trade – in country *H,* the demand of the manufacturing good is equal to the total output produced in country *F* and then imported, and that of agricultural good is equal to domestic output minus export, respectively. We need to remark that manufacturing output in country *F* is only for exportation. Thus, we have

$$D_M = M^* , \qquad (16a)$$
$$D_A = A - \underline{w}L_M{}^* - \gamma Z^* . \qquad (16b)$$

3. Analysis

In this section, we derive the equilibrium conditions of the model outlined above. Our main aim is to investigate the effects of a change in environmental subsidies in country *H* in a situation where the country has no possibilities to influence country *F* environmental policy (γ is fixed and exogenously given).

From (1a), (1c),(2a), (3), and (8) after some algebraic manipulation we have:

$$\bar{E}^2 - (\lambda - \mu f(L_B))g(L_M{}^*) - w^2 = 0 . \qquad (17)$$

From (1c), (11), (14a) and (16a), we obtain:

$$awL - p_M g(L_M^*) - sf(L_B) = 0 . \tag{18}$$

Finally from (1c), (2b), (10), (14b) and (16b), we have:

$$(1-\alpha)wL - w(L - L_B) + [\underline{w}L_M^* - \gamma\delta(\lambda - \mu f(L_B))g(L_M^*)] = 0 . \tag{19}$$

In equilibrium we have four equations, (5), (17), (18), and (19) which determine four endogenous variables, L_M, L_B, w, and p_M, given the exogenous variables $\bar{E}, \alpha, \mu, L, s, \gamma, \delta$ and λ [10] (see Appendix for the solution of the system of equations and an analysis on the sign of the determinant, Δ,). Equations (9) and (11), respectively, determine p and t.

Under our underlying assumption that the foreign country *F* is a large underdeveloped economy with a rather loose environmental policy (in terms of the model this implies that both the wage rate, $\underline{w}$, and the penalty of pollution, γ, are sufficiently small), we can conclude that the determinant, $\Delta < 0$ [11].

3.1 The Effects of Environmental Policy

In this section our aim is to investigate the effects of a subsidy granted by the Government of the rich country H to the producer of "green technology industries", ie the pollution abatement sector where the countries has a comparative advantage. At least potentially, the subsidy might be an indirect way to influence total emission in a country, *F*, where alternative forms of environmental regulations are absent (for instance due to non-binding international agreements) or weak (in case of loose national environmental rules). We depict a stylized situation which is faced by several developed countries in the real world.

The effects on wage rate and labor input of manufacturing industry in country *F*

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[10] It might be necessary to remark that from (9), (18), and (19), we easily derive (15).

[11] See details on the sign of the determinant, Δ, can be found in the Appendix. Under the above assumption that penalty cost is sufficiently small, $d\pi_M^*/dB$ might be negative and in this case there exists no economic motivation for manufacturing sector to introduce pollution abatement equipment but for instance the use of pollution abatement equipment might be imposed by environmental regulation in *F*.

caused by an increase in subsidy can be expressed as follows by comparative static analysis,

$$\frac{dw}{ds} = \frac{Bg'}{\Delta}\{-(\lambda - \beta\mu L_D)(w - \gamma\delta\mu g f') \\ - L_M * \mu f'[\underline{w} + \gamma\delta(\lambda - \mu B)g']\} > 0, \tag{20}$$

$$\frac{dL_M *}{ds} = \frac{Bg'}{\Delta}[L_M * \mu f'(-\alpha L + L_B) + 2w(w - \gamma\delta\mu g f') < 0\,. \tag{21}$$

Hence an increase in the subsidy pushes up nominal wages in country H and decreases labour demand in the manufacturing sector in country F.[12] Moreover the indirect utility function of a representative worker can be defined as

$$v = v(p_M + t, w)\,.$$

We can evaluate the welfare effect caused by an increase in subsidy by applying Roy's Identity, (14a), and (16a), as follows:

$$\begin{aligned} \frac{dv}{ds} &= \frac{\partial v}{\partial(p_M + t)}\frac{d(p_M + t)}{ds} + \frac{\partial v}{\partial w}\frac{dw}{ds} \\ &= \frac{\partial v}{\partial w}(-\frac{d(p_M + t)}{ds}\frac{g(L_M *)}{L} + \frac{dw}{ds}) \\ &= \frac{\partial v}{\partial w}[\frac{(p_M + t)g'}{L}\frac{dL_M *}{ds} + (1-\alpha)\frac{dw}{ds}], \end{aligned} \tag{22}$$

and the sign of (22) is negative if the efficiency of (subsidized) pollution abatement equipment, measured by the parameter μ, is sufficiently large and thus the emission of

[12] Note that from (8) we have the following relationship $\operatorname{sgn}\frac{dw}{ds} = \operatorname{sgn}\frac{dE}{ds}$. A subsidy to the pollution abatement industry will have a similar effect on environmental capital stock and competitive wage rate. This is due to the fact that an increase in the total stock of natural environment, E, implies an increase of productivity of agricultural industry. As in our model, the competitive wage rate is marginal products of labor in this sector, w will increase.

pollutant, $\lambda - \mu B$, is sufficiently small. In other words, if pollution abatement equipment is already sufficiently effective and most of the emission caused by foreign manufacturing industry have already been removed, then a decrease in subsidy will be effective to improve economic welfare even though the nominal wage rate of domestic workers and the stock of natural environment will be reduced in this case. Intuitively, if the environmental damage caused by the smokestack manufacturing sector is not too large because pollution abatement technique have already reached a "critical level" of efficiency than the negative effects due to a reduction in subsidies to the "green" pollution-abatement sector might be more than compensated by the removal of the inefficiency associated to the subsidy program.

From the above results we can establish the following proposition.

PROPOSITION 1

Assume that foreign wage rate and penalty of pollution are sufficiently low.

1) Environmental capital stock and nominal wage rate of a representative worker can be improved by increasing subsidy.

2) Economic welfare of the representative worker will be increased by decreasing subsidy if pollution abatement equipment is sufficiently effective.

The implication of the first part of proposition 1 is that an increase in subsidy, s, will enhance labor input and output of pollution abatement equipment sector. It causes positive effect on environmental capital stock. And because of domestic labor mobility between sectors, labor input of agricultural industry will decrease. As we assume Cobb-Douglas utility function, in case of sufficient small foreign wage rate and penalty of pollution, trade of agricultural good is also relatively small. Therefore labor input and output of manufacturing good in F are also decreasing. In turn, the reduction in output of the polluting industry causes positive effect on domestic environmental capital stock. The second part of proposition 1 is due to the fact that the positive effect on the wage rate caused by an increase in subsidy is small under the condition that pollution abatement equipment is already sufficiently effective. On the other hand, the increase in subsidy creates other costly distortion – in our model through an increase in the price of manufactured good with tariff, $p_M + t$ - and this negative effect on welfare dominates under the above assumptions.

The proposition implies as a corollary that an industrial subsidy to pollution-abatement firms might be welfare improving only in some cases where the trans-boundary externality is particularly strong and only at the initial stage when the efficiency of pollution-abatement technology is still low. The result is due to the trade-off between the reduction of the environmental damage and the increase in market distortion generated by the subsidy.

3.2 The Effects of Introducing Foreign Workers

In this section we consider the potential effects of migration flows from the poor country *F* to the rich country *H*. In fact, migration will be an important channel linking countries that are sufficiently close geographically – as it is implicit due to the fact that pollution is cross-boundary - and that present a significant wage gap as in our stylized model. The effect on wage rate and labor input of manufacturing sector caused by international immigration can be expressed as follows:

$$\frac{dw}{dL}=\frac{1}{\Delta}\{(\lambda-\mu B)\alpha wf'g'p+[p_M-\gamma\delta(\lambda-\mu B)]\mu\alpha wL_M*f'g'g''\}, \quad (23)$$

$$\frac{dL_M*}{dL}=-\frac{1}{\Delta}[\alpha wf'g'(\mu L_B L_M*+2wp)]>0. \quad (24)$$

The sign of equation (23) is positive if pollution abatement equipment is sufficiently effective and thus $\lambda-\mu B$ is sufficiently small. An increase in the labor force of the rich country *H* will induce an increase in the demand of manufacturing goods and in turn increase import (and output) from *F*.

Let consider now the effect on welfare in the home country. Similar to the analysis reported in eq. (22), we obtain:

$$\frac{du}{dL}=\frac{\partial u}{\partial w}[\frac{(p_M+t)}{L}\frac{dL_M*}{dL}+(1-\alpha)\frac{dw}{dL}], \quad (25)$$

from which we can conclude that if pollution abatement equipment is sufficiently effective and thus $\lambda-\mu B$ is sufficiently small, the increase in the home country population is welfare improving since the sign of (25) is positive. The following proposition is established.

PROPOSITION 2

Assume that foreign wage rate and penalty of pollution are sufficiently low.

If pollution abatement equipment is sufficiently effective, an increase in the *population of the rich country due to international immigration will increase the environmental capital stock, the nominal wage rate and economic welfare of a representative worker.*

The intuition for the result outlined above is the following. An increase in labor endowment through immigration implies an increase in labor supply in both domestic industries. An increase in L_B - the stock o workers employed in pollution abatement equipment - causes positive effect on environmental capital stock and in turn on wage rate. An increase in L_A directly implies an increase in agricultural output. On the other hand, the expansion of the home economy, *H*, will imply an increase in the demand for manufacturing products that are produced and imported from *F*. The increase in output of the polluting manufacturing industry will have a negative effect on the stock of environmental capital.. If pollution abatement equipment are already quite effective, the former effect dominates. Differently from the case of an increase in subsidy, as the output of both manufacturing and agricultural sector also increases, welfare of representative worker will unambiguously increase in the case of increased immigration.

4. Concluding Remarks

Many governments in rich countries subsidize in different ways – for instance through R&D or production subsidies, targeted public procurement or cheap credit lines – "green" industries which provide products and services aimed at reducing pollution emissions. Many "national champions" have emerged with leading role in the global economy. In this paper we present a stylized North-South model where the polluting manufacturing industry is located in the poor and relatively less environmentally regulated South but generates trans-boundary negative externalities in the rich North. We then use this framework in order to analyze the welfare implications for representative workers in the North of subsidies to the pollution abatement industry. In addition we investigate the effects of immigration in the rich North.

Our findings suggests that a subsidy to the pollution abatement sector might increase welfare – by inducing polluting firms to reduce emissions - in situations where pollution abatement technology are not-well developed (ie the starting point is one with low efficiency) and when the poor country has a weak environmental standards. When the pollution-abatement technology has already surpassed a certain critical level of efficiency, although subsidies then could enhance the environmental capital stock, this might reduce economic welfare. In fact, the welfare distortion generated by the subsidy program might dominate the positive effect due to an improvement in the environmental stock. The results calls for a selective subsidy policy which should be preferably be targeted to environmental technology that are still in their infancy stage. As in Kondoh (2009) we also find that immigration in the North unambiguously increases welfare and might increase the environmental stock if pollution abatement technology are sufficiently developed in the South. Hence under certain condition free immigration might be a superior solution to the environmental externality than a costly and distortive subsidy program to environmental industry.

Appendix

Totally differentiating (5), (17), (18), and (19) yields,

$$\begin{bmatrix} [p_M - \gamma\delta(\lambda-\mu B)]g'' & \gamma\mu f' g' & 0 & g' \\ -(\lambda-\mu B) & L_M^* \mu f' & -2w & 0 \\ -p_M & -sf' & \alpha L & -g' \\ \underline{w}+\gamma\delta(\lambda-\mu B)g' & w-\gamma\delta g f' & -\alpha L + L_B & 0 \end{bmatrix} \begin{bmatrix} dL_M^* \\ dL_B \\ dw \\ dp_M \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ B \\ 0 \end{bmatrix} ds + \begin{bmatrix} 0 \\ 0 \\ -\alpha w \\ \alpha w \end{bmatrix} dL. \tag{A1}$$

The determinant of the matrix is,

$$\begin{aligned} \Delta = & [\underline{w}+\gamma\delta(\lambda-\mu B)g'] \\ & \quad [(-\alpha L L_M^* \mu + 2ws) f' g' - 2w\gamma\delta\mu^2 (f')^2 L_M g' g] \\ & -[w-\gamma\delta\mu g f'] \\ & \quad \{[\alpha L(\lambda-\mu B)+2p_M w]g' - 2w[p_M - \gamma\delta(\lambda-\mu B)]gg''\} \\ & +(-\alpha L + L_B) \\ & \quad \{[-(\lambda-\mu B)sf' - p_M L_M^* \mu f']g' \\ & \quad +[p_M - \gamma\delta(\lambda-\mu B)]\mu f' gg'' L_M^* + \gamma\delta(\lambda-\mu B)\mu f' gg']\}, \end{aligned} \tag{A2}$$

To obtain the negative sign of (A2), we need to remark the following equations.

$$D_A = (1-\alpha)wL = wL_A - [\underline{w}L_M * + \gamma\delta(\lambda - \mu B)M*],$$
$$wL_B = w(L - L_A) = \alpha wL - [\underline{w}L_M * + \gamma\delta(\lambda - \mu B)M*],$$
$$L_B = \alpha L - \frac{1}{w}[\underline{w}L_M * + \gamma\delta(\lambda - \mu B)M*],$$
$$\alpha L > L_B.$$
,

But if $\underline{w}$ and γ are sufficiently small, $-\alpha L + L_B$ is negative but also sufficiently small.

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