Environmental Big Push

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Abstract

In this paper, we analyze whether the development of a growing economy could be impeded if a binding climate agreement were signed at the international level. Specifically, we study, in the case of a developing country, the initial momentum for development in the presence of binding emission standards. To this end, we enhance the Big Push static general equilibrium model, developed by Murphy, Shleifer, and Vishny (1989) by introducing both exogeneous emission standards and abatement investments with fixed costs. Our findings show that in the case of a developing country this model could lead to two equilibria: a "bad" equilibrium and a "good" equilibrium. The "bad" equilibrium is a situation in which the development is brought to a halt because of stringent emission standards. The "good" equilibrium, or what we call the "Environmental" Big Push, corresponds to a situation in which a

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given number of modern sectors have an incentive both to modernize production while investing in new abatement technology.

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1 Introduction

The public good nature of the climate change problem requires that developing countries make efforts to cut their greenhouse gas (hereafter denoted as GHG) emissions in the future, along with the industrialized countries which are historically responsible for this problem. The Bali Action Plan, which was the outcome of the December 2008 United Nations climate change conference, marks the first time that developing countries recognized the need to do their fair share in what has to be a global effort. Their combined emissions are projected to exceed those of industrialized countries by around 2020 (Environment for Europeans, 2008). This has led us to ask if the development of a growing economy could be impeded under a binding global climate agreement.

This paper focuses on the interplay between the development of a growing economy and international emission standards. We posit that binding emission standards in a climate agreement are negotiated worldwide. This paper addresses the question whether exogenous emission standards could bring to a halt the development of a country with a growing economy. To this end, we enhance the Big Push static general equilibrium model developed by Murphy, Shleifer and Vishny (1989) (hereafter denoted as MSV (1989)). Specifically, we examine if situations could emerge where we find that multiple sectors of a developing country are modernizing their production, while at the same time they are adopting a new abatement technology, what we are calling here an "Environmental" Big Push.

The concept of Big Push is related to the concept of the vicious circle of poverty (see, among others, Rosenstein-Rodan (1943), Singer (1949), Nurkse (1953), Schitovsky (1954), and Flemming (1955)).[1] When it is not worthwhile for a single producer to increase production, a Big Push could exist when all producers enter production together. In this model, the move from a "bad" equilibrium (underdevelopment) to a "good" equilibrium (industrialization) takes place thanks to intersectoral complementarities in investment through market size effects. An important assumption in this model is that increasing returns to scale in production technology exist (presence of fixed costs). This assumption is also common to other studies in the literature on environmental economics (see, among others, Grossman and Krueger (1991), Barbier (1997), John and Pecchenino (1994), Jones and Manuelli (1995), Suri and Chapman (1998), Stokey (1998), Andreoni and Levinson (2001), Xepapadeas (1997), and le Van et al. (2007)). Even though not specific to the case of developing countries, the literature on the link between appropriate environmental regulation and competitiveness deserves attention (especially in terms of the Porter's hypothesis). For example, Greaker (2006) has shown that a stringent environmental regulation could improve competitiveness through more innovation. This regulation triggers a higher supply of new abatement equipment, which reduces their price. Then the profits, and in turn the export output of polluting sectors, may increase. However, none of these studies, has investigated a model that accounts for the initial momentum for development in the presence of binding emission standards. To this end, and to the best of our knowledge, for the first time binding emission standards and a possibility for the private sector to invest in new abatement technology have been introduced into the Big Push static general equilibrium model.

The emission standards take the form of an ambient emission standard,

[1] Nurkse (1953, p.4) defines a vicious circle of poverty in the following way: "*circular constellation of forces tending to act and react upon one another in such a way as to keep a poor country in a state of poverty*".

i.e., a maximum allowable level of emissions for the entire developing country, and in the case of collective non-compliance, the payment of an abatement cost for all involved in the industrial sector. The investment in new abatement technology allows the firm to reduce its marginal abatement costs, but requires the payment of fixed costs. These costs can include the acquisition of a new plant and new machines (setup costs), or the hiring and training of new engineers. For example, in developing countries for wastewater management, "many large hotels, resorts and non-incorporated residential communities build stand-alone sewage treatment works" (OECD (2005), p. 133). The construction of these plants represents a large fixed cost of investment.

Under some conditions, this model leads to two equilibria: a "bad" equilibrium and a "good" equilibrium. The "bad" equilibrium is a situation in which the development is brought to a halt because of stringent emission standards. The "good" equilibrium, or what we call the "Environmental" Big Push, corresponds to a situation in which a given number of industrialized sectors have an incentive both to modernize their production while investing in new abatement technology. The latter situation requires a coordination of the efforts of some polluting firms to undertake a costly investment in new abatement technology. Our model leads to the multiplicity of equilibria via the following channel: the existence of an ambient emission standard and the abatement investment requiring the payment of fixed costs.

The paper is organized as follows. Section 2 represents the full industrialization equilibrium. The equilibria of the "Environmental" Big Push model is characterized in Section 3. Finally, in Section 4 we discuss our findings in terms of a post-Kyoto protocol and a Pigouvian tax.

2 Full Industrialization Equilibrium

In this section we follow Murphy-Shleifer-Vishny (1989), with no environmental constraint.[2]

We have a one-period economy, and we take into account a developing country with (k) sectors. Each sector, either traditional or modern, produces a different product.

There is one price-taking consumer who supplies (L) units of labor, inelastically. It owns all the profits of the economy.

The utility function of the consumer is the following:

$$U = x_1 x_2 .... x_k \tag{1}$$

where k goods are imperfect substitutes. The utility function does not depend on emissions because in general developing countries have not had the means to put the environment first.

Let (R) denote the aggregate income and (p_i) the price of good (i). The maximization of (1) subject to the budget constraint $(R = \sum_{i=1}^{k} p_i x_i)$ gives the demand function for good (i):

$$x_i = \frac{R}{kp_i} \tag{2}$$

We assume that the wage is numeraire. The aggregate income is as follows:

$$R = \bar{\pi} + L \tag{3}$$

where $(\bar{\pi})$ represents the aggregate profit earned in the economy.

Let us now describe the market structure in each sector. The competitive fringe of firms, called traditional firms, can convert 1 unit of labor into 1 unit of output (so the marginal cost of production is 1). Hence these firms are

[2] The presentation of this model is inspired by Basu (2003, chapter 2).

identical, and operate with a constant returns to scale production technology. We assume that these firms can enter into and exit from the industry costlessly. The zero profit condition for competitive firms implies that they have a perfectly elastic supply at price 1 ($p_i = 1$).

Moreover, in each sector, there is potentially a modern firm (a monopolist) that can convert 1 unit of labor into $\alpha > 1$ units of output (so the marginal cost of production is $\frac{1}{\alpha} < 1$) if it incurs a fixed cost $F > 0$ (for example, the cost of a patent), which corresponds to F units of labor. Hence the monopolist has access to an increasing returns to scale production technology. The industrialization of a sector is realized if a monopolist enters production in that sector. The price of the monopolist is also 1 because of the potential competition of the competitive fringe of firms.[3] The demand of the market is then equal to ($x_i = \frac{R}{k}$). The profit of the monopolist is given by the following expression: $(1 - \frac{1}{\alpha})(R/k) - F$, which can be rewritten as:

$$\pi = \frac{\alpha - 1}{\alpha}\frac{R}{k} - F \equiv \frac{aR}{k} - F \tag{4}$$

with $1 > a > 0$, which represents the mark-up of the monopolist.

Let $R(n)$ denote the aggregate income when (n) sectors industrialize; it is written in the following way: $R(n) = n[\frac{aR(n)}{k} - F] + L$. The resolution of this equation gives:

$$R(n) = \frac{k(L - nF)}{k - na} \tag{5}$$

When (n) sectors have already modernized, the profit of the monopolist in each of these sectors is given by:

$$\pi(n) = \frac{aL - kF}{k - na} \tag{6}$$

The denominator of (6) is always positive. The sign of $\pi(n)$ is then

[3] It could seem odd that the monopolist cannot fix its price; nevertheless, at equilibrium, its profit is strictly positive contrary to that of each competitive firm.

determined by that of $(aL - kF)$, which is independent of (n), the number of modernized sectors. Let us suppose that $(aL - kF)$ is positive so that it is in the interest for a firm to industrialize. Let (n) sectors be modernized, and look at the incentive of a monopolist to enter production. Its profit will be: $\pi(n+1) = \frac{aL-kF}{k-(n+1)a}$, which is positive because $(aL - kF)$ is positive by assumption. Consequently, the only equilibrium in this case is that all sectors modernize. On the contrary, if $(aL-kF)$ is negative, the unique equilibrium is that no sectors modernize. Except the knife-edge case, i.e., $(aL-kF) = 0$, there is a uniqueness of equilibria.

As MSV (1989) have shown, without a wage premium in the modern sector, there is only one equilibrium in the model. By introducing an environmental constraint for modern firms, we show that the model can lead to a multiplicity of equilibria. This is due to spillovers between the various modern sectors through the abatement cost channel.

3 "Environmental" Big Push Equilibria

Let consider, for a growing economy, the transition of economic development from a clean agrarian economy to a polluting industrial economy. Modern sectors refer to those which modernized their production, such as the manufacturing sector in developing countries. These sectors are more polluting than agrarian traditional sectors (Arrow et al. (1995)).

The government of a developing country sets an ambient emission standard for its polluting firms in the form of a maximum allowable level of emissions, denoted as $(\bar{E})$. We assume for simplicity that each modern sector causes a fixed amount of emissions (P). If there are (n) sectors that have industrialized, two situations emerge: 1) $(n \times P) \leq \bar{E}$ or 2) $(n \times P) > \bar{E}$. In the first case, the total level of emissions in the economy is low enough to not exceed the ambient emission standard. Then, modern sectors are not constrained by the environmental regulation; they do not pay abatement costs. In the second case, the emission standard is violated because there is a significantly high number of sectors which had modernized, but which did not invest in new abatement technology. The excess amount of emissions compared to the ambient emission standard is equal to: $(n \times P - \bar{E})$. The emission standard requires each monopolist to pay the following abatement cost:

$$v[\frac{n \times P - \bar{E}}{n}]$$

where $(v > 0)$ represents the marginal abatement cost associated with the existing (traditional) abatement technology.

We implicitly assume that the monopolist completely complies with this emission standard. This requires the assumption that the government is able to commit to the stringency of a penalty for the firm which does not respect emission standards.

Modern sectors have the possibility to invest in new (modern) abatement technology. We assume for simplicity that this technology is so sophisticated that the marginal abatement cost is null, but its investment requires the payment of a fixed cost(S). [4] Thus, firms do not emit pollution when they invest in this technology. A modern sector will invest in new abatement technology if and only if its fixed cost of investment is lower than the abatement cost associated with the existing abatement technology:

$$S < v[\frac{n \times P - \bar{E}}{n}]$$

The respective profits of (n) modern sectors, (m) of which investing in the new abatement technology can be written as such:

[4] This fixed cost of investment does not depend on the number of sectors that has already invested in this technology, contrary to the assumption of the Greaker (2006) model of development of technology. Thus, we exclude learning or imitation possibilities across sectors.

$$\begin{aligned}\pi^{mt} &= x_i(1-\frac{1}{\alpha}) - F - v[P - \frac{\bar{E}}{n-m}] \\ \pi^{mm} &= x_i(1-\frac{1}{\alpha}) - F - S\end{aligned} \tag{7}$$

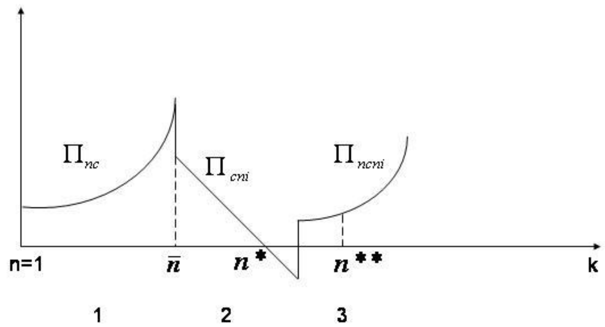
where the index '*mt*' denotes the profit of the monopolist with the traditional abatement technology, and the index '*mm*' denotes the profit of the monopolist with the modern abatement technology. Remember that the profit of the competitive fringe of the market is zero.

3.1 The characterization of two equilibria

We refer to Figure 1 to illustrate the idea of an "Environmental" Big Push. This figure represents the profit of a modern sector which did not invest in new abatement technology as a function of the number of sectors that industrialized (n). In the figure, the abbreviations define the following: '*nc*': not environmentally-constrained, '*cni*': environmentally-constrained and no investment in new abatement technology, and '*ncni*': not environmentally-constrained and no investment in new abatement technology.

- **REGION 1: Modernization – No Environmental Constraint**

We assume that, in Region 1, the emission standard is not violated, i.e., $(n \times P) \leq \bar{E}$ with $n \leq \bar{n}$. The threshold number of modern sectors $\bar{n}$ is simply equal to $\frac{\bar{E}}{P}$. It decreases with the stringency of the emission standard (low $\bar{E}$) and the level of unit emissions (high P). Region 1 corresponds to the case where each sector has an incentive to modernize if $(aL - kF) > 0$. Then, full industrialization requires the following condition: **Condition 1**: $\dfrac{L}{k} > \dfrac{F}{a}$



Profit of a modern sector as a function of the number of industrialized sectors

- **REGION 2: Modernization – Environmental Constraint – No investment in New Abatement Technology**

We assume that, in Region 2, the emission standard is not met, i.e., $(n \times P) > \bar{E}$, because of the absence of investment in new abatement technology by $n > \bar{n}$ modern sectors ($m = 0$). In this case, the profit of a modern sector is written in the following way:

$$\pi^{mt} = x_i(1 - \frac{1}{\alpha}) - F - v[P - \frac{\bar{E}}{n}] \tag{8}$$

The market demand for each sector is equal to $x_i = R/k$. The aggregate income of the economy is given by:

$$R = n[\frac{aR}{k} - F - vP + \frac{v\bar{E}}{n}] + L \tag{9}$$

because the profit of the competitive fringe of the market is zero and the wage is equal to 1. This equation gives the expression of the aggregate income R:

$$R = \frac{[L - nF - nvP + v\bar{E}]k}{k - na} \tag{10}$$

If we substitute this expression with the profit of each monopolist, we obtain:

$$\pi^{mt} = \frac{La - k[F + v(P - \frac{\bar{E}}{n})]}{k - na} \tag{11}$$

This profit is null for the specific number, n^*, of sectors which industrialize:

$$n^* = \frac{v\bar{E}}{vP - \frac{La}{k} + F} \tag{12}$$

For this specific number of industrialized sectors, the profit of the modern sector which did not invest in new abatement technology nullifies. This specific number of industrialized sectors diminishes with the stringency of the environmental standard (low $\bar{E}$), with unit emissions P (high P), with the level of the fixed cost of investment in production F (high F) as well as with the marginal abatement cost of the traditional abatement technology v (high v). On the contrary, n^* increases with the extent of scale economies in modern production (high a), and with the income of wage (high L) which stipulates the demand for each product in the economy.

This specific number of sectors is positive, $n^* > 0$, if the following condition is satisfied:

$$\textbf{Condition 2}: vP > \frac{aL - Fk}{k} \tag{13}$$

Another condition we look for is that none of the first (n^*) modern sectors have an incentive to invest in new abatement technology. This condition becomes the following: $v[\frac{n^* \times P - \bar{E}}{n^*}] < S$, so that the new investment is too costly compared to the abatement cost associated with the existing abatement technology. From the condition $\pi^{mt} = 0$, we have the following equality: $\frac{aL}{k} - F = v[P - \frac{\bar{E}}{n^*}]$. This implies $\frac{aL}{k} - F < S$. So we have:

$$\frac{La}{k} - F < S \tag{14}$$

- **REGION 3: Modernization –No Environmental Constraint –Investment in New Abatement Technology**

We assume that, in Region 3, the emission standard is met thanks to the investment in new abatement technology by ($m > 0$) modern sectors. So we have: $((n - m) \times P) \leq \bar{E}$, with $n \geq n^*$.

The profit of a modern sector that did not invest in new abatement technology, when m others did, is written as:

$$\pi^{mt} = \frac{aR}{k} - F \tag{15}$$

The aggregate income of the economy is given by:

$$R = (n - m)[\frac{aR}{k} - F] + m[\frac{aR}{k} - F - S] + L \tag{16}$$

where the first term corresponds to the profit of the ($n - m$) modern sectors with the traditional abatement technology. The second term represents the profit of (m) modern sectors that invested in new abatement technology. This equation gives us the expression of the aggregate income R:

$$R = \frac{[L - nF - mS]k}{k - na} \tag{17}$$

If we substitute this expression with the expression of the profit of each monopolist (that did not adopt the new abatement technology), we obtain:

$$\pi^{mt} = \frac{La - mSa - Fk}{k - na} \tag{18}$$

We need the positivity of the profit of the m firms which invested in the new abatement technology, $\pi^{mm} = \pi^{mt} - S$. To match this condition, we consider a specific m^{**} such that $n^{**} - m^{**} = \frac{\bar{E}}{P}$. This implies that m^{**} is the minimum number of modern firms which invest in the new abatement technology, required to avoid the environmental constraint. The positivity of the profit of this firm, $\pi^{mm}(m^{**})$, implies the following condition:

$$\frac{La}{k} - F > S - \frac{aS\bar{E}}{kP} \tag{19}$$

The two conditions in Equations 14 and 19 can be summarized by the following condition:

Condition 3: $S - \frac{aS\bar{E}}{kP} < \frac{La}{k} - F < S$

The right-hand-side of the inequality implies that none of the modern firms invest in the new abatement technology because the investment is too costly. The left-hand-side of the inequality implies that the profit of the modern firm which invests in the new abatement technology is positive, without subsidies. This condition guarantees the positivity of the profit of each modern sector which does not undertake the costly investment.

3.2 Main result

We can now write the main proposition of the paper.

Proposition *If Conditions 1, 2 and 3 are satisfied, then two equilibria emerge:*

1) a "bad" equilibrium characterized by a low level of development (n^*) without adoption of the new abatement technology, and

2) a "good" equilibrium characterized by a higher level of development (n^{**}) with the adoption of new abatement technology [**"Environmental" Big Push**].

The "bad" equilibrium corresponds to an equilibrium with a low level of development without adoption of the new abatement technology, because none of the modern sectors invest in this technology. Therefore, the ambient emission standard is not respected. This defines a situation in which the development is impeded because of stringent emission standards.

The "good" equilibrium, or what we call "Environmental" Big Push, can be explained as follows. If the number of sectors which industrialize increases, the cost of modernization will increase because of the abatement costs that modern sectors are held to pay in the case when the emission standard is collectively violated. This could prevent some sectors from industrializing. However, if some of these modern sectors invest in new abatement technology, the environmental constraint for all modern sectors could disappear because in this case the environmental standard will be respected. This could encourage some more traditional sectors to modernize.

Our findings show that binding emission standards do not necessarily impede the development of a growing economy. They can even incite some sectors to both modernize their production while at the same time investing in new abatement technology. This stems from the spillovers across sectors channelled through the level of the ambient emission standard and the implied level of the abatement cost in the case when the standard is collectively violated. However, if there is to be a move towards this “good”equilibrium, a coordination of the efforts of some polluting firms to undertake a costly investment in abatement technology is needed. The coordination of the abatement investments across sectors could be effectuated by government policies. Moreover, given these conditions, it is no longer necessary to ask developed countries to provide international aid to developing countries.

4 Conclusion

In this paper, we have illustrated in a simple example, under what conditions an “Environmental” Big Push could come about. This concept is used to define a situation in which a number of sectors are modernizing their production while at the same time investing in new abatement technology. To this end, we have adopted a static general equilibrium model with multiple sectors inspired from the analytical Big Push model developed by Murphy, Shleifer and Vishny (1989). We have enhanced this model by introducing binding emission standards and the possibility of abatement investments requiring the payment of fixed costs. Our findings show that this model could lead to a multiplicity of equilibria. A “bad” equilibrium is a situation in which the development is impeded because of stringent emission standards. A “good” equilibrium corresponds to the case in which binding emission standards lead to an “Environmental” Big Push. These results suggest that developing countries supposed future big emitters of GHG emissions could have an incentive to participate in a post-Kyoto protocol, because the internationally negotiated emission standards could induce some of their traditional sectors both to modernize their production while investing in new abatement technology. However, if there is to be a move towards this “good”equilibrium, it is necessary to coordinate the efforts of some polluting firms to undertake a costly investment in abatement technology. The coordination of the abatement investments across sectors could be effectuated by government policies.

This analysis is limited in some respects. In this simple general equilibrium model, the price effects (substitution effects) are absent; only the revenue effects are highlighted. Furthermore, in this analysis, we have dealt with the most frequent environmental policy instrument, which is a regulation by emission standards. A next step would be to investigate the outcomes of the model when all the unit emissions are taxed, as would be the case with a Pigouvian tax. Modern sectors would then be obliged to pay both the abatement costs and the costs of residual emissions when the binding emission standard is collectively violated.

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