Big Push, adoption of environmentally-friendly technology, and the Porter hypothesis

Basak BAYRAMOGLU*, Jean-François JACQUES†

May 3, 2017

Abstract

This study presents a theoretical example which brings a new insight on the Porter hypothesis linking it with aggregate income effects. We investigate for a developing economy whether more stringent emission standards could induce investments in a new abatement technology without jeopardizing economic development. We incorporate an environmental counterpart into the Big Push general equilibrium model of Murphy, Shleifer and Vishny (1989). Our findings show that this model can lead to a multiplicity of equilibria: a "bad" equilibrium without any clean environmental investment, and a "good"

*Economie Publique, INRA, AgroParisTech, Université Paris-Saclay, 78850 Thiverval-Grignon, France. E-mail: Basak.Bayramoglu@inra.fr.

†Université Paris-Est, ERUDITE (EA 437), UPEM 77454 Marne la Vallée, France et LEDa-CGEMP, Université Paris-Dauphine, Paris, France. E-mail: Jean-Francois.Jacques@u-pem.fr.

equilibrium with full modernization and clean investment. 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 modern sectors have an incentive both to modernize production while investing in new abatement technology because the old technology becomes too costly. We also discuss the potential of a tax-subsidy scheme for solving the coordination problem of investments in clean technology.

Keywords: environmental policy, emission standard, emission tax, investment, technology, Porter hypothesis, development, big push, poverty trap.

1 Introduction

This paper presents a theoretical example where stringent environmental standards can paradoxically push a low-income country to the highest level of development. This result is linked to two main hypotheses: the presence of fixed cost which gives rise to large increasing returns to scale in production, and the possibility for polluting firms to invest in clean technology which is profitable beyond a high abatement level. This technology has a property of a public good.

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, 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. The U.S. Energy Information Administration has reported that energy-related carbon dioxide emissions from developing countries will be 127 percent higher than in the world's most developed economies by 2040 (U.S. Energy Information Administration (2014)).

In December 2015, 195 countries succeeded in signing the Paris Agreement (2015) for reducing GHG emissions. In contrast to the Kyoto Protocol

(1997), the Paris Agreement (2015) does not include internationally negotiated emission standards. The countries are only held to communicate their national objectives of mitigation efforts, called Intended Nationally Determined Contributions (INDCs).[1] Even though these targets are not binding at the international level, they could be translated into binding emission standards at the national level if a developing country aims to respect them. This has led us to ask if the development of a low-income country could be impeded under binding national emission standards.

This paper develops a simple model building on Murphy, Shleifer and Vishny (1989) work on Big Push (hereafter denoted as MSV (1989)). It incorporates an environmental counterpart, through binding emission standards, into the Big Push general equilibrium model of MSV (1989) without changing the assumptions neither on preferences of the consumer nor on the production technology. As MSV(1989), our model is based on the existence of large aggregate demand spillovers.[2] The profit of each modern sector is redistributed to consumers which increases the demand, and thus the profit of the other sectors. The question we ask in this paper is to know if this cumulative aggregate demand effect is sufficiently large for a number of traditional

[1]For instance, in its INDC report, Chile commits in all the sectors excluding Use of the land, Change of use of the land and Forestry (LULUCF) "*to reduce its CO2 emissions per GDP unit by 30% below their 2007 levels by 2030, considering a future economic growth which allows to implement adequate measures to reach this commitment*" (INDC website). Nigeria communicates an unconditional mitigation target of 20% to reduce its emissions of 2010-2014 by 2030.

[2]For extensions of the model developed by MSV (1989) in the literature, see for instance de Fontenay (2004) on the market power of firms and the quality of institutions, and Trindade (2005) on tradable intermediate goods.

sectors to modernize both their production and abatement technology.

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)).[3] When it is not worthwhile for a single producer to increase production, a Big Push could exist when all producers enter production all 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 has been also introduced in endogenous growth models with pollution abatement (see, among others, Smulders and Gradus (1996), and Xepapadeas (1997)), and in overlapping generations model of growth and the environment (see, among others, John and Pecchenino (1994)). Andreoni and Levinson (2001) have also used this assumption in a static model to explain the empirical evidence on the Environmental Kuznets Curve (Grossman and Krueger (1995)).[4]

As concerns the question of poverty traps, Xepapadeas (1997) has shown that poor countries with environmental concerns can be trapped in poverty

[3]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*".

[4]As written, our model could not be compared to a model of Environmental Kuznets Curve as emissions do not exceed the emission standard at the equilibrium, i.e. any excess of emissions is automatically abated.

because the low level of capital does not allow increasing returns in abatement to be exploited. Prieur et al. (2013) have shown, in the framework of an overlapping generations model that environmental and poverty traps could exist in the presence of a potential irreversibility of pollution. Fodha and Seegmuller (2014) have shown, using an overlapping generations model that an environmental poverty trap could emerge if the initial capital stock is low in an economy where environmental policies are financed by public debt. Unlike the literature based on endogenous growth theory and overlapping generations models, we adopt a model with a large aggregate demand effect, namely the Big Push general equilibrium model to account for the initial momentum for development in the presence of binding emission standards. Hence, our model applies specifically to the context of low-income countries because it highlights the mechanism of demand spillovers which gives rise to multiple equilibria.

Even though not specific to the case of developing countries, the literature on the link between appropriate environmental regulation, innovation, and competitiveness deserves attention, especially in terms of the Porter Hypothesis.[5] The Porter Hypothesis says that well-designed environmental regulation could increase competitiveness by inducing more innovation (Porter and Van der Linde (1995)). For example, Mohr (2002) has shown that an

[5]Ambec et al. (2013) survey the theoretical approaches that have been put forward to explain the Porter Hypothesis including behavioral arguments (see for instance, Ambec and Barla (2006)), market failures (Simpson and Bradford (1996), and Mohr (2002)), and organizational failures (Ambec and Barla (2002)).

environmental regulation combining a technology standard with an emission standard could simultaneously improve environmental quality and increase productivity. Some studies analyze how stringent environmental regulation affects the competitiveness and environmental quality through the development of the upstream pollution abatement sector (eco-industry): via a higher supply of new abatement equipment (Greaker, 2006) or more entry into the eco-industry (David et al., 2011).

This paper presents an extension to the literature on the Porter Hypothesis by linking the hypothesis to the work on poverty traps for developing economies. More specifically, it introduces a theoretical example which brings a new insight on the Porter hypothesis linking it with aggregate income effects. We investigate how increased stringency in environmental regulation affects the incentives for traditional sectors both to modernize their production and adopt a cleaner abatement technology. An emission standard is analyzed in this respect. If the number of (modern) clean sectors is sufficiently large (to cancel the payment of abatement costs for other (modern) dirty sectors), then some traditional sectors may modernize. Hence, we show that in a situation where an economy overcomes a poverty trap it might, through a similar mechanism also achieve an "Environmental" Big Push that yields both economic development and improved environmental performance.

We construct a simple theoretical example which leads to a multiplicity of equilibria: a "bad" equilibrium without any clean environmental investment, and a "good" equilibrium with full modernization and clean investment. The "bad" equilibrium is a situation in which the development is brought to a halt because of stringent emission standards. The "good" equilibrium could be paradoxically reached if the emission standard is strong enough to make profitable the adoption of the clean technology. This situation requires a coordination of the efforts of some polluting sectors to undertake a costly investment in new abatement technology. We show that the coordination problem could be solved thanks to a tax-subsidy scheme.

The paper is organized as follows. Section 2 represents the full industrialization equilibrium without any environmental constraint. The equilibria with an environmental constraint, in particular the "Environmental" Big Push equilibrium are presented in Section 3. Finally, Section 4 provides concluding remarks.

2 Equilibrium without an environmental constraint

In this section, we present a developing economy where sectors are not constrained by an environmental regulation.[6] We consider, for a developing 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

[6]The presentation of the model of Murphy, Shleifer and Vishny (1989) is inspired by Basu (2003, chapter 2).

countries. These sectors are more polluting than agrarian traditional sectors (Arrow et al. (1995)). At the beginning of time, we assume that k traditional sectors do not pollute. Once they become modern by paying a fixed cost, each modern sector emits P. In this section, we posit that the pollution is not high enough to be regulated.

In this model, there is an implicit dynamics through the entry condition. Here, we focus on the steady-state equilibria. Each sector, either traditional or modern, produces a different product. There is one price-taker 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:

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

where k goods are imperfect substitutes, $\delta > 0$, and E stands for total emissions. The linear term δE represents the disutility of the consumer from pollution. The consumer has no control on that term because it is an externality. Here, we do not focus on welfare effects, but only on national income effects.[7] As MSV (1989), we stress the importance of aggregate revenue effects for the emergence of positive spillovers across sectors via market size effects.

Let (R) denote the aggregate income and (p_i) the price of good (i). The

[7] As will be exposed later on, because of the perfect competition, the price of the goods for traditional and modern sectors is the same. Thus, substitution effects would not play a role.

maximization of Equation 1 subject to the budget constraint ($R = \sum_{i=1}^{k} p_i x_i$) gives the demand function for good (i): $x_i = \dfrac{R}{kp_i}$. Note that (k) is the number of sectors, and will place an upper bound on the number of modern sectors. We assume that the wage is numeraire. The aggregate income is as follows: $R = (\overline{\pi} + L)$ where ($\overline{\pi}$) represents the aggregate profit earned in the economy.

The competitive fringe of firms, called traditional firms, can convert 1 unit of labor into 1 unit of output (a constant returns to scale production technology). We assume that these firms can enter into and exit from the industry without cost. 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, a monopolist (modern firm) can emerge if it pays a fixed cost. It 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 $F > 0$ (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.[8] 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: $\pi = \dfrac{\alpha - 1}{\alpha}\dfrac{R}{k} - F \equiv \dfrac{aR}{k} - F$ with $0 < a < 1$, which represents both the mark-up of the monopolist and the measure of scale economies.

[8]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.

When (n) sectors have already modernized, the profit of the monopolist in each of these sectors is given by[9]: $\pi(n) = \dfrac{aL - kF}{k - na}$. The denominator of this equation is always positive because $n \leq k$ and $a < 1$. The sign of $\pi(n)$ is then determined by that of $(aL - kF)$, which is independent of (n), the number of modernized sectors. In the sequel, we assume that $(aL - kF)$ is positive so that it is in the interest for a firm to industrialize before it is constrained by an environmental regulation: **Condition 1**: $(aL - kF) > 0$.

This condition means that the potential monopoly rent generated by labor resource from all the sectors, if they were all modern, is greater than the total cost of modernization. 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, without an environmental constraint, the only equilibrium is that all sectors modernize. With an environmental constraint, we will show in the next section that the development can slow down, meaning that the number of modern sectors could be less than k.

3 "Environmental" Big Push Equilibrium

We present now a simple theoretical example to express the idea that the increase of the aggregate demand arising from modernization can overcome the

[9]When (n) sectors industrialize, the profit of the monopolist is equal to $\pi = \frac{aR(n)}{k} - F$. The aggregate income when (n) sectors industrialize is given by $R(n) = n[\frac{aR(n)}{k} - F] + L$. The resolution of this equation leads to: $R(n) = \frac{k(L-nF)}{k-na}$.

cost of negative spillover (pollution) if a sufficient number of modern sectors invest in new abatement technology. If the social gain of the "public" good (environmental investment) is not sufficient, the development of the economy will cease because of the environmental constraint. All modern firms will face an abatement cost which reduces their profit. Consequently, the aggregate profit and aggregate revenue will be reduced too. But if the social gain of private environmental investment is high enough, simultaneous investments of a group of modern sectors create a big push and help the economy to escape from the trap of underdevelopment by an aggregate demand mechanism.

The government of a developing country sets an ambient emission standard for its polluting sectors in the form of a maximum allowable level of emissions, denoted as ($\overline{E}$). The ambient emission standard could translate here the Intended Nationally Determined Contribution (INDC) of a developing country motivated to respect its obligations in the Paris Agreement (2015). In our model, there are both positive and negative spillovers between sectors. As in MSV (1989), there are positive aggregate demand spillovers among sectors through market size effects. A larger modernization of the industry increases profits to all sectors in the economy via demand effects. More modern sectors imply, however, more pollution. If the ambient emission standard is violated, each modern sector abates a fraction of its pollution P (hence pays an abatement cost) such that $\overline{E}$ is met collectively. This is a negative spillover across sectors because the higher the number of dirty modern sectors, the more the polluting sectors have to pay individually. Modern sectors also have the option to invest in a new abatement technology. We assume for simplicity that this technology is so sophisticated that once modern sectors invest in by paying a fixed cost, they do not emit anymore (i.e., the marginal abatement cost is null). Thus, if a sufficiently high number of modern sectors invest in this technology, the ambient emission standard could be more easily met collectively. This is another channel for positive spillovers across sectors.

We now detail the environmental counterpart of the model. We assume for simplicity that each modern sector causes a fixed amount of emissions (P).[10] If there are (n) sectors that have industrialized, two situations emerge: 1) the total level of emissions $E = n \times P$ is lower than the standard: $E = n \times P \leq \overline{E}$, or 2) the total level of emissions exceeds the standard $E = n \times P > \overline{E}$. We define $\overline{n}$ the number of modern sectors for which $\overline{n}P = \overline{E}$. 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

[10]We have relaxed this assumption to consider endogenous emissions proportional to production $P = \beta x_i$ with $\beta > 0$ in Appendix 3. This extension reduces the mark-up of the monopolist from a to $(a - v\beta)$ in the first equilibrium without investment in clean technology. The conditions in this case are very similar to those with exogenous emissions. As concerns equilibria with investment in clean technology, the extension complicates the analysis which becomes non tractable. Nevertheless, the basic mechanisms remain.

amount of emissions compared to the ambient emission standard is equal to: $E - \overline{E} = n \times P - \overline{E}$. The emission standard requires each monopolist to pay the following abatement cost: $v[\frac{n \times P - \overline{E}}{n}]$, where $(v > 0)$ represents the marginal abatement cost associated with the existing (traditional) abatement technology. We assume that the monopolist completely complies with this emission standard. This requires, implicitly, the assumption that the government is able to commit to the stringency of a penalty for the sectors which do not respect emission standards.

Modern sectors have the possibility to invest in new (modern) abatement technology. We call this technology the clean technology. This investment requires the payment of a fixed cost (S)[11], but allows modern sectors not to emit pollution P.[12] The fixed cost of investment S can include the acquisition of a new plant and new machines (setup costs). Thus, $(F+S)$ represents the total cost to invest in modern production and modern abatement technology.[13]

Let us suppose now that m out of the n modern sectors invest in new abatement technology. The excess of emissions with respect to the ambient emission standard then becomes $E - \overline{E} = (n-m) \times P - \overline{E}$. In order to decide

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

[12]Here we consider two extreme cases of abatement technology: an old technology without a fixed cost but only a variable abatement cost, and a modern technology with the opposite assumption. A more realistic model should include both costs in the two cases, but with a larger fixed cost for the new technology.

[13]$(F + S)$ can represent the cost of investment in a cleaner production technology such as a technology with a better energy efficiency.

to invest in new abatement technology, the monopolist will compare its cost of investment S with the abatement cost associated with the old abatement technology $v[P - \frac{\overline{E}}{n-m}]$. It is clear that the monopolist will be more willing to invest, the more stringent is the emission standard ($\overline{E}$ small) and/or the larger is the number of polluting sectors ($(n-m)$ large).

Moreover we assume that there exist a threshold ratio $\overline{P} = \frac{\overline{E}}{N}$ with a special number of dirty modern sectors $N = n - m$ (see Figure 1) above which it is in the interest of a modern sector to become clean, while it is not the case below this threshold. Notice that, as $\overline{P}$ is fixed, N depends on $\overline{E}$. The idea is that the larger the number of polluting sectors, the higher are the individual abatement costs associated with the old technology. This **Assumption A** could be written as:

Assumption A

$$\begin{aligned}
S &= v(P - \overline{P}) \\
\text{with } \overline{P} &= \frac{\overline{E}}{N} \\
S &< v(P - \frac{\overline{E}}{n-m}) \text{ if } n - m > N \\
\text{in particular } S &< vP \\
\text{and } S &> v(P - \frac{\overline{E}}{n-m}) \text{ if } n - m < N
\end{aligned}$$

We then define dirty and clean modern firms.

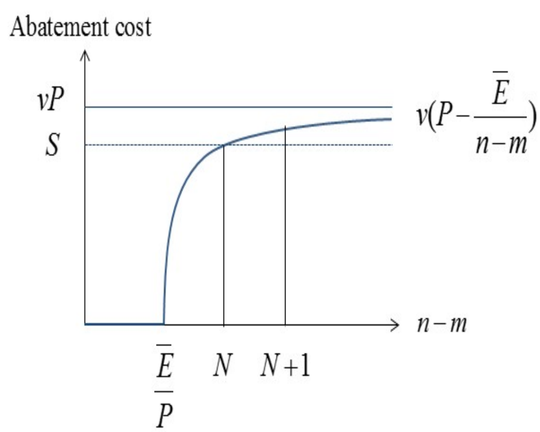


Figure 1: Threshold number of dirty modern sectors

Definition 1 *A dirty modern sector, denoted by 'mt', is a monopolist which uses the traditional abatement technology. Its abatement cost is* $v(P-\dfrac{\overline{E}}{n-m})$.

Definition 2 *A clean modern sector, denoted by 'mm', is a monopolist which invests in and uses the modern abatement technology. Its abatement cost is fixed* S.

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

$$\begin{aligned} \pi^{mt} &= ax_i - F - v[P - \frac{\overline{E}}{n-m}] \\ \pi^{mm} &= ax_i - F - S \end{aligned} \qquad (2)$$

Remember that the profit of the competitive fringe of the market is zero.

3.1 The characterization of equilibria

We shall present successively two kind of equilibrium. In Case 1, we study an equilibrium n_1^* without investment in clean technology $m = 0$ ("bad" equilibrium). In Case 2, we study two equilibria: n_2^* without investment in clean technology $m = 0$, and an equilibrium of full modernization $n_2^{**} = k$ with a group of m modern sectors which invests in the clean technology $m > 0$. This last equilibrium could be attained if the emission standard is strong enough to make profitable the adoption of the clean technology.[14] Nevertheless the economy can stay in the bad equilibrium, so we suggest an incentive scheme that can pull out the economy from the bad equilibrium. We show that this scheme should combine the taxation of dirty modern sectors with a subsidy for clean ones.

3.1.1 Case 1: equilibrium without adoption of clean technology

We consider a loose level of environmental standard $\overline{E}_1$ such that a modern sector has no interest in adopting the clean technology because it is too costly, so $m = 0$.

$$\textbf{Condition 2: } S > v(P - \frac{\overline{E}_1}{k})$$

We must have a strictly positive number of modern sectors n_1^* [15]:

$$n_1^* = \frac{v\overline{E}_1}{vP - \dfrac{aL}{k} + F} \tag{3}$$

We have $n_1^* > 0$ if $aL < k(vP + F)$ (**Condition 3**).

For this specific number of industrialized sectors, the profit of the mod-

[14] We have also studied the whole set of unstable equilibria (each one is associated to a particular $m > 0$) in Case 2. They are not stable because the clean monopolist is worse off compared to the dirty one. These equilibria become stable thanks to a subsidy to clean modern sectors funded by a tax on dirty ones. For the sake of simplicity, we do not include this analysis in the paper.

[15] Setting the numerator of $\pi^{mt} = \frac{aLn - Fkn - vPnk + v\overline{E}_1 k}{(k - an)n}$ equal to zero and solving for n allows us to derive n_1^*.

ern sector which did not invest in new abatement technology nullifies. This specific number of industrialized sectors decreases with the stringency of regulation $\overline{E}$ (low $\overline{E}$), 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_1^* increases with the extent of scale economies in modern production (high a), and with the income of wage (high L) which stimulates the demand for each product in the economy.

We also have $n_1^* \leq k$ if:

Condition 4: $aL \leq k(vP + F) - v\overline{E}_1$

Condition 4 is more constraining than Condition 3, so we only need to verify Condition 4. Condition 4 that could be also written as, $vk(P - \frac{\overline{E}_1}{k}) > aL - kF$, means that the total abatement cost is greater than the net monopoly rent extracted from the labor resource, if all the sectors were modern.

Lemma 1 *The profit of a dirty modern sector π^{mt} is a decreasing function of the number of modern sectors n* (with $\overline{n} < n < n_1^*$), *if Condition 4 holds.*

Proof. See Appendix 1. ■

Lemma 1 shows that the profit of a modern sector with the old abatement technology decreases with (n), when Condition 4 is satisfied. At first sight, we could think that this profit depends positively on the number of modern sectors thanks to positive demand spillovers. The increased modernization is associated, however, with greater pollution. Hence the abatement cost increases when the number of dirty modern sectors goes up, and in turn, the individual profit drops.

3.1.2 Case 2: equilibrium with adoption of clean technology

Now the government implements a stronger environmental regulation, and reduces $\overline{E}_1$ to $\overline{E}_2$. In this case, we exhibit two equilibria: a bad equilibrium n_2^* and a good equilibrium $n_2^{**} = k$ (see Figure 2).

The **bad equilibrium** is defined by $\pi^{mt} = 0$ with the number of modern sectors $0 < n_2^* \leq k$ and by the absence of investment in clean technology $m = 0$. The latter requires the condition, **Condition 5:** $S > v(P - \frac{\overline{E}_2}{n_2^*})$, with

$$n_2^* = \frac{v\overline{E}_2}{vP - \frac{aL}{k} + F} \tag{4}$$

This condition implies that it is not interesting for a modern sector to invest in clean technology with the number of sectors n_2^* even though the environmental standard is stricter now $\overline{E}_2 < \overline{E}_1$.

Lemma 2 *The number of modern sectors in Case 2 (bad equilibrium) is lower than that in Case 1:* $n_2^* < n_1^*$.

Proof. Equations 3 and 4 lead to $n_2^* < n_1^* \leq k$, because $\overline{E}_2 < \overline{E}_1$.

Thanks to Condition 3, we also have $n_2^* > 0$. ■

Lemma 2 shows that the bad equilibrium in Case 2 is worse than the equilibrium of Case 1 in terms of modernization, because the standard is more stringent so fewer traditional sectors can become modern.

Now, we study the **good equilibrium** of Case 2. It is defined by $n_2^{**} = k$ and $m > 0$. Before presenting the full industrialization equilibrium, we define the profit of dirty and clean monopolists for any $n > m$ with $\overline{E} = \overline{E}_2$. So, we assume that a group of m modern firms invests in clean technology.

The profit of a dirty monopolist for any $n > m$ is

$$\pi^{mt} = \frac{aL - k(F + v(P - \frac{\overline{E}_2}{n-m})) - am(S - v(P - \frac{\overline{E}_2}{n-m}))}{k - na} \quad (5)$$

because $\pi^{mt} = \frac{a}{k}R - F - v(P - \frac{\overline{E}_2}{n-m})$ with $R = \frac{L - nF - nv(P - \frac{\overline{E}_2}{n-m}) - m(S - v(P - \frac{\overline{E}_2}{n-m}))}{1 - \frac{na}{k}}$.

Lemma 3 *The profit of a dirty modern sector π^{mt} is increasing in the number of clean modern sectors m if Assumption A is satisfied.*

Proof. $\pi^{mt} = \frac{a}{k}R - F - v(P - \frac{\overline{E}_2}{n-m})$ with $R = \frac{L - nF - nv(P - \frac{\overline{E}_2}{n-m}) - m(S - v(P - \frac{\overline{E}_2}{n-m}))}{1 - \frac{na}{k}}$. R is increasing with m (because Assumption A implies $vP > S$) and $v(P - \frac{\overline{E}_2}{n-m})$ is decreasing with m. ■

The clean technology has the property of a public good, it abates all the pollution of the clean monopolist. Consequently it abates more than it has to do. Other traditional sectors can take advantage of that by becoming modern. Hence the aggregate profit is higher, so is the aggregate revenue. The demand for each good increases so does the profit of monopoly.

The profit of a clean monopolist is

$$\pi^{mm} = \frac{aL - k(F+S) + na(S - v(P - \frac{\overline{E}_2}{n-m})) - ma(S - v(P - \frac{\overline{E}_2}{n-m}))}{k - na} \tag{6}$$

because $\pi^{mm} = \frac{a}{k}R - F - S$ with $R = \frac{L - nF - nv(P - \frac{\overline{E}_2}{n-m}) - m(S - v(P - \frac{\overline{E}_2}{n-m}))}{1 - \frac{na}{k}}$.

The profit of a clean monopolist is lower than the profit of a dirty one as long as $v(P - \dfrac{\overline{E}_2}{n-m}) < S$.

We now focus our attention on the full industrialization equilibrium to show that a more stringent emission standard $\overline{E}_2 < \overline{E}_1$ makes the new abatement technology profitable if too many sectors pollute.

Lemma 4 *For $n = k$, π^{mm} is increasing with m.*

Proof. $\pi^{mm} = \frac{am(vP-S)+aL-k(F+S)-avPk+akS+av\overline{E}_2}{(1-a)k}$ and $vP > S$ by Assumption A. ■

This result is due to the aggregate revenue effects which augment all the sectoral demands.

We now present **Condition 6** to obtain the next result:

$aL - kF < kS - akS - av\overline{E}_2 + avPk$

Lemma 5 *For the full modernization $n = k$, there exist m^* such that $\pi^{mm} = 0$.*

Proof. Replacing n by k in π^{mm} and solving for $\pi^{mm} = 0$ allows us to obtain $m^* = \frac{k(S+F)+avPk-akS-aL-av\overline{E}_2}{a(vP-S)} > 0$ thanks to Condition 6 and $S < vP$ (Assumption A). ■

As far as $v(P - \dfrac{\overline{E}_2}{k - m^*}) < S$, there is no incentive yet to invest in clean technology so m^* is not stable.

We now look at the condition to obtain a stable equilibrium: no clean sector wants to become dirty. We must show that the clean monopolist does not have any incentive to deviate from this equilibrium. This is the subject of Lemma 5. Thanks to the threshold level of abatement above which the new technology is less costly, provided in Assumption A, the equilibrium could be attained if the emission standard is more stringent.

We now present **Condition 7** to obtain the next result:

$aL > k(F + S) - av\overline{E}_2$

Lemma 6 *For $n = k$, consider $\overline{E}_2$ a more stringent policy ($\overline{E}_2 < \overline{E}_1$),* and *$m^{**}$ such that $\overline{P} = \frac{\overline{E}_2}{k-m^{**}}$ with $v(P - \frac{\overline{E}_2}{k-m^{**}}) = S$ (Assumption A), then (k, m^{**}) ensures a stable equilibrium if Condition 7 holds.*

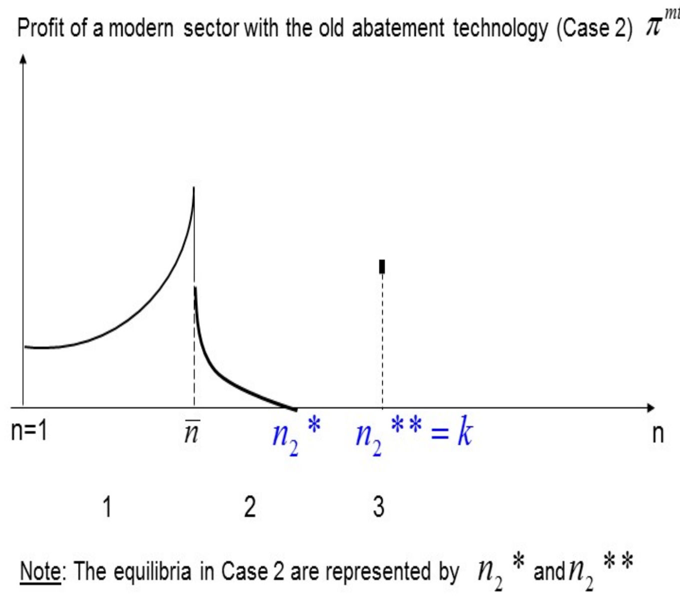
Proof. In that case, we have $\pi^{mm} = \pi^{mt}$. Moreover, $m^{**} > m^*$ is equivalent to $m^{**} = \frac{k(vP-S)-v\overline{E}_2}{vP-S} > \frac{k(S+F)+avPk-akS-aL-av\overline{E}_2}{a(vP-S)} = m^*$. This last inequality holds if and only if $aL > k(F+S) - av\overline{E}_2$ (Condition 7). Because π^{mm} is increasing with m (Lemma 4), $\pi^{mm}(k, m^{**}) > \pi^{mm}(k, m^*) = 0$. As $v(P - \dfrac{\overline{E}_2}{k - m^{**}}) = S$, then $\pi^{mt}(k, m^{**}) = \pi^{mm}(k, m^{**}) > 0$. Moreover, if a clean modern monopoly wants to become dirty, m will decrease so does π^{mt} (Lemma 3), and $v(P - \frac{\overline{E}_2}{k-(m^{**}-1)}) > S$. Consequently, it is not in its own interest to do that. So there is a stable equilibrium with $n_2^{**} = k$. ■

This lemma guarantees the existence of an equilibrium by m^{**} which is greater than m^*. We do not know the exact value of m at the equilibrium. To do this, it would be necessary to compare for each $m \geq m^{**}$ the profits π^{mm} and π^{mt}, which is very tedious. What we do know is that there are at least m^{**} modern firms that invest in clean technology when $n = k$ (full industrialization).

The preceding lemma says that a more stringent emission standard can lead to the full industrialization because the new abatement technology becomes profitable in that case. The positive spillovers of the aggregate demand associated with the services of the public good (new technology implemented) dominate the negative spillovers coming from the cost to abate more emissions. The Porter hypothesis can be thus verified in a low-income economy with large demand effects.

3.1.3 Tax-subsidy scheme

Let focus on the bad equilibrium n_2^* in Case 2 associated with $\overline{E}_2$. We ask the following question. Is it possible to implement the following scheme: tax $(n_2^* - m)$ dirty modern sectors at rate $\left(t\frac{\overline{\overline{E}}}{n_2^*-m}\right)$ and subsidy m clean



new.jpg

Figure 2: Profit of a modern sector with the old abatement technology, as a function of the number of modern sectors

modern sectors at rate $\left(\sigma = t\frac{\overline{\overline{E}}}{m}\right)$ such that[16]

$$
\begin{aligned}
\pi^{mt}(\overline{E}_2, n_2^*) &\leq \pi^{mt}(\overline{E}_2, n_2^*, t) \text{ or} \\
v(P - \frac{\overline{E}_2}{n_2^* - m}) + t\frac{\overline{E}_2}{n_2^* - m} &\leq v(P - \frac{\overline{E}_2}{n_2^*}) \\
\pi^{mm}(\overline{E}_2, n_2^*) &\leq \pi^{mm}(\overline{E}_2, n_2^*, t) \text{ or} \\
S - t\frac{\overline{E}_2}{m} &\leq v(P - \frac{\overline{E}_2}{n_2^*})
\end{aligned}
\tag{7}
$$

The first (*resp.* second) equation says that the tax-subsidy scheme is profitable for the dirty modern sector (*resp.* clean modern sector). If such t and σ exist, then the economy can escape from the bad equilibrium to reach the good equilibrium with a more stringent environmental regulation. This policy could then facilitate the coordination of investment decisions of modern sectors in order to converge towards the good equilibrium.

Lemma 7 *The tax-subsidy policy* (t, σ) *can be implemented.*

Proof. We can exhibit such t and m. The first equation is equivalent to $\frac{t}{m} \leq \frac{v}{n_2^*}$. If we take the equality $\frac{t}{m} = \frac{v}{n_2^*}$, and put it into the second equation, we obtain $S < vP$ which is Assumption A. So the two equations are not contradictory, and t and m can exist. ■

[16] The budget constraint is balanced because the collection of the tax is equal to $T = (n_2^* - m)\left(t\frac{\overline{E}_2}{n_2^* - m}\right) = t\overline{E}_2$, and the revenue from the tax is redistributed as a uniform subsidy σ to each clean sector: $\sigma = \frac{T}{m} = \frac{t\overline{E}_2}{m}$.

This scheme can be easily replicated from the equilibrium with m clean modern firms to the equilibrium with $m+1$ clean modern firms etc., in order to reach the full industrialization equilibrium which is stable. Once this "good" equilibrium is reached, it will stay even if the tax-subsidy policy is stopped because this equilibrium is stable.

Before writing the main proposition of the paper, we shall reduce the set of Conditions 1 to 7 to the **Assumption B.**

Assumption B

Condition 1 : $(aL - kF) > 0$

Condition 2 : $S > v(P - \frac{\overline{E}_1}{k})$

Condition 3 : $aL < k(vP + F)$

Condition 4 : $aL \leq k(vP + F) - v\overline{E}_1$

Condition 5 : $S > v(P - \frac{\overline{E}_2}{n_2^*})$

Condition 6 : $aL - kF < kS - akS - av\overline{E}_2 + avPk$

Condition 7 : $aL > k(F + S) - av\overline{E}_2$

We show in Appendix 2 that it is always possible to find $aL - kF$ such that Conditions 1,2,3, 4, 5, 6 and 7 are simultaneously verified if $\overline{E}_1$ is not too high and $\overline{E}_2$ is not too low, and S is high enough.

3.2 Main result and policy implications

We can now write the main proposition of the paper.

Proposition 1 *Assume that Assumptions A and B hold, then two stable equilibria arise:*

Case 1: with a loose emission standard, one equilibrium arises without adoption of the new abatement technology $n_1^* \leq k$.

Case 2 with a stronger emission standard,

1) a "bad" equilibrium characterized by a low level of development n_2^* *with* $n_2^* < n_1^* \leq k$ *without adoption of the new abatement technology.*

2) a "good" equilibrium characterized by full industrialization $n_2^{**} = k$ *with adoption of the new abatement technology.*

The last equilibrium can be implemented using a tax-subsidy scheme.

The equilibrium in Case 1 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. This seems paradoxical: the environmental standard is too stringent to limit the development and too loose to give incentives for sectors to invest in the new abatement technology.

The "bad" equilibrium in Case 2 is worse than that in Case 1 in terms of development because the new policy is more stringent. In terms of the environmental investment, this equilibrium is equivalent to the equilibrium in Case 1 because no modern firm adopts the new technology.

The "good" equilibrium in Case 2, 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 when the emission standard is collectively violated. This could prevent some sectors from industrializing. However, if some of these modern sectors invest in the 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 thanks to higher profits and a higher level of demand. This process can repeat until a new equilibrium is reached with a highest number of modern sectors k.

Our findings show that binding emission standards do not necessarily impede the development of a low-income country. 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 channeled through the level of the ambient emission standard and the implied level of the abatement cost when the standard is collectively violated. However a coordination of efforts of some polluting sectors to undertake a costly investment in abatement technology is needed. We have shown that a scheme that combines the taxation of dirty modern sectors with a subsidy to clean ones can help the economy converge towards the good equilibrium.

4 Conclusion

In this study, we have presented a simple theoretical example which brings a new insight on the Porter hypothesis linking it with aggregate income effects. We have investigated for a developing economy whether more stringent emission standards could induce investments in a new abatement technology without jeopardizing economic development. To this end, we have incorporated an environmental counterpart into the Big Push general equilibrium model of Murphy, Shleifer and Vishny (1989). An ambient emission standard leads to negative spillovers, whereas individual abatement investments give rise to positive spillovers across modern sectors.

Our findings show that this model can lead to a multiplicity of equilibria: a “bad” equilibrium without any clean environmental investment, and a “good” equilibrium with full modernization and clean investment. 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 modern sectors have an incentive both to modernize production while investing in new abatement technology to avoid the burden of stringent emission standards. These overall results show that binding emission standards do not necessarily impede the development of a low-income country. They can even incite some sectors to modernize both their production and abatement technology.

The Environmental Big Push requires a coordination of the efforts of some polluting sectors to undertake a costly investment in new abatement technology. At the national level, we have shown that this coordination problem could be solved thanks to a tax-subsidy scheme. A scheme that combines the taxation of dirty modern sectors with a subsidy to clean ones can help the economy converge towards the good equilibrium. In an international context, monetary transfers across countries could help. In the Paris Agreement (2015), developed countries agreed on to maintain their existing collective goal to transfer USD 100 billion per year towards developing countries, until 2025 when a new collective goal will be set (European Commission, Climate Action[17]). This fund can help developing countries to respect their environmental commitment in their economic development.

[17] http://ec.europa.eu/clima/index_en.htm.

References

[1] **Ambec, S., Barla, P**. (2002): "A theoretical foundation of the Porter hypothesis", Economics Letters, 75(3), 355-360.

[2] **Ambec, S., Barla, P**. (2006): "Can environmental regulations be good for business? An assessment of the Porter hypothesis", Energy Studies Review, 14(2), 42.

[3] **Ambec, S., Cohen, M. A., Elgie, S., Lanoie, P**. (2013): "The Porter hypothesis at 20: can environmental regulation enhance innovation and competitiveness?", Review of Environmental Economics and Policy, res016.

[4] **Andreoni, J., Levinson, A.** (2001): "The simple analytics of the environmental Kuznets curve", Journal of Public Economics, vol. 80, 269-286.

[5] **Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C., Jansson, B.O., Levin, S., Maler, K.G., Perrings, C., Pimentel, D.** (1995): "Economic growth, carrying capacity, and the environment", Science, vol. 268, 520-521.

[6] **Basu, K.** (2003): Analytical Development Economics - The Less Developed Economy Revisited, MIT Press.

[7] **David, M., Nimubona, A-D., Sinclair-Desgagné, B.** (2011): "Emission taxes and the market for abatement goods and services", Resource and Energy Economics, vol. 33 (1), 179-191.

[8] **Flemming, J.M.** (1955): "External economies and the doctrine of balanced growth", Economic Journal, vol. 65, 241-256.

[9] **de Fontenay, C.C.** (2004): "The dual role of market power in the Big Push: from evidence to theory", Journal of Development Economics, vol. 75, 221-238.

[10] **Fodha, M., Seegmuller, T.** (2014): "Environmental quality, public debt and economic development", Environmental and Resource Economics, vol. 57, 487-504.

[11] **Greaker, M.** (2006): "Spillovers in the development of new pollution abatement technology: a new look at the Porter-hypothesis", Journal of Environmental Economics and Management, vol. 52, 411-420.

[12] **Grossman, G. M., Krueger, A. B.** (1995): "Economic growth and the environment", The Quarterly Journal of Economics, vol. 110(2), 353-377.

[13] **John, A., Pecchenino, R.** (1994): "An overlapping generations model of growth and the environment", The Economic Journal, vol. 104, 1393-1410.

[14] **Mohr, R. D**. (2002): "Technical change, external economies, and the Porter hypothesis", Journal of Environmental Economics and Management, 43(1), 158-168.

[15] **Murphy, K.M., Shleifer, A., Vishny, R.** (1989): "Industrialization and the Big Push", The Journal of Political Economy, vol. 97(5), 1003-1026.

[16] **Nurkse, R.** (1953): Problems of Capital Formation in Underdeveloped Countries, Oxford University Press, New York.

[17] **Porter, M., C. van der Linde**. (1995): "Toward a new conception of the environment-competitiveness relationship", Journal of Economic Perspectives, vol. 9 (4), 97–118.

[18] **Prieur, F., Jean-Marie, A., Tidball, M.** (2013): "Growth and irreversible pollution: are emission permits a means of avoiding environmental and poverty traps?", Macroeconomic Dynamics, vol. 17, 261-293.

[19] **Rosenstein-Rodan, P.N.** (1943): "Problems of industrialization in eastern and south-eastern Europe", Economic Journal, vol. 53, 202-211.

[20] **Schitovsky, T.** (1954): "Two concepts of external economies", Journal of Political Economy, vol. 62, 143-151.

[21] **Simpson, R. D., Bradford III, R. L**. (1996): "Taxing variable cost: environmental regulation as industrial policy", Journal of Environmental Economics and Management, 30(3), 282-300.

[22] **Singer, H.** (1949): "Economic progress in underdeveloped countries", Social Research, vol. 16, 1-11.

[23] **Smulders, S**., **Gradus, R**. (1996): "Pollution abatement and long-term growth", European Journal of Political Economy, vol. 12, 505–532.

[24] **Trindade, V**. (2005): "The big push, industrialization and international trade: The role of exports", Journal of Development Economics, vol. 78.1, 22-48.

[25] **U.S. Energy Information Administration** (2014): International Energy Outlook 2014, September 2014.

[26] **Xepapadeas, A.** (1997): "Economic development and environmental pollution: traps and growth", Structural Change and Economic Dynamics, vol. 8, 327-350.

Appendix

Appendix 1: Proof of Lemma 1

Here, we ask the question if $\frac{d\pi^{mt}}{dn} < 0$ for $\overline{n} < n < n_1^*$.

$$\begin{aligned}\frac{d\pi^{mt}}{dn} &= \frac{(-k^2 v\overline{E} + 2kv\overline{E}na + n^2a^2L - n^2akF - n^2akvP)}{n^2(-k+na)^2} \\ &= \frac{v\overline{E}(-k^2+2kna) + n^2a(aL - kF - kvP)}{n^2(-k+na)^2} < \\ &\quad \frac{v\overline{E}(-k^2+2kna) + n^2a(-v\overline{E})}{n^2(-k+na)^2} \text{ if Condition 4 holds.}\end{aligned} \tag{8}$$

$$\frac{d\pi^{mt}}{dn} < \frac{v\overline{E}\left[-k^2 + 2kna - n^2a\right]}{n^2(-k+na)^2} \tag{9}$$

$$\frac{d\pi^{mt}}{dn} < \frac{-v\overline{E}\left[(k-na)^2 - n^2a^2 + n^2a\right]}{n^2(-k+na)^2} = \frac{-v\overline{E}\left[(k-na)^2 + n^2a(-a+1)\right]}{n^2(-k+na)^2} < 0 \tag{10}$$

Appendix 2: Assumption B

Assumption B

$$
\begin{aligned}
\textbf{Condition 1} &: \ (aL - kF) > 0 \\
\textbf{Condition 2} &: \ S > v(P - \frac{\overline{E}_1}{k}) \\
\textbf{Condition 3} &: \ aL < k(vP + F) \\
\textbf{Condition 4} &: \ aL \leq k(vP + F) - v\overline{E}_1 \\
\textbf{Condition 5} &: \ S > v(P - \frac{\overline{E}_2}{n_2^*}) \\
\textbf{Condition 6} &: \ aL - kF < kS - akS - av\overline{E}_2 + avPk \\
\textbf{Condition 7} &: \ aL > k(F + S) - av\overline{E}_2
\end{aligned}
$$

Condition 1 $aL - kF > 0$ implies that the net monopoly rent extracted from the labor resource, if all sector were modern, is positive.

Condition 2 says that the standard $\overline{E}_1$ is too loose to make the clean abatement technology profitable.

Condition 4 is stronger than Condition 3.

Condition 5 says that no modern firm finds an interest to invest in the clean technology at the equilibrium n_2^*. Condition 5 is equivalent to $aL - kF < kS$ which says that the net monopoly rent extracted from the labor resource, if all sector were modern, is bounded above by the total cost of the clean technology if all modern sectors invest in.

Condition 7 can be rewritten as $aL - kF > kS - av\overline{E}_2$.

We have to check that Conditions 4, 5, 6 and 7 are compatible.

Condition 5 and 7 are compatible because $kS > kS - av\overline{E}_2$.

Conditions 4 and 7 are compatible if

$$\begin{aligned} kS - av\overline{E}_2 &< kvP - v\overline{E}_1 \qquad (11) \\ \text{or } v(\overline{E}_1 - a\overline{E}_2) &< k(vP - S) \end{aligned}$$

which is true if $\overline{E}_2$ is not too low.

Conditions 6 and 7 are compatible if

$$\begin{aligned} kS - av\overline{E}_2 &< kS - akS - av\overline{E}_2 + avPk \qquad (12) \\ \text{or } S &< vP \end{aligned}$$

which is true if we assume Assumption A.

It is always possible to find $aL - kF$ such that Conditions 1,2,3, 4, 5, 6 and 7 are simultaneously verified if $\overline{E}_1$ is not too high and $\overline{E}_2$ is not too low, and S is high enough.

Appendix 3: Endogenous Emissions

We consider endogenous emissions proportional to production $P = \beta x_i$ with $\beta > 0$. We focus on the equilibria n_1^* and n_2^*, and the sufficient conditions

1, 2, 3, 4 and 5 to obtain them. They changed by replacing a by $(a - v\beta)$, and putting P equal to 0. To see this, remark that

$$\begin{aligned}
\pi^{mt} &= \frac{a}{k}R - F - v(\frac{\beta R}{k} - \frac{\overline{E}}{n^*}) = \frac{a - v\beta}{k}R - F + \frac{v\overline{E}}{n^*} = 0 \\
\text{with } R &= \frac{L + v\overline{E} - n^*F}{1 - \dfrac{n(a - v\beta)}{k}}, \text{ so } n^* = \frac{v\overline{E}}{F - L\frac{a - v\beta}{k}}
\end{aligned}$$

The main difficulty is to study the equilibrium n_3^*. First remark that m^{**} which nullifies π^{mm}, when $n = k$ is:

$$\begin{aligned}
\pi^{mm} &= \frac{a}{k}R - F - S = 0 \qquad (13) \\
m^{**} &= \frac{av\overline{E}_2 + aL - kF - kFv\beta - kS + kaS - kSv\beta}{aS - Fv\beta - Sv\beta}
\end{aligned}$$

Consequently, we define implicitly m^{***} such that the two technologies have the same cost:

$$\begin{aligned}
S &= v(\beta\frac{R}{k} - \frac{\overline{E}_2}{k - m^{***}}) \qquad (14) \\
\text{with } R &= \frac{(kF - v\overline{E}_2 + m^{***}S - L)k}{k(a - 1) - kv\beta + m^{***}v\beta}
\end{aligned}$$

The main condition to obtain the good equilibrium becomes $m^{***} > m^{**}$. It is not easily tractable because m^{***} is the solution of a second degree equation.