Economics Bulletin

Volume 42, Issue 2

Does entrepreneurial behaviour matter for the strong Porter hypothesis?

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Abstract

The traditional economic argument states that compliance with environmental policy diverts resources from innovation. In their paper, Porter and van der Linde (1995) argue counterintuitively that more stringent environmental policies induce innovations the benefits of which exceed the costs. We build an R&D-driven endogenous growth model that takes account of both arguments by including satisficing and profit-maximizing managers. Our theoretical results enable us to determine the validity condition of the strong Porter hypothesis that is consistent with empirical results.

I am grateful for invaluable comments and suggestions from an anonymous referee of this journal, which helped me to substantially improve this paper. The author has benefited from discussions with Philippe Aghion, Ivan Ledezma, Jimmy Lopez, and with participants at the LEDi Innovation seminar in Dijon and at the French Economic Association (AFSE) annual conference in Nancy. Special thanks to Evens Salies and Aurore Pélissier for useful comments. Financial support from Plan Urbanisme Construction Architecture (PUCA) is gratefully acknowledged. The usual disclaimer applies.

Citation: Dominique Bianco, (2022) "Does entrepreneurial behaviour matter for the strong Porter hypothesis?", *Economics Bulletin*, Volume 42, Issue 2, pages 867-876

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Submitted: February 21, 2021. **Published:** June 30, 2022.

1. Introduction

Growing concern among citizens around the world has impelled governments in many countries to move environmental issues higher up their policy agendas. Environmental policies introducing taxes and standards could prove important in controlling polluting emissions. The main goals of such policies is to improve environmental outcomes and ensure sustainable growth by increasing the opportunity cost of pollution.

Responding to that challenge, in their engaging paper, Porter and van der Linde (1995, p. 98) go further, arguing "that properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them" and presenting several case studies supporting this idea. Jaffe and Palmer (1997) called that argument the "strong Porter hypothesis" (henceforth SPH).

From most overviews of empirical contributions to the SPH (e.g. Brännlund and Lundgren (2009) and Ambec et al. (2013) among others), we can draw an incontrovertible conclusion: their empirical results are inconclusive. Early studies using U.S. data concluded that stricter environmental policy reduced productivity. For example, Gollop and Roberts (1983) seek to quantify the impact of sulphur dioxide emission restrictions on productivity growth in a sample of 56 electric utilities for the period 1973-1976. Their results show that environmental regulation reduces annual average productivity growth by 0.59 percentage points.[1]

By contrast, some empirical studies find evidence supporting the SPH. For example, Rassier and Earnhart (2015) seek to identify the relationship between clean water regulations and actual profitability in a sample of U.S. manufacturing industries. Their results suggest that stricter environmental policy actually increases profitability.[2]

Even if the conflicting evidence might arise from methodological or measurement problems (e.g. Lankoski (2010)), we believe that these results echo the theoretical debate. A large body of research has emerged in the literature focusing on its theoretical underpinnings. According to Ambec et al. (2013), the exploratory models developed in that literature so far can be roughly categorized as either (i) models that focus on behavioural arguments; (ii) models based on market failures (e.g. market power, asymmetric information, and R&D spillovers); or (iii) models based on organizational failure. Theories relating to the emerging behavioral economics literature depart from the assumption of profit-maximization, in line with what Porter and van der Linde (1995) postulate, by assuming that managers behave in ways not conducive to profit maximization. More precisely, managers may be opposed to costly change (Aghion et al. (1999)). Theories within (ii) and (iii) maintain the assumption of profit-maximization in line with what Palmer et al. (1995) postulate.

Thus in response to the opacity surrounding empirical contributions as well as the fundamental disagreement over the theoretical contributions about the assumption of profit-maximization, this paper is the first attempt to reach a comprehensive understanding of the validity conditions of the SPH by developing a unified framework that considers the contradictory assumptions of profit-maximization. For that purpose, in the vein of Aghion et al. (1999), we build a R&D-driven endogenous growth model which we extend to allow for pollution and environmental policy so the SPH can be examined.

[1]See also Rexhäuser and Rammer (2014), Rubashkina et al. (2015), Hille and Möbius (2019) for recent studies.

[2]See also Berman and Bui (2001), Alpay et al. (2002), Costantini and Mazzanti (2012), Xie et al. (2017), Liu et al. (2020).

The main rationale for this is that their models cover two types of firms: conservative firms in which managers choose just enough innovation to avoid bankruptcy; and profit-maximizing firms in which managers' decisions regarding innovation are to maximize profits.

Our main finding is that the stringency of the environmental policy affects both types of firm in opposite directions. Managers of conservative firms, who fear for their jobs, respond by increasing the size of innovation, which in turn boosts economic growth and downstream firms' profits. In contrast, managers of profit-maximizing firms are constrained to reduce the size of innovation, which in turn reduces economic growth and downstream firms' profits. Thus, the validity conditions of the SPH depends on the prevalence of one effect relative to the other.

The remaining part of the paper is organized as follows. Section 2 reviews the recent theoretical literature on the SPH. Section 3 sets out the basic model. Section 4 investigates the validity condition of the SPH by focusing on the effects of a stricter environmental policy on growth, pollution, and downstream firms' profits. Section 5 concludes.

2. Related literature

A sizable majority of authors assume that firms pursue profit maximization in all markets. It includes Nakada (2004) who allows for pollution and environmental policy in a framework *à la* Aghion and Howitt (1992). More precisely, the author builds his explanatory model on two key assumptions. First, he assumes that the agregate level of pollution is mainly driven by the level of intermediate inputs. Second, he also assumes that the government is to levy an environmental tax proportional to the level of pollution on the final good producer. The author shows the existence of two opposite effects. First, the "general equilibrium effect", i.e., the reallocation of labour from the intermediate sector to the R&D sector enhances innovation. Second, the "profitability effect", i.e., the loss in profits of the intermediate sector, reduces innovation. Overall a stricter environmental policy (in the form of an increase in environmental tax) stimulates innovation, which in turn boosts economic growth and reduces pollution. Although Nakada (2004) does not focus on the SPH, this version of the Porter hypothesis is confirmed by Bianco and Salies (2016, 2017) in the sense that the long-term effect of an increase in the tax rate on downstream firms' profits is positive.

Hart (2004, 2007) extends the multi-sector model of Aghion and Howitt (1996) to allow for environmental policy in responding to environmental damage caused by the firms' production. The author makes two key assumptions. First, there are two discrete R&D sectors, ordinary and environmentally-friendly, leading respectively to ordinary and environmentally-friendly innovations. This assumption allows the author to consider the direction of technological change. Second, fixed costs and decreasing returns to scale in the intermediate sector allow for a truncation of the number of vintages used. A stricter environmental policy (in the form of a higher sales tax) promotes recent and cleaner vintages, reducing environmental harm and boosting downstream firms' profits, which in turn spurs R&D firms to conduct research.

Ricci (2007) extends Hart's (2004, 2007) multi-period framework in the sense that he takes into account flexibility in the technological choice of R&D firms. In this framework, the effect of an environmental policy (in the form of a tax on polluting emissions) impacts economic growth through two opposite effects. First, the "direct input effect", i.e., the incentive for R&D firms to design cleaner technologies, which reduces the marginal effect of R&D on productivity growth. Second, the "green crowding-out effect", i.e., the decrease in profits of older and dirtier vintage producers, which in turn spurs innovation through the reallocation of labour from the productive sector to the R&D sector. Although the overall effect of the environmental policy is a priori ambiguous, by means of simulations, the author shows that the "direct input effect" dominates the "green crowding-out effect". Thus, unlike in Hart (2004, 2007), the SPH is never supported.

In contrast to this literature, Bianco and Salies (2017) relax the assumption of profit-maximization regarding managers' decisions about innovation. The authors develop the R&D-driven endogenous growth model of Aghion and Griffith (2005, chap.2) with conservative managers only, which they extend to allow for pollution and environmental policy. Given this assumption, it is possible to demonstrate the SPH. Stricter environmental regulation (in the form of a higher pollution tax) makes the survival constraint of intermediate firms tighter and so satisficing managers, who fear losing their jobs, respond by increasing the size of innovation, which in turn raises the quality of intermediate inputs and reduces pollution as well. Furthermore, a higher environmental tax increases economic growth and downstream firms' profits, thus confirming the SPH.

3. The basic model

This section presents a basic model in which the economy is designed to illustrate the two main effects found in both the empirical and theoretical literature described above. In this framework, the economy consists of three agents. First, producers of the final good hire a set of differentiated intermediate inputs to produce that final good which is sold in the market at unit price. Second, each incumbent firm makes two related decisions: they choose the price of their good, facing the competitive fringe; and they adopt new technology enabling each innovating incumbent firm to produce the leading-edge intermediate input. Departing from the previous literature, we assume two types of intermediate firms: conservative firms in which managers' decisions regarding the size of innovation are just enough to avoid bankruptcy; and profit-maximizing firms in which the managers' objective aligns with the shareholders' aims, i.e., to maximize profits. Third, the government, whose objective is to reduce pollution, levies an environmental tax on the producer of the final good.

3.1 Production and the environment At time t,[3] one homogenous final good y_t serving as the *numéraire* of the economy is produced competitively employing a continuum of inputs (or intermediate goods) $i \in [0,1]$. The production technology of the final good is:

$$y_t = \int_0^1 A_{i,t}^{1-\alpha} x_{i,t}^{\alpha} di, \quad \alpha \in [0,1], \tag{1}$$

where $x_{i,t}$ is the quantity of the input i and $A_{i,t}$ is its quality.

We follow Bianco and Salies (2017) who assumes that the structural pollution in each

[3]The model is set in discrete time.

industry i is given by:[4]

$$P_{i,t} = \frac{x_{i,t}}{A_{i,t}}. \tag{2}$$

Equation (2) means that the higher the quality of i, the lower the level of pollution per unit of input. Environmental policy takes the form of a tax, $\tau_{i,t}$. The tax, which varies directly with polluting emissions $P_{i,t}$, is paid by downstream firms to discourage pollution. As suggested by Porter and van der Linde (1995, p. 111), government should "regulate as late in the production chain as practical, which will normally allow more flexibility for innovation there and in the upstream stage".

For the sake of simplicity, we follow Bianco and Salies (2016) by defining the quality-adjusted environmental tax as $\phi_t \equiv \frac{\tau_{i,t}}{A_{i,t}}$: a similar assumption can be found in the endogenous growth model with pollution and labour as input of Verdier (1995), who adjusts the tax to wages.[5] In what follows, we assume that unadjusted tax $\tau_{i,t}$ rises at the same rate as the productivity parameter, which implies that the adjusted tax ϕ_t does not depend on time. Thus, we can write $\phi_t \equiv \phi$. Combining all these assumptions, the solution leads to the following inverse demand:

$$p_{i,t} = \alpha \left(\frac{x_{i,t}}{A_{i,t}} \right)^{\alpha-1} - \phi. \tag{3}$$

3.2 Incumbent firms' decisions As in Bianco and Salies (2016, 2017), incumbents make two related decisions: the selling price which in turn gives the selling quantity (regardless of the degree to which this amount will degrade the environment) and the size of innovation.

3.2.1 Intermediate production decisions (for a given technology) Incumbents produce inputs from the final good at a unit marginal cost. Innovation is assumed to be non-drastic. This assumption implies that the incumbent exerts its market power by charging the limit price, $p_{i,t} = \chi$, so as to prevent the competitive fringe of firms from entering their market. In addition to the variable cost of production, they incur a fixed cost of production equal to $k_{i,t} = \kappa A_{i,t-1}$. κ is sufficiently large to allow for bankruptcy, in which case, managers would lose their jobs. Managers live for one period. Under these assumptions, the value for profit net of the fixed cost of production is: $\pi_{i,t} = [\chi - 1]\, x_{i,t} - \kappa A_{i,t-1}$. Then, using the limit price, we obtain partial equilibrium sales and profits of the monopolist in sector i:

$$x_{i,t} = \delta(\phi) A_{i,t}, \tag{4}$$
$$\pi_{i,t} = (\chi - 1)\delta(\phi) A_{i,t} - \kappa A_{i,t-1}, \tag{5}$$

where $\delta(\phi) \equiv \left(\frac{\chi+\phi}{\alpha}\right)^{\frac{1}{\alpha-1}}$ is constant over time.

It is noteworthy that environmental tax ϕ reduces partial equilibrium sales, which in turn decreases the profit net of the fixed cost.

[4]We could also introduce an opportunity cost in R&D when targeting cleaner innovations as in Bianco and Salies (2017). This extension does not change the results.

[5]See also Nakada (2004) and Bianco (2017).

3.2.2 Entrepreneurial behaviours and the adoption of new technologies For simplicity, we split the intermediate goods sector between profit-maximizing managers who monopolize intermediate goods markets ($i \in [0, m]$) and satisficing managers who own the remaining markets ($i \in]m, 1]$) and assume that incumbents are self-financed as in Aghion et al. (1999), Aghion and Griffith (2005, chap.2), and Bianco and Salies (2016, 2017). In addition, we assume a deterministic innovation process at the firm level, given by: $A_{i,t} = \gamma_i A_{i,t-1}$, where $\gamma_i > 1$ represents the size of innovation (or the incremental improvement in quality).

3.2.2.1 Profit-maximizing managers and the size of innovation. As in Aghion and Griffith (2005, chap.2), we denote the sunk cost of adopting the leading-edge technology by $\frac{\gamma_i^2}{2} A_{i,t-1}$. The firm's net profit flow is thus $\tilde{\pi}_{i,t} = (\chi - 1)\delta(\phi)A_{i,t} - \left[\kappa + \frac{\gamma_i^2}{2}\right] A_{i,t-1}$. Maximizing gives us the optimal size of innovation:

$$\gamma_M = (\chi - 1)\delta(\phi). \tag{6}$$

It is noteworthy that the size of innovation decreases with the environmental tax ϕ. This means that environmental policy decreases incentive to innovate for profit-maximizing firms. This result is in line with the basic argument developed in the literature which invalidates the Porter hypothesis (see Palmer et al. (1995), and specially the "profitability effect" developed by Nakada (2004)).

3.2.2.2 Satisficing managers and the size of innovation. According to Aghion et al. (1997, 1999), these satisficing managers can survive in capitalism economy for at least one reason: the existence of an agency problem between intermediate producers and theirs outside financiers. So, I model the decision of satisficing managers on the size of innovation as in Bianco and Salies (2017, p.2645): $\max_{\gamma_i}\{B - \gamma_i : \pi_{i,t} \geq 0\}$, where B is the private benefit a manager gets from controlling the intermediate firm. This modeling allows a measure of the organizational slack at the equilibrium equals to $B - \gamma_S$ where γ_S is:

$$\gamma_S = \frac{\kappa}{(\chi - 1)\delta(\phi)}. \tag{7}$$

It is particularly noteworthy that the size of innovation increases with the environmental tax ϕ. This means that environmental policy prompts the satisficing manager to innovate which in turn reduces the organizational slack which is consistent with the empirical literature (Nohria and Gulati (1996) and Paeleman and Vanacker (2015).

4. The validity conditions of the SPH

Predicting the SPH in our model requires finding that a stricter environmental policy, i.e., a higher ϕ, reduces pollution ($\frac{\partial P_t}{\partial \phi} < 0$), enhances growth ($\frac{\partial g}{\partial \phi} > 0$),[6] and benefits downstream firms in terms of profits. As in Bianco and Salies (2016, 2017,) this latter condition only needs to be verified in the downstream sector since conservative firm's profits in the intermediate sector are set equal to zero by satisficing managers.[7] Proposition 1 below states that our model confirms these conditions.

[6] See Appendix B for more details on the growth rate of the economy.

[7] See Appendix A for the consistency with Porter's argument in terms of firms' net profits.

Proposition 1 *If innovation is non-drastic, for a proportion of profit-maximizing firms sufficiently small* $m < \tilde{\tilde{m}}$*, a stricter environmental policy*

(i) *enhances growth;*
(ii) *reduces pollution;*
(iii) *increases downstream firms' profits.*

Proof. See Appendix C. ■

For simplicity's sake, we break these impacts up into direct and indirect effects. A higher environmental tax ϕ increases the cost of pollution, i.e., $\phi x_{i,t}$ for all i, which has a direct negative effect on downstream firms' profits. These firms respond by reducing their demand for intermediate goods, which can be seen from equation (4), holding $p_{i,t}$ constant. This shift in demand implies a fall in output y_t but also lower production costs $\left(\int_0^1 p_{i,t}x_{i,t}di\right)$ and a lower cost of the environmental policy $\left(\int_0^1 \phi x_{i,t}di\right)$ in the downstream sector, holding $A_{i,t}$ constant. Although it also reduces monopoly rents $(\chi - 1)x_{i,t}$ of both profit-maximizing and conservative incumbent intermediate firms, managers react in exactly the opposite way. In profit-maximizing firms, managers respond by reducing the size of innovation, which in turn reduces productivity $A_{i,t}$ ("traditional effect") while in conservative firms, satisficing managers respond by raising the size of innovation just enough to avoid bankruptcy, which in turn raises productivity $A_{i,t}$ ("satisficing effect"). Thus, at the firm level, the "satisficing effect" always dominates the "traditional effect". However, at the aggregate level, the effect of a stricter environmental policy on growth depends upon the proportion of profit-maximizing firms. If the latter is sufficiently small ($m < \tilde{m}$), environmental policy sustains growth. This means that the "aggregate satisficing effect" dominates the "aggregate traditional effect" and explains part (i) of Proposition 1.

Consider the impact of environmental policy on pollution. Combining our assumption that pollution intensity is inversely proportional to the productivity parameter $A_{i,t}$ with the assumption about constant returns to scale in the production of the final good entails that the partial equilibrium sales of the monopolist in sector i is an increasing linear function of $A_{i,t}$ (see equation (4)), which in turn involves constant aggregate pollution (see equation (C.2)). Thus a stricter environmental policy decreases the demand for intermediate inputs, which in turn decreases aggregate pollution through $\delta(\phi)$ (see equation (C.3)). This explains part (ii) of Proposition 1.

Finally, it is obvious that the effect of the environmental policy on the downstream firms' profits is ambiguous, either positive or negative, depending upon the proportion of profit-maximizing firms, i.e., the parameter m.[8] Indeed, the impact of a stricter environmental policy can be broken up into two main effects, i.e., the "growth effect" including both "aggregate satisficing" and "aggregate traditional" effects and the "direct effect". As showed in the previous paragraph, the former could be positive or negative while the latter is always negative. As a consequence, a stricter environmental policy increases downstream firms' profits provided that the "aggregate satisficing effect" offsets both "aggregate traditional" and "direct" effects, i.e., $m < \tilde{\tilde{m}}$. This explains part (iii) of Proposition 1.

Table I below summarizes the various effects described above by using the proportion of profit-maximizing firms in the economy, i.e., the parameter m. This latter allow us to present the validity condition of the SPH. Indeed, this condition is confirmed provided

[8]For details, see equation (C.6) in Appendix C.

that the proportion of profit-maximizing firms is low enough ($m < \tilde{\tilde{m}}$). In this case, a stricter environmental policy increases growth as well as downstream firms' profits whereas it decreases pollution. This result is consistent with the empirical literature, for instance, Rassier and Earnhart (2015) and more recently Cohen and Tubb (2018) who perform a meta-analysis of 103 publications relating to the Porter hypothesis. In the other cases, at least one condition of the SPH is invalidated either because the effect on growth is negative for $m > \tilde{m}$ or because the effect on downstream firms' profits is also negative for $m > \tilde{\tilde{m}}$.

m	0		$\tilde{\tilde{m}}$		$\tilde{m}$		1
P_t		−		−		−	
g		+		+	0	−	
$\pi_t(y)$		+	0	−		−	

Table I: The validity conditions of the SPH.

It is noteworthy that our theoretical results are also consistent with the weak version of the Porter hypothesis. For intermediate values for the share of profit-maximizing firms, i.e., $\tilde{\tilde{m}} < m < \tilde{m}$, a stricter environmental policy still increases growth whereas it reduces both pollution and downstream firms' profits. For instance, this result is consistent with the empirical work of Lee et al. (2011) and more recently van Leeuwen and Mohnen (2017). In addition to these results, our theoretical results are also consistent with another case in which the Porter hypothesis is not supported at all. For a large proportion of profit-maximizing firms in the economy, i.e., $m > \tilde{m}$, a stricter environmental policy reduces growth, pollution, and downstream firms' profits as well. This result is still consistent with another part of the empirical literature, for instance, Gollop and Roberts (1983).

5. Concluding remarks

This paper is the first attempt to reach a comprehensive understanding of the validity condition of the SPH by developing a unified framework that makes two opposite assumptions about profit-maximization, i.e. profit-maximizing and conservative managers. These assumptions enable us to show that managers behavior can radically affect the impact of environmental policy: with profit-maximizing managers, a more stringent environmental policy tends to reduce innovation and thus both growth and profit, whereas with satisficing managers, both effects are reversed. As a consequence, our theoretical results predict the SPH that a stricter environmental policy (a higher tax in our model) improves growth, the environment, and induces profitable innovations provided that the proportion of profit-maximizing firms does not exceed a threshold, otherwise the lack of evidence supporting the SPH emerges. However, even in this case, our theoretical results are also consistent with either the weak version of the Porter hypothesis, for a larger proportion of profit-maximizing firms or the lack of evidence supporting the Porter hypothesis for an even higher proportion of profit-maximizing firms.

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