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Abstract

In this study we investigate how firm level environmental performance (*EP*) affect firm level economic performance measured as profit efficiency (*PE*) in a stochastic profit frontier setting. Analyzing firms in Swedish manufacturing 1990-2004, results show that *EP* induced by environmental policy *is not* a determinant of *PE*, while voluntary or non-policy induced *EP* seem to have a significant (+) effect on firm *PE* in most sectors. The evidence generally supports the idea that good *EP* is also good for business, as long as *EP* is not brought on by policy measures, in this case a CO_2 tax.

JEL-classification: D20, H23.

Key words: CO2 tax, environmental performance index, profit efficiency, stochastic frontier analysis.

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1. Introduction

This study's overall goal is to analyze the effect of Swedish manufacturing firms' environmental performance (*EP*) on their profit efficiency (*PE*) during 1990-2004. We build on the work of Brännlund et al. (2011), and Lundgren and Marklund (2011), where the effect of environmental taxation on firms' *EP* and *PE* was analyzed, respectively. Brännlund et al. (2011) found that *EP* has improved in all sectors in Swedish manufacturing since the CO_2 tax scheme was introduced in 1991; this in terms of production having increased at the same time as emissions having decreased in most sectors. Also, they found that the tax scheme contributed significantly to this particular development. However, Lundgren and Marklund (2011) found no general significant dynamic or Porter effect of CO_2 taxation on firm's *PE* within Swedish manufacturing during the same time.[2] In sum; these two studies show that the CO_2 tax is good for the environment but the effects on firm performance are inconclusive. In that perspective it becomes interesting to find out whether improved *EP* – policy induced or not - may have positive impact on firms' *PE*. This is the topic in this paper.

The empirical analysis is conducted in three steps:

(1) A Malmquist-type of quantity index is adopted to derive and calculate *EP*;

(2) Policy induced variation in *EP* is determined;

(3) The effects of policy and non-policy induced changes in *EP* on *PE* are evaluated.

Studies on the determinants of *PE* at the firm level are rare and, to the best of our knowledge, there is no study that explicitly explores the relationship between actual *EP* and *PE*.[3] Furthermore, variation in *EP* is divided into policy induced and voluntary, or non-policy, induced variation.[4] The empirical approach allows us to look at the whole chain from the impact of CO_2 taxation on firms' *EP*, to the impact of *EP* on *PE*. This is the major and new contribution of this paper.

Anthropogenic climate change has become a major challenging global problem and the urgency of implementing proper measures to solve this problem is at the top of the political

[2] Lundgren and Marklund (2011) explicitly address the Porter hypothesis (Porter, 1991; Porter and van der Linde, 1995). They find evidence of a "Porter effect" in Mining, Food, and Textile, but for most sectors the effect is non-existing or negative.
[3] Dam et al. (2009) look at cost and profit efficiency for a range of corporate social responsibility factors (ethical rankings), where environmental issues are included.
[4] Our methodology is similar to the approach in Hamamoto (2006).

agenda in many countries around the world. However, it is also important to address the firms' environmental behavior per se. If firms themselves would benefit from by considering the environment, yet they do not do so due to markets being characterized by imperfect information, the policy measure then becomes to inform about this potential.[5] If there is a positive relationship between *EP* and *PE* there are not only environmental gains to be expected, but also private gains for firms helping to improve their productivity and competitiveness. In studying this issue, it is desirable to consider actual *EP*, which is rare in the literature on *EP* and profitability.[6] Commonly, in the literature (especially in business/management and finance), *EP* is proxied by ratings provided by consulting firms, highly contributing to a subjective picture of firms' performance.[7] This literature is extensive and studies almost exclusively make use of financial performance measures[8] when relating firm performance to *EP* ratings; results are mixed and non-conclusive, but a positive correlation seems more frequent, possibly due to publication bias.[9] When it comes to firm actual *EP* and economic performance, the research is much less common. The *Journal of Productivity Analysis* recently published a theme issue on corporate social responsibility (CSR) and economic performance (Paul and Siegel, eds., 2006). They note that the vast number of studies on CSR rankings and the effect on financial measures is, from an economic perspective, unfortunate. Instead, they suggest that a more salient issue is the relationship between actual *EP* and economic performance, where economic performance entails technological and economic inter-actions between the production of output and input utilization, recognizing the opportunity costs of inputs and capital formation. In this paper we attempt to take this into account by using a framework which especially accounts for how actual *EP* impact firm level management and its efficient use of energy inputs to produce output and generate profits. By doing so, we add a novel methodological framework and new findings to the bulk of literature on CSR and firm performance.

[5] This argument is similar to that of the Porter hypothesis. Environmental policy brings with it information that makes firms aware about inefficiencies in their operational activities.
[6] In the productivity literature there are quite a few recent studies where *EP* is defined and calculated using actual data on good and bad outputs; e.g., Färe et al. (2004), Färe et al. (2006), and Färe et al. (2010). However, *EP* is not linked explicitly to profitability.
[7] A review of empirical studies on corporate social responsibility (CSR) and its impact on financial performance is provided in Orlitzky and Swanson (2008). See also Lundgren (2011) for a compact review of the literature and a general theory of the socially responsible firm and the potential motivations for voluntary responsible behavior.
[8] Stock prices, firm value, return on assets, Tobin's q, etc.
[9] See e.g. Hay et al. (2005).

To construct the *EP* index we follow Färe et al. (2004), Färe et al. (2006), and Färe et al. (2010) and make use of a Malmquist-type of index based on ratios of Shephard-type output distance functions. This index reflects the development of the relationship between firms' good output and bad output, in our case between sales (index) of the marketed product and the emissions of CO_2. Then, adopting a methodological approach similar to the one suggested in Hamamoto (2006), we isolate variation in predicted *EP* scores into CO_2 tax triggered variation and variation due to voluntarily taken measures. Voluntary measures are triggered by other exogenously given factors than CO_2 taxation, such as fossil fuel price, but also by changed preferences for the environment in firms and society, which may perhaps include purely strategic reasons (improved *EP* is simply "good business").[10] In a final step, conditional *PE* scores are estimated using a stochastic frontier analysis approach, where efficiency is allowed to depend on both types of *EP* and some control variables.[11]

Generally, the results demonstrate that policy induced *EP* is not a significant determinant of *PE* while voluntary or non-policy induced *EP* seems to have a positive and significant effect on *PE*. That is, good *EP* is good business, but only if that *EP* does not stem from the CO_2 tax, a result that would disagree with the so called Porter hypothesis advocating a "win-win" outcome of environmental policy.

The empirical model framework is presented in Section 2. This is followed by data and results in Section 3 and 4. Finally, Section 5 offers a conclusion.

2. Empirical framework

The main objective is to explore the relationship between firms' environmental performance (*EP*) and their profit efficiency (*PE*), measuring the percentage loss in profits due to output technical inefficiency in production. Specifically, we use the modeling approaches in Brännlund et al. (2011) and Lundgren and Marklund (2011).

The empirical analysis is conducted in three steps: (1) Calculating *EP*; (2) Deriving CO_2 and voluntarily induced variation in calculated *EP*; (3) Testing statistically the effects of CO_2 and voluntarily induced changes in *EP* on *PE*.

[10] Note that even policy induced *EP* is voluntary in a sense. A tax is not forcing but gives incentives to a firm to change its behavior. What we mean here is that a fraction of a firm's *EP* is triggered by policy, while if we consider total variation in *EP*, also voluntary measures are included.

[11] The *PE* approach adopted is based on Kumbhakar and Lovell (2000) and Kumbhakar (2001). The stochastic frontier estimating approach is based on Battese and Coelli, (1995) and Coelli (1996).

Calculating environmental performance (EP)[12]

Primarily following Färe et al. (2006) we start from neoclassical production theory and, based on ratios of Shephard-type output distance functions, calculate a Malmquist-type of *EP* index on firm level, k, as[13]

$$EP_k^t = \frac{y_k^t / b_k^t}{y_k^{t-1} / b_k^{t-1}}, \qquad k = 1,...,K \text{ firms} \tag{1}$$

where y^τ and b^τ, $\tau = t-1, t$, denote production of good output (*index*) and bad output (*CO_2 emission*) in period τ, respectively.[14] We assume that bad output is produced as a by-product in production of the marketed good output.[15] If the relationship between good and bad outputs is unchanged between two periods there is no change in environmental performance (measured as observed good output per unit observed bad output), and $EP^t = 1$. If environmental performance changes for the worse or improves then $EP^t < 1$ or $EP^t > 1$, respectively.[16]

Deriving CO_2 tax induced variation in EP

To explicitly divide variation in *EP* in Equation (1) into CO_2 triggered variation and variation due to what we here denote voluntarily actions by firms, we adopt a methodological approach similar to that suggested in Hamamoto (2006). First, a log-linear function is estimated,[17]

$$\begin{aligned} \log(EP)_k^t &= c_k + a_1 \log(CO2_k^{t-1}) + a_2 \log(pf_k^{t-1}) + a_3 \log(sfuel_k^{t-1}) + a_4 \log(capin_k^{t-1}) \\ &\quad + \sum_{size}^{4-1} a_{5size} size_k^{t-1} + a_5 trend^{t-1} + a_7 (trend^{t-1})^2 + e_k^t \end{aligned} \tag{2}$$

where we are mainly interested in the effects of $CO2_k^{t-1}$ and pf_k^{t-1}. We also add control variables representing firm characteristics: $sfuel_k^{t-1}$ is the cost share of fossil fuels in period

[12] For a more detailed presentation and discussion, see Brännlund et al. (2011).
[13] See also, e.g., Färe et al. (2004, 2010).
[14] The expression in Equation (1) is valid in the case of a single good output and a single bad output. However, as output distance functions are the building blocks of this particular index, an expression that considers multi-good/bad output production can be derived.
[15] To model the opportunity cost of reducing the by-product, good outputs are assumed strongly disposable and good outputs and bad outputs together weakly disposable. Furthermore, it is assumed that good and bad outputs are null-joint, i.e., good outputs cannot be produced without producing bad outputs (see, e.g., Färe and Grosskopf, 2003).
[16] Note that the expression in Equation (1) works as a measure of decoupling.
[17] More details are provided in Brännlund et al. (2011).

$t-1$, $capin_k^{t-1}$ is capital intensity (capital stock over total employees), and different size is captured by the $size_k^{t-1}$ variable. A general time-trend, possible non-linear, is modeled by a *trend* variable.

To explicitly isolate the variation in firms' *EP* due to CO_2 taxation, we follow the procedure in Hamamoto (2006), and predicted values are calculated as

$$\hat{EP}1_k^t = \hat{a}_1(\Delta CO2_k^t)\frac{EP_k^t}{CO2_k^{t-1}}, \qquad (3)$$

where $\hat{a}_1$ is the estimated percentage change in *EP* due to a percentage change in the tax rate (the tax elasticity). Furthermore, to detach the variation in *EP* due to firms' voluntary actions, we use Equation (1) and (3) and solve residually for voluntary variation as

$$\hat{EP}2_k^t = EP_k^t - \hat{EP}1_k^t. \qquad (4)$$

This means that voluntary variation in *EP* is due to firms adjusting to other factors than CO_2 taxation, e.g., increased energy prices, but also possibly due to firms acting strategically as a response to changed environmental preferences on markets (improved *EP* is simply good business).[18]

Stochastic frontier analysis: profit efficiency

To explicitly test the significance of firms' *EP* on their *PE* in Swedish manufacturing during 1990-2004, the performance indicators, as given by Equations (2) to (6), are used in a stochastic profit frontier framework.

Underlying the stochastic profit frontier estimations is the theoretical framework of Kumbhakar and Lovell (2000) and Kumbhakar (2001), where it is shown that profit efficiency only depends on output technical efficiency in production when assuming that the underlying production function is homogenous of degree r in inputs.[19] This assumption supports the adoption of a stochastic frontier estimating approach, suggested by Battese and Coelli (1995) (see also Coelli, 1996), which is a single-stage estimating procedure including both the frontier and explaining variation in efficiency. In our particular case, the profit frontier is

[18] See Orlitzky et al. (2011) for a discussion on strategic green or social behavior.
[19] For a more detailed model presentation, see Lundgren and Marklund (2011).

estimated simultaneously with profit technical efficiency scores being estimated contingently on environmental performance variables and control variables. Specifically, the profit of firm k in period t is estimated as a translog flexible functional form[20]

$$\begin{aligned}\ell n\left(\frac{\pi_k^t}{p_k^t}\right) &= \alpha_0 + \gamma_K \ell n K_k^t + \gamma_L \ell n L_k^t + \alpha_E \ell n(\frac{w_{E,k}^t}{p^{kt} e^{-u^{kt}}}) + \alpha_F \ell n(\frac{w_{F,k}^t}{p^{kt} e^{-u^{kt}}}) \\ &+ \frac{1}{2}\gamma_{KK}\left(\ell n K_k^t\right)^2 + \gamma_{KL}\ell n K_k^t \ell n L_k^t + \eta_{KE}\ell n K_k^t \ell n(\frac{w_{E,k}^t}{w_{F,k}^t}) \\ &+ \frac{1}{2}\gamma_{LL}\left(\ell n L_k^t\right)^2 + \eta_{LE}\ell n L_k^t \ell n(\frac{w_{E,k}^t}{w_{F,k}^t}) + \\ &+ \frac{1}{2}\alpha_{EE}\left(\ell n(\frac{w_{E,k}^t}{w_{F,k}^t})\right)^2 \\ &+ \alpha_\tau T + v_k^t - u_k^t \end{aligned} \qquad (7)$$

where $1-\alpha_E-\alpha_F=\alpha_p$, $\alpha_{EE}=-\alpha_{EF}=\alpha_{FF}$, and $-\eta_{KE}=\eta_{KF}$. The profit function in (7) satisfies symmetry and homogeneity of degree 0 in prices, and it also satisfies a number of restrictions that enable us to separate out the inefficiency effect as simply a function of u_k^t (see Kumbhakar and Lovell, 2000, p. 197). Furthermore, the function is convex and continuous in prices, non-decreasing in the marketed good output price, pe^{-u}, and non-increasing in electricity price, w_E, and fossil fuel price, w_F. A positive sign is expected for the quasi-fixed input factors capital, K, and labor, L. We also model technological development as being Hicks neutral by introducing a trend variable, T. Representing the stochastic part of the frontier v_k^t captures random shocks and measurement errors and is assumed $iid\ N(0,\sigma^2)$. Finally, independent of v_k^t is the nonnegative random variable, u_k^t, that captures technical inefficiency. It follows a truncated normal distribution, independently (but not identically) distributed.

To explicitly test the effects of environmental performance on profit efficiency following expression is, following Battese and Coelli (1995), in a single-stage estimating procedure, simultaneously estimated with the expression in Equation (7);[21]

[20] Kumbhakar and Lovell (2000) argue it is appropriate to estimate profit functions in a short-run framework, modeling at least one input as quasi-fixed. As we are interested in effects of *EP* on *PE* related to energy use in production, we treat capital and labor as quasi-fixed.

$$-u_k^t = \delta_0 + \delta_1(\hat{EP1})_k^{t-1} + \delta_2(\hat{EP2})_k^{t-1} + \delta_3 capin_k^{t-1} + \delta_4 fuelin_k^{t-1} + \sum_{s=1}^{S-1}\delta_{5s}D_{size}^s + \delta_t trend^t + \upsilon^{kt}. \quad (8)$$

Previous period capital intensity is denoted $capin_k^{t-1}$ (capital stock over employees), and $fuelin_k^{t-1}$ is fuel intensity (fuel over total employees). Furthermore, allowing for efficiency to vary due to size specific profit frontiers, dummies, D_{size}^s, are included. The size dummies are based on firms being divided into size quartiles, $s = 1,...,4$, based on number of employees. To account for time-specific events, not related to Hicks neutral technological development modeled in the profit function, a trend variable, $trend$, is added, Finally, υ_k^t is white noise (see Battese and Coelli, 1995). To fulfill the main objective of this paper, t-tests are performed on the estimates $\hat{\delta}_1$ and $\hat{\delta}_2$ in order to evaluate the tax effects on profit efficiency.

To avoid endogeneity problems and to account for the (reasonable) possibility of delayed or dynamic *EP* effects, all variables in Equation (8) are lagged one period.

Technical efficiency, $-u_k^t$, in Equation (8) is related to profit technical efficiency, $-u_k^{\pi,t}$,as $-u_k^{\pi,t} = -\rho \cdot u_k^t$, i.e., profit efficiency is a constant multiple of technical efficiency in production. This relationship holds under the assumption of the underlying production function being homogeneous of degree r in inputs (Kumbhakar, 2001), and $\rho = 1/(1-r) = \alpha_p$. Finally, profit technical efficiency is calculated as

$$PE_k^t = \exp\left(-\hat{u}_k^{\pi,t}\right) = \exp\left(-\hat{\rho}\hat{u}_k^t\right) \quad (9)$$

3. Data

This study uses the same Manufacturing panel data set as in Brännlund et al. (2011) and Lundgren and Marklund (2011). An overview of the thirteen different sectors in the data set available is provided in Table 1. The raw data contain information from all firms in manufacturing industries in Sweden (SNI 10-37).

Table 1. Swedish manufacturing data 1990-2004.

[21] See Lundgren and Marklund (2011) for a specification of the log likelihood equation in a profit function setting, which is a reproduction of the log likelihood function in a production function setting presented in Battese and Coelli (1993).

SNI 2002 (branch code)	**Sector**
10, 11, 13.1-13.2, 14	Mining
15-16	Food
17-19	Textile
20.1-20.5	Wood
21.11-21.12, 21.21-21.24	Pulp/Paper
22	Printing
23.1-23.3, 24	Chemical
25.1-25.2	Rubber/Plastic
26.1-26.8	Stone/Mineral
27-28	Iron/Steel
29	Machinery
30-33	Electro
34	Motor vehicles

Notes: Industry branch code classification of Swedish manufacturing (SNI 2002) according to Statistics Sweden.

The data set used in this paper is a balanced panel for industrial firms covering the years 1990 to 2004. The set contains data on output (sales), and input data on quantities and values of labor, electricity and fuels, and gross investment (machinery and buildings). Capital stocks are calculated using investment data and the perpetual inventory method together with the assumption that capital stocks are in steady state in 1990. Profits are measured as gross profits (revenues minus costs) before taxes. The data also contain detailed information on emissions of CO_2 and total payment of CO_2 tax for each firm. This enables us to construct a variable for "effective" CO_2 tax, which varies considerably across firms, sectors, and over time.[22]

Output price indices are sector-specific, and firm-specific input prices can be calculated from the costs and quantities for labor, electricity, and fuels. We assume that output and input prices are exogenous to the firm. The calculation of the user cost of capital is based on national and industry based indexes.

A few descriptive statistics for the different industry sectors are given in Table 2. As mentioned above, the CO_2 tax varies considerably across sectors, ranging from about 0.04 SEK/kg in the wood product sector to almost 0.15 SEK/kg for Food.

[22] For a detailed description of the CO2 tax scheme, see Brännlund et al. (2011).

Table 2. Descriptive statistics. Mean values 1990-2004 (base = 1990).

Sector						
Variable	Mining	Food	Textile	Wood	Pulp/paper	Printing
Capital stock	524777	259549	97186	88450	775387	63998
	(1365816)	(509303)	(181651)	(157760)	(1511305)	(102548)
Employees	275	208	148	115	325	142
	(472)	(227)	(120)	(138)	(308)	(269)
Price electricity	0,292	0,279	0,293	0,296	0,240	0,314
	(0,126)	(0,080)	(0,093)	(0,096)	(0,087)	(0,096)
Price fossil fuels	0,282	0,286	0,341	0,359	0,235	0,494
	(0,112)	(0,456)	(0,179)	(0,175)	(0,150)	(0,205)
CO_2 tax	0,074	0,145	0,127	0,041	0,125	0,058
	(0,068)	(0,063)	(0,078)	(0,064)	(0,070)	(0,076)
Nobs	193	2037	399	1800	1285	945

Note: Standard deviation in parenthesis. The capital stock is in thousands of SEK, prices are in SEK/Kwh, and the CO_2 tax is in SEK/kilo.

Table 2. Cont.

Sector						
Variable	Chemical	Rubber/ plastic	Mineral/ stone	Steel /iron	Machine/ electro	Motor vehicles
Capital stock	631622	113645	108487	191806	238416	581917
	(1717444)	(186114)	(178253)	(479269)	(752930)	(2155773)
Employees	214	140	129	190	228	466
	(260)	(123)	(122)	(326)	(319)	(1062)
Price electricity	0,259	0,282	0,306	0,292	0,314	0,303
	(0,105)	(0,074)	(0,096)	(0,086)	(0,093)	(0,091)
Price fossil fuels	0,272	0,369	0.235	0.314	0.395	0.137
	(0,152)	(0.165)	(0.115)	(0.146)	(0.161)	(0.134)
CO_2 tax	0.123	0,111	0,134	0,137	0,108	0,137
	(0.079)	(0,081)	(0,065)	(0,069)	(0,078)	(0,065)
Nobs	974	917	1042	2753	3649	1098

Note: Standard deviation in parenthesis. The capital stock is in thousands of SEK, prices are in SEK/Kwh, and the CO_2 tax is in SEK/kilo.

4. Results

The essential results from step 2, estimating the *EP* equation shown in (2) are presented in Table 3, which shows *EP*'s response to changes in the CO_2 tax. The estimation of each sector's elasticity is based on standard panel data techniques.[23]

Table 3. Elasticities of *EP* with respect to the CO_2 tax for each sector.

Sector	***EP*-CO_2 tax elasticity**
Manufacturing	0.313***
Mining	0.100
Food	0.107***
Textile	0.580***
Wood	0.346***
Pulp/paper	0.208***
Printing	0.008
Chemical	0.293***
Rubber/plastic	0.280***
Stone/mineral	0.723***
Iron/steel	0.161
Machinery	-0.084
Electro	0.010
Motor vehicles	0.611***
Energy intensive	0.349***
Non-energy intensive	0.184***

*Significant at 10% level. **Significant at 5% level. ***Significant at 1% level.

The elasticities in Table 3 are used to compute policy induced *EP* as explained in equation (2). We see that in most sectors *EP* has a positive but inelastic relation to the tax. The elasticity is not statistically significant in some sectors, indicating the relationship may be weak or non-existing in those cases. From the data we can then calculate that, on average, the policy induced *EP* share of total *EP* is about 5% for Manufacturing as a whole and slightly higher for Energy intensive firms. This shows that the CO_2 tax is responsible for a small but not insignificant part of total *EP*. We now go on to present the impact of *EP* on *PE* estimating sector by sector.

Table 4. Impact of *EP* on profit efficiency;

[23] The reader is referred to Brännlund et al. (2011) for full disclosure of estimation results.

Sector	Policy *EP* (δ_1)	Voluntary *EP* (δ_2)	*PE* score	Policy *EP* share
Manufacturing	0,100	0,077***	0,786	0,046
Mining	-1,147	-0,060	0,573	0,035
Food	-0,256	0,122**	0,665	0,010
Textile	0,217	0,532**	0,696	0,028
Wood	0,896	0,994	0,747	0,124
Pulp/Paper	-0,085**	-0,069***	0,571	0,176
Printing	-6,368	0,092	0,602	0,001
Chemical	0,139*	0,128**	0,469	0,114
Rubber/Plastic	0,039	-0.073**	0,737	0,041
Stone/Mineral	-0,025	0,097***	0,351	0,052
Steel/Iron	0,003	0,039	0,416	0,011
Machinery	-0,404	0,097***	0,362	0,000
Electro	-23,21	0,184	0,787	0,000
Motor vehicles	0,036	0,067**	0,495	0,054
Energy int.	0,090	0,074*	0,788	0,067
Non-energy int.	0,209*	0,138***	0,685	0,021

* Significant at 10% level. **Significant at 5% level. ***Significant at 1% level.

We estimate Equation (7) and (8) simultaneously[24] for each individual sector of manufacturing (as given in Table 1). Summarized results shown in Table 4 reveal that all sectors are to some extent inefficient.[25] A notable result is that Pulp/paper show a negative policy effect. However, policy induced *EP* do have a significant and positive effect (a Porter effect) on profit efficiency in Chemical and the aggregate Non-energy intensive firms. Profit efficiency in the industry as a whole responds positively and significantly to what we label voluntary *EP*. Results from different sub-sectors, and the aggregate Energy intensive firms, confirm this general result with a few exceptions; Pulp/Paper and Rubber/Plastic show a significant negative relationship between profits and *EP*, while a few other sectors show no link at all. The policy induced *EP* shares vary between sectors with the highest shares are recorded in Wood and Pulp/Paper, the latter being the only sectors showing a significantly negative relationship between policy *EP* and profits.

[24] Full estimation results can be obtained from the authors upon request.
[25] The stochastic frontier approach is pertinent, i.e., all estimations produce statistically significant inefficiency scores.

Table 4 results suggest that voluntary *EP* in general seems to push firms to be more profit efficient while policy induced *EP* is not an important determinant of profit efficiency. Again, in line with Lundgren and Marklund (2011), the general evidence speaks against the Porter hypothesis since policy has no statistically significant or neutral effect on profit efficiency.

5. Conclusion and discussion

The overall purpose of this paper has been to empirically analyze the effects of environmental performance (*EP*) in production on profit efficiency (*PE*). *EP* is explicitly related to CO_2 performance and *PE* is estimated as a constant multiple of output technical efficiency in production, indicating the percentage loss in profits due to inefficient use of energy inputs. The study was performed on a panel data set of firm level data in Swedish manufacturing, covering the period 1990-2004.

Besides studying the relationship between *EP* and *PE*, the contribution of the paper is also that variation in *EP* is divided into policy induced variation due to firms facing a CO_2 tax, and non-policy induced, or voluntary variation. Voluntary variation is triggered by other exogenously given factors, such as changed relative energy prices, but also possible by firms acting strategically; good *EP* is good business. Moreover, the methodological approach taken allows us to consider the whole chain from the impact of CO_2 taxation on firms' *EP* to the impact of *EP* on firms' *PE*.

The results reveal that Swedish manufacturing in general was producing profit inefficiently during the period in study. That is, energy inputs (in terms of fuels and electricity) were not used efficiently and therefore firms suffered profit losses. Furthermore, policy induced *EP* constituted a relatively small part of total *EP*, compared to non-policy *EP* (approximately 5 percent for manufacturing as a whole).

The main result is that policy induced *EP* is not an important determinant of profit efficiency, but voluntary *EP* seems to push firms to be more profit efficient. In other words, given technology used in production, firms' voluntary actions to be more carbon efficient appear to be more integrated with economic performance.

The results presented here are in line with the numerous empirical studies that show a positive relationship between financial performance measures such as return on assets (ROA) or Tobin's q, and environmental performance in terms of subjective ranking measures (see e.g. review by Orlitzky and Swanson, 2008). However, our evidence is generated from using a more “primal” methodology where the performance measures are derived from actual firm behavior, and we take into account firm technology by explicitly allowing for inter-actions and trade-offs between different uses of energy inputs and the production of outputs.

We find that environmental policy (via *EP*) is not an important driver of firm performance in Swedish industry. This result disagrees with Hamamoto (2006)[26] who find that policy (via R&D) is promoting performance in terms of total factor productivity in Japanese industry. On the other hand, our results are by and large in line with many studies on the so called Porter effect that find no convincing evidence of a “win-win” outcome of environmental policy (see e.g. review by Brännlund and Lundgren, 2009). Since policy induced *EP* seem to have a neutral effect on profit efficiency it indicates that measures taken to improve *EP* as a result of an increase in regulatory pressure are neither promoting nor impeding *PE*. This in turn point toward that any “bad” effects of this type of *EP* behavior is balanced out by “good” effects. The neutrality of policy impact on profits is good news for both policy makers and firms; the environment can be improved via a tax scheme policy without imposing inefficiencies on the firm.

The rationale behind the general result that the main part of *EP* seem to be beneficial for profits, is related to the fact that good *EP*, to an extent that it is not kindled by policy, is related with a more efficient use of energy inputs to produce outputs. But it may also stem from reasons associated with market conditions such as green consumerism, etc., or other circumstances that affect the firm’s operative environment, e.g. institutional aspects. From a policy maker’s point of view, a relevant course of action is to put efforts into informational campaigns to enlighten sectors and firms that are currently operating inefficiently about the prospective to increase profitability through environmental considerations; i.e. encourage the “worst-in-class” firms to mimic the “best-in-class” firms in terms of technology choice and environmental behavior. Also, voluntary approaches to environmental policy, such as public disclosure programs, have the potential to be useful in a market setting where firms are rewarded (punished) for good (bad) *EP* (Khanna, 2001). Furthermore, Rauscher (2006), in a study of voluntary emission reductions, suggest that if there is a social or market reward (punishment) for good (bad) *EP*, then traditional environmental instruments, e.g. taxes and subsidies, may crowd out the private provision of voluntary actions to improve the environment. This implies that if environmental conduct observed in Swedish manufacturing

[26] This study uses similar methodology.

is for the most part voluntary, then policy makers should take this into account when designing the appropriate policy instruments.

A final cautionary remark; even though we find that *EP* is to a large extent integrated with economic performance, we are not able to disentangle the true causal relationship[27] in this modeling framework. On that matter we can only speculate, and it calls for further investigation, perhaps using VAR or other Granger causality-type of methods.

[27] See e.g. Waddock and Graves (1997) for a discussion and investigation of the causal relationship between the "good actions" of a firm and its financial performance.

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