

Some Micro-Evidence on the 'Porter Hypothesis' from Austrian VOC Emission Standards

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Abstract

This paper presents some microevidence on the techno-economic consequences of Austrian VOC emission standards, the most restrictive of their kind in the world. Using firm-level survey data and complementing it with highly disaggregated foreign trade data, the paper explores whether the standards had a palpable impact on the competitiveness of Austrian manufacturers of paints, coatings, printing inks and adhesives, whether compliance stimulated innovation in this industry, whether the standards crowded out other, more productive R&D, and whether compliance efforts gave rise to unexpected benefits of compliance. It finds no unequivocal aggregate impact on the competitiveness of regulated firms, yet some interesting variation at the firm-level. However, the standards appear to have dampened import competition. The standards gave rise to considerable changes in firms' product range and appear to have accelerated the rate of product innovation in the regulated industry. R&D spending to develop compliant products is found to be very unevenly distributed, mainly due to technological to a lesser extent organisational factors. There is evidence that compliance efforts displaced or postponed existing R&D projects. However, there is also evidence that search for compliant products yielded unexpected and beneficial ideas, knowledge and competencies.

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1. Introduction

What are the techno-economic consequences of environmental regulation? To the extent that any adaptations are required, standard economics predicts that compliance efforts may induce R&D, which may lead to the development of new, environmentally benign technologies. However, compliance innovations come at a price to the individual firm. Since adding a constraint to the profit maximisation problem of a firm inevitably reduces profits, for example through higher production costs and/or the crowding out of more productive activities, regulated firms become less competitive vis-à-vis their unregulated rivals. Society as whole, however, may benefit through the removal of an undesirable externality (see Palmer and Oates 1995).

In a series of papers, Michael Porter challenged this view, arguing that it was the result of a 'static mindset' (Porter 1991; Porter and van der Linde 1995a, b). Instead, in what has subsequently become known as the 'Porter Hypothesis', he suggested that there may be a positive relationship between environmental regulation and the competitiveness of regulated firms, as 'properly designed' environmental regulation may set off efforts by firms to find more efficient ways of producing or to develop new products that command higher margins. Such benefits from innovation may partially or even fully offset private adaptation costs.

Porter's argument implies the systematic existence of hitherto unexploited, profitable investment opportunities, which firms only realise if prodded by regulators. Quite naturally, this proposition has attracted a great deal of attention in the policy community. Economists, meanwhile, have devoted considerable effort to theoretically and empirically exploring the validity of Porter's reasoning. Theoretical research within the neo-classical framework has identified a number of instances where the presence of some sort of positive externality may indeed produce results consistent with Porter's hypothesis (for example Xepapadeas and de Zeeuw 1999; Mohr 2002). Dropping the assumption of perfectly rational, monolithic firms and arguing instead in terms of routine-based behaviour in the spirit of Cyert and March (1992), additional situations can be construed in which the introduction of an environmental regulation may uncover opportunities to save money that previously went unnoticed, for example due to the absence of appropriate reporting systems (Gabel and Sinclair-Desgagné 1999). However, whether any of these situations *systematically* occur is an empirical question.

Empirical efforts to test the 'Porter Hypothesis' have focused on the impact of environmental regulation and competitiveness or innovation, attempting to establish a link between some measure of regulatory stringency and some measure of competitiveness or innovation (for reviews, see Jaffe *et al.* 1995; Jeppesen *et al.* 2000; Mulatu *et al.* 2001). The results of these exercises, however, are mixed and rather vague. The considerable number of studies investigating the link between the stringency of environmental regulation and shifts in trade-patterns of pollution intensive goods or shifts in the location of capital investment in pollution intensive industries (foreign direct investment flows or plant location behaviour) as proxies for changes in competitiveness have produced few statistically significant results. Of these, the majority have the expected negative sign, but there are also some estimates of a positive relationship (for

example Xu 2000). Moreover, parameters tend to be rather small. Econometric studies on the impact of environmental regulation on innovation (Lanjouw and Mody 1996; Jaffe and Palmer 1997) find that increases in environmental compliance expenditures may boost R&D spending and patenting of compliant technologies. They do not, however, find evidence that environmental regulation has a positive (or for that matter any) impact on total innovative activity.

There are essentially two explanations for these rather unsatisfactory results: *First*, there are substantial measurement problems. Owing to the large number of direct and indirect cost components (for a thorough discussion, see Jaffe *et al.* 1995, pp. 139-142), it is virtually impossible to obtain accurate measures of the full costs of environmental regulation, especially across countries and over time. Moreover, compliance costs and hence by implication the impact of environmental regulation are highly industry- or even firm-specific. However, lack of sufficiently disaggregated data forces researchers to use country-level or highly aggregated industry-level data that may systematically bias results (see Levinson 2001). *Second*, actual costs of compliance are rather low, representing only a minor fraction of total production costs (see Stewart 1993, p. 2105; Jaffe *et al.* 1995, p. 158).

In order to confront some of these shortcomings, this paper will adopt a different strategy. Rather than looking for a suitable proxy for the stringency of environmental regulation and regressing it on appropriate proxies for competitiveness or innovation, it will start out with a set of environmental regulations which are known to have had a considerable impact on the regulated industry, and look for evidence relevant to the 'Porter Hypothesis'. The standards in question are Austrian Volatile Organic Compound (VOC) emission standards, which were and still are by far the strictest of their kind in the world. Using firm-level survey data and complementing it with highly disaggregated foreign trade data, the following questions will be addressed: *First*, did Austrian VOC emission standards have a palpable impact on the competitiveness of Austrian manufacturers of paints, coatings, printing inks and adhesives? *Second*, did these regulations stimulate or even accelerate innovation in this industry? *Third*, did the standards crowd out other, more productive R&D? *Fourth*, did compliance efforts give rise to unexpected benefits of compliance?

It must be emphasised that the benefits of the case study approach adopted in this paper, namely the ability to highlight effects which are difficult or even impossible to pinpoint with more aggregate data, come at a price: Because of the specificity of the data and the small number of observations, it is impossible to go beyond a purely descriptive analysis.

The remaining sections of this paper are structured as follows. Section 2 briefly describes the Austrian VOC emission standards and the data used in this paper. Section 3 explores the impact of the regulations on the competitiveness of Austrian paint, coating, printing ink and adhesive manufacturers. Section 4 examines how the standards affected regulated firms' innovation behaviour, investigating above all whether and to what extent the environmental regulations affected other R&D and whether compliance efforts gave rise to beneficial side effects implied by the 'Porter Hypothesis'. Section 5 summarises the main results and gives directions for future research.

2. Regulations and data

Volatile Organic Compounds (VOCs) are a diverse set of highly reactive organic chemical compounds that play a major role in ground-level ozone formation. In the mid- and late 1980s, ground-level ozone had become a major environmental concern in Austria, leading to the adoption of a series of three legislative measures to reduce the use and emission of VOCs as solvents in paints, coatings, printing inks and adhesives as well as the application of conventional, that is solvent-based, systems in industrial production processes, which together account for roughly 40 per-cent of total anthropogenic VOC emissions in Austria. Two product standards restricted the maximum content of aromatics and organic solvents in these products while a process standard mandated the installation of pollution control equipment for industrial applications emitting more than a fairly low amount of VOCs each year. The product standards and process standards pertaining to new installations entered into force in 1996 while slightly less restrictive rules regulating existing installations were staggered by size and became binding in 1998 and 2000, respectively.

Two sources of data will be used to explore the techno-economic consequences of the VOC emission standards. Foreign trade data has been obtained from the UN commodity trade database via the Austrian Institute of Economic Research. Since data is available at the SITC 5-digit level, it has been possible to pinpoint the respective product categories, which are SITC 5332 (printing ink), 5334 (paints & varnishes; stamping foils; dye packs etc), 59227 (glues from starches, dextrans or other modified starches) and 59229 (prepared glues & adhesives n.e.s; retail packages etc).

The second data source is a survey conducted by the author on the Austrian paints, coatings, printing inks and adhesives industry. The survey had been designed as an exploratory pilot study to obtain fairly broad information on the industry and technologies as well as the techno-economic consequences of the Austrian VOC emission standards. Because of the large amount of desired information and the relatively small size of the industry under scrutiny, the survey was conducted via standardised in-depth interviews with senior executives, mostly managing directors or the respective heads of R&D. Interviews lasted between 30 minutes and two hours. After several rounds of development and revision, the survey was conducted by the author in 1999 from July 28 to Oct 17. It covered 28 out of 29 independent, Austrian manufacturers of paints, coatings, printing inks and adhesives. Although precise figures are not available, this represents more than 95% of the industry in terms of turnover and employment, amounting essentially to a *full survey*.

The paint, coating, printing ink and adhesive industry is a highly fragmented industry, dominated by a handful of large, multinational enterprises and very large number of small and medium-sized niches players. For instance, the average German paint and coating manufacturer has 50-100 employees and an annual turnover of EUR 15-20 million (Deutsches Lackinstitut 2001). However, it must be noted that such statistics can be misleading as subsidiaries of multinational firms are mostly locally registered firms, and firm and plant size easily get confused.

Table 1 displays the size distribution of firms in the Austrian paint, coating, printing ink and adhesive industry. Firms were assigned to size categories according to Recommendation 96/280/EC by the Euro-

pean Commission which sets out size categories for small and medium-sized enterprises in Europe. According to this classification, a firm is small if it has annual revenues of less than EUR 7 million, medium sized if its annual revenues are greater EUR 7 but less than EUR 40 million and large if it generates annual revenues in excess of EUR 40 million. Table 1 shows that there are six small, twelve medium-sized and ten large firms in the data set.

Table 1: Structure of the Austrian paint, coating, printing ink and adhesive industry (1998)

	Small	Medium-Sized	Large	Total
<i>Product group</i>				
OEM	2	5	6	13
Architectural coatings	1	6	1	8
Printing inks	2	1	1	4
Adhesives	1	0	2	3
All firms	6	12	10	28

Note: OEM stands for Original Equipment Manufacture, which are industrial coatings. n=28

Moreover, Table 1 displays information on firms' technological profiles. Paints, coatings, printing inks and adhesives are related, yet distinctly different technologies. Based on information on firms' product range, each firm could be assigned to one of four categories, namely manufacturer of industrial coatings (original equipment manufacture, OEM), architectural coatings, printing inks and adhesives. Table 1 shows that there are 13 manufacturers of industrial coatings, eight architectural coatings manufacturers, four firms manufacturing printing inks and three manufacturers of adhesives. In terms of the distribution of technology profiles across size categories, OEM are predominantly medium-sized and large firms, while manufacturers of architectural coatings are mostly medium-sized firms. Printing ink manufacturers are small and medium-sized, while adhesive manufacturers are predominantly large firms.

3. Competitiveness

In principle, the expected sign of the net impact of environmental regulation on the competitiveness of regulated firms or industries is by no means clear, as three conflicting forces may be at work:

- ◆ *First*, restrictive environmental regulations, in particular process regulations and liability rules, may raise production costs and divert resources from more productive investments, which should hurt the competitiveness of regulated firms and cause them to lose market share abroad. Environmental product regulations may have similar effects, which applies even if exports are exempt from domestic rules due to lower scale economies.
- ◆ *Second*, if foreign rivals are not subject to similar product, process or liability rules, regulated firms may also lose market share in their home markets. Having said that, facially non-discriminatory regulations imposing uniform product standards may effectively favour domestic firms, as domestic manufacturers are likely to enjoy economies of scale in compliant products (for some empirical examples, see Stewart 1993, p. 2043). This may inflict a cost disadvantage on foreign firms.

- ◆ *Third*, dynamic 'innovation offsets' may more than fully offset negative static effects. To the extent that such innovation offsets lead to lower production costs and/or more profitable products, regulated firms should become more competitive. The latter argument is also known as the 'strong version' of the 'Porter Hypothesis' (see Jaffe and Palmer 1997).

In the case of Austrian VOC emission standards, any of these three forces may be at work. Although products destined for export need not comply with the rules governing organic solvents if so required by foreign customers, obtaining such an exemption involves administrative paperwork which imposes additional costs and may be a serious obstacle in the case of time-critical orders. Also, Austrian manufacturers must effectively split their scarce resources between cleaner and conventional products with obvious consequences for scale economies in R&D and production. At the same time, domestic product standards may put foreign firms at a disadvantage as export volumes to Austria may be too small to warrant the development of compliant products. Finally, compliant products may create new chances for domestic firms abroad, either through first-mover advantages because of subsequent environmental regulation in other countries, or because new products are genuinely better (and cheaper) than their conventional rivals.

A common measure of the competitiveness of a sector or industry is the revealed comparative advantage (RCA) index, which is an empirical estimate of a country's comparative advantage in a particular commodity group as revealed by actual trade patterns. The evolution of this index will be used to explore the net impact of Austrian VOC emission standards on the competitiveness of Austrian manufacturers of paints, coatings, printing inks and adhesives. Because it is an index, it is insensitive to inflation, macro-economic imbalances and growth effects, all of which may impact on the value of international trade flows (see Xu 2000). Several measures of RCA have been proposed in the literature, each of which may be distorted by aggregation and policy effects (see Greenaway and Milner 1993, pp. 184-187). However, assuming distortions to be relatively stable over limited periods of time, these well-known problems are of little concern in the present case, as the focus is on changes over time, not absolute levels.

Because we are interested in the net impact of Austrian VOC emission standards on both exports and imports, the following widely used formula (see, for example, Siebert 2000, p. 82) will be used, which expresses RCA as

$$RCA = \ln \left(\frac{X_{ij} / \sum_j X_{ij}}{M_{ij} / \sum_j M_{ij}} \right),$$

where X are exports, M are imports, i is the exporting country, and j is the commodity group (industry). The index takes the natural logarithm of the ratio of country i 's net-exports of commodity j (X_{ij}/M_{ij}) and country i 's total net-exports (of all goods or of all goods of a certain type, $\sum X_{ij}/\sum M_{ij}$). Values greater one reveal a comparative advantage.

In order to ascertain the impact of the Austrian VOC emission standards on the competitiveness of manufacturers of regulated products, the RCA of the Austrian paint, coating, printing ink and adhesive industry will be compared to the RCA of its German and EU counterpart for the period 1990-1999, the most recent year for which data is available. Germany and the EU are selected as yardsticks since they are subject to

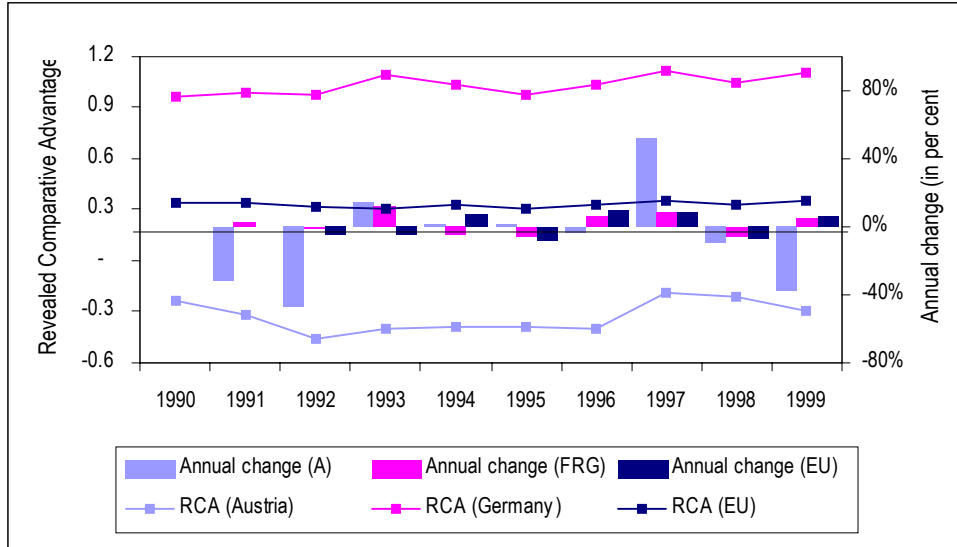
similar macroeconomic conditions but did not adopt comparable regulations during this period. Austria is closely integrated into the German economy (in 1998, 42% of total exports and 36% total imports were traded with Germany), has had a currency peg for about thirty years and tends to track the German economy very closely. Although the paint, coating, printing ink and adhesive industry in the two countries is not fully comparable – Germany is home to some of the world's largest players – in terms of intervening macroeconomic factors Germany is by far the most similar country. As an additional check, the entire EU paint, coating, printing ink and adhesive industry is also considered.

The underlying data series feature a number of structural breaks, including the German reunification and the expansions of the EU in 1995, when Austria, Sweden and Finland joined the EU. With regard to Austria, the removal of trade barriers in the aftermath of joining the EU significantly boosted foreign trade, both with fellow member states and third countries due to the EU's lower external tariffs (Breuss 2000). Moreover, Austria's accession to the EU also had important consequences for the nature of Austrian foreign trade data. Prior to 1995, all foreign trade data was recorded at the border. Since Austria's accession to the EU, this practice has only been maintained for trade with third countries (Extrastat), while trade with fellow EU member states (Intrastat) has been measured by a selective mail survey. However, unless any of these events has had an uneven impact on exports or net-exports of the paint, coating, printing ink and adhesive industry in any of the regions considered, the effect will vanish as the index is based on ratios, not absolute values.

Figure 1 shows the evolution of comparative advantage as 'revealed' by the RCA index. The line charts stand for the respective RCA values, while the bar charts display the annual rate of change of each data series. The German series increases slightly while the EU series remains almost flat during the observation period. With regard to the critical period in the second half of the 1990s, both series show a slight decline in 1995, followed by a rise in 1996 and 1997, a drop in 1998 and an increase in 1999. In contrast, the Austrian series exhibits a strong slump in the early 1990s, followed by a prolonged decline until 1995, a brief drop in 1996, a strong jump in 1997 and a decline in the subsequent two years.

As with many comparable studies, it is difficult to make out an unequivocal effect, for the Austrian series neither displays a clear negative trend consistent with the standard view on the impact of environmental regulation on competitiveness, nor the unambiguously positive relationship posited by proponents of the 'Porter Hypothesis'. Since the implementation of the standards in 1996, the Austrian RCA in paints, coatings, printing inks and adhesives has declined in three out of the four years for which data is available. While this is also true of the yardstick series in 1998, the deterioration in 1996 and especially 1999 is confined to the Austrian series. On the other hand, the general downward trend is interrupted by a strong jump in the Austrian series in 1997, which is mainly driven by a 20 per cent increase in exports of the regulated commodity groups, at a time when any negative impact of the environmental regulations should have been felt strongest. Although the two yardstick series also exhibit a rise in 1997, it is moderate compared to the Austrian series.

Figure 1: Revealed comparative advantage, SITC 533x, 5922x



If it was not for the sharp decline in 1999, one would thus conclude that the strictest environmental regulations of their kind have certainly not harmed the competitiveness of Austrian manufacturers of paints, coatings, printing inks and adhesives. Whether the deterioration in 1999 is a singular event or the beginning of a prolonged downward trend due to the process standards slowly starting to bite cannot be ascertained in the absence of more recent data.

Survey evidence, however, points to the former interpretation. In the survey, Austrian paint, coating, printing ink and adhesive manufacturers were asked whether their competitiveness had been affected by the VOC emission standards, a) in their Austrian home market, b) in the EU and EFTA, and c) in other countries, that is mainly Central and Eastern Europe. Table 2 shows that the large majority of firms (between two thirds and three quarters) found themselves unaffected in each region. In some cases (roughly 10-15%), competitiveness deteriorated, while in a roughly equal number of cases it actually improved. This is particularly striking in the case of the EU/EFTA area, where the number of firms that report an improved competitiveness outweighs the number of firms whose competitiveness was negatively affected by a margin of two to one.

It is interesting to note that almost 20 per cent of the small firms saw their competitiveness deteriorate and not a single one experienced an improvement, while just one large firm suffered a decline and this only in Austria, and up to 30 per cent report an improved competitiveness. However, only one firm suffered in all three regions. One firm reports to have benefited in each region, while another firm benefited both in Austria and its main export markets. The remaining firms discriminate quite carefully, which supports the reliability of the results. For example, one firm declares to have suffered in Austria but benefited in one export region. Other companies were unaffected in some regions but suffered or benefited elsewhere.

Table 2: Reported impact of VOC emission standards on competitiveness – Austrian paint, coating, printing ink and adhesive manufacturers (1999)

Region	Austria	EU/EFTA	Other countries
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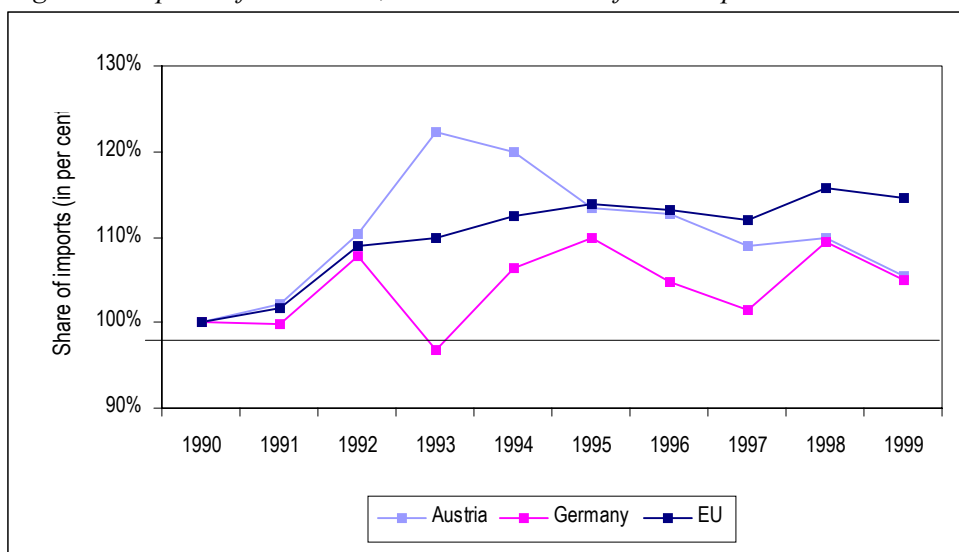
Frequency	no.	%	no.	%	no.	%
Unaffected	21	75.0	12	66.7	15	78.9
Deteriorated	4	14.3	2	11.1	2	10.5
Improved	3	10.7	4	22.2	2	10.5

n=28

The survey results are interesting in that they highlight that even within a fairly homogeneous industry, firms may be unevenly affected by an external shock. In other words, even if an environmental policy intervention threatens to impose costs on the majority of targeted firms, there may be some firms who actually benefit from a restrictive regulation, which may have important consequences for the policy design process.

Which factors account for this result? Regarding Austria, a possible factor may be reduced import competition, which also affects the above measure of RCA which is based on net-exports. In order to check whether Austrian VOC emission standards indeed reduced import competition, Figure 2 maps the evolution of imports of paints, coatings, printing inks and adhesives (SITC categories 533x, 5922x) as a share of total imports in Austria, Germany and the EU. In other words, the figure displays how imports of SITC categories 533x, 5922x evolved relative to total imports in each country/region. To ensure comparability, the data has been normalised with 1990 as base year.

Figure 2: Imports of SITC 533x, 5922x as a share of total imports



For Austria, the line chart shows an inverted U-shaped pattern. Until 1993, the share of imports of paints, coatings, printing inks and adhesives increased relative to overall imports. As of that year, it declined again, except for a small rebound in 1998. In contrast, the German series fluctuates quite substantially around a more or less stable mean and the EU series displays a slight upward trend during most of the observation period. Although the inflection in the Austrian series occurs prior to the implementation of the VOC emission standards in 1996, the prolonged decline after 1996 provides some tentative evidence that import growth in paints, coatings, printing inks and adhesives has indeed been held back by the Austrian VOC emission standards. This result is not unexpected in light of the existing literature, yet interest-

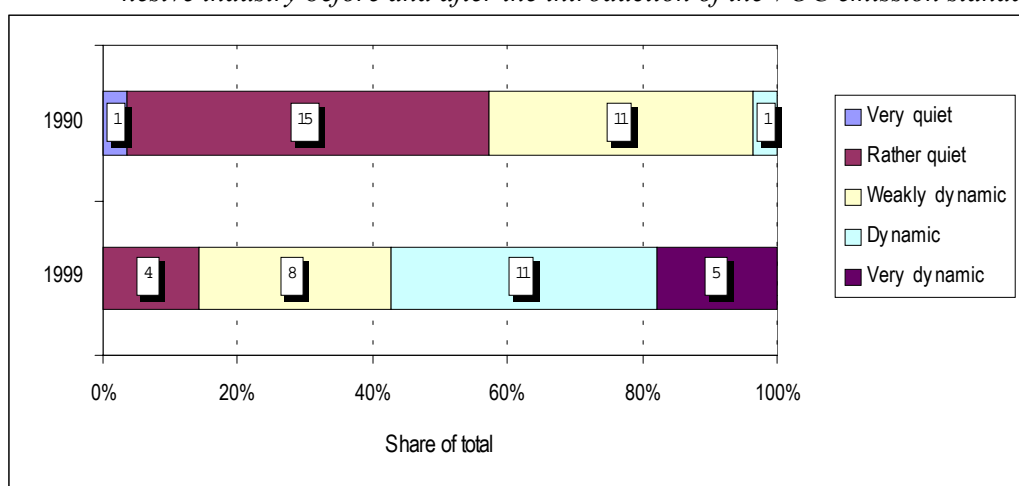
ing in this specific case, since the industry has generally recorded a substantial increase in competition since joining the EU in 1995.

4. Innovation

Another factor that may account for the rather positive development of the competitiveness of the Austrian paint, coating, printing ink and adhesive industry may be innovation offsets, as predicted by the 'Porter Hypothesis'. Survey evidence indeed shows that Austrian VOC emission standards triggered considerable adaptations in the product range of Austrian manufacturers of paints, coatings, printing inks and adhesives. Almost one in three firms reports substantial changes and 60 per cent of the firms had to change a sizeable part of their product range. Less than ten per cent of the surveyed firms report only minor changes.

Naturally, the mere fact that firms had to adapt their product range is no evidence for innovation offsets, as firms may simply have replaced conventional solvent-borne products with existing cleaner systems, which presumably were more costly and/or technologically inferior; otherwise they would have been introduced without regulatory pressure. In order to find out whether this was indeed true or whether compliance had stimulated innovation, Austrian manufacturers of paints, coatings, printing inks and adhesives were asked in the survey about their perception of how dynamic the technological environment in the industry had been in 1990, that is before the first VOC emission standard had been adopted and the time the survey was conducted in 1999. As can be seen in Figure 3, there is a clear shift. While the majority of firms perceived their technological environment as 'rather quiet' or 'weakly dynamic' in 1990 and not a single firm appraised it as 'very dynamic', in 1999 the most frequent responses were 'dynamic' and 'weakly dynamic'. Five firms even rated the technological environment as 'very dynamic'.

Figure 3: Technological environment in the Austrian paint, coating, printing ink and adhesive industry before and after the introduction of the VOC emission standards



Note: The numbers in the boxes represent absolute frequencies

n=28

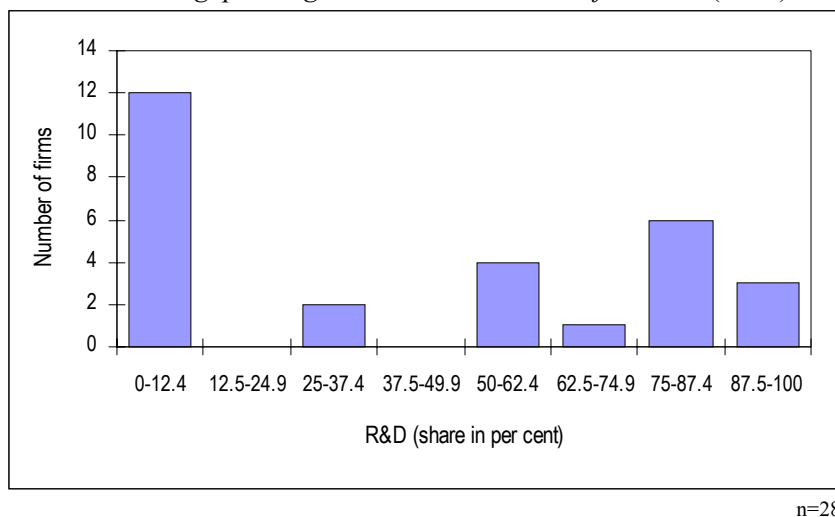
Interestingly, the variation in how firms describe their technological environment increased substantially between 1990 and 1999. In 1990, responses are quite homogeneous across the size classes and product

groups delineated above. In 1999, the differences between the different categories become much more pronounced. In absolute terms, small firms perceive their technological environment as most dynamic, albeit subject to considerable variation. Medium-sized and large firms also report a considerable increase in technological dynamism, yet not as much as their smaller rivals. With regard to technology, the increase in technological dynamism is strongest in the OEM segment, followed by architectural coatings and adhesives. Printing ink manufacturers report almost no change.

However, even the fact that Austrian VOC emission standards appear to have accelerated the rate of product innovation in the Austrian paint, coating, printing ink and adhesive industry is insufficient evidence for innovation offsets, as it does not convey any information on how creating innovations affected firms' other activities and whether firms were able to reap benefits predicted by proponents of the 'Porter Hypothesis'.

In order to find out whether and if so how compliance affected firms other activities, Austrian manufacturers of paints, coatings, printing inks and adhesives were asked which share of their R&D budget they had devoted to developing compliant products. Figure 4 displays a histogram of the reported shares. It reveals a multi-modal distribution. Twelve out of the 28 surveyed firms spent less than 12.5 per cent of their R&D budget on compliance innovations, of which six firms reported a share of zero. At the other extreme, 14 firms devoted more than half of their R&D budget to developing compliant products. Shares are distributed very unevenly, with multiple peaks in the range of 5, 30, 60 and 75 per cent, and considerable ranges remaining entirely blank.

Figure 4: Compliance R&D as a fraction of total R&D – Austrian paint, coating, printing ink and adhesive manufacturers (1999)



Which factors account for these startling variations? Firm size does not, as the breakdown into size categories according to Recommendation 96/280/EC reveals no sizeable differences (the respective means are 37, 46 and 38%), yet huge standard deviations indicating the presence of other factors. Table 3 shows these to be technology and organisational status.

The column totals reveal considerable differences in how much manufacturers of the different product groups spent on developing compliant products. On average, manufacturers of OEM spent 57 per cent of

their total R&D budget on compliance R&D, while manufacturers of architectural coatings spent 47 per cent. In contrast, the respective share for manufacturers of printing inks and adhesives is only eight and three per cent. Since there is little variation between the different product groups in how much firms' product range was affected by the Austrian VOC emission standards, these results point to a qualitative difference in firms' compliance behaviour. While compliance by printing ink and adhesive manufacturers appears to have required little new technology, manufacturers of OEM and architectural coatings had to undertake greater development efforts.

Table 3: Compliance R&D as a fraction of total R&D – Austrian paint, coating, printing ink and adhesive manufacturers (1999)

Product group	OEM			Architectural Coatings			Printing inks			Adhesives			Total		
	Mean	(SD)	no.	Mean	(SD)	no.	Mean	(SD)	no.	Mean	(SD)	no.	Mean	(SD)	no.
<i>Corporate Status</i>															
Single Establishment	80.0	(10.0)	3	75.0	(0.0)	2	0.0	(0.0)	1	–	–	–	65.0	(32.6)	6
Multi-Establishment	50.0	(32.3)	10	37.5	(41.9)	6	6.6	(9.8)	3	3.3	(5.8)	3	34.8	(35.0)	22
<i>Head Office</i>	55.0	(34.0)	4	42.0	(32.0)	3	–	–	–	–	–	–	49.3	(31.3)	7
<i>Regional/Divisional Head Office</i>	34.0	(26.0)	3	0.0	(0.0)	2	5.0	(0.0)	1	0.0	(0.0)	1	15.4	(23.3)	7
<i>Branch Plant</i>	59.0	(41.0)	3	100.0	(0.0)	1	13.0	(18.0)	2	5.0	(7.0)	2	39.0	(42.1)	8
Total	56.9	(31.2)	13	46.9	(39.5)	8	7.5	(11.9)	4	3.3	(5.8)	3	41.3	(36.2)	28

n=28

Moreover, organisational factors have a clear impact on the relative importance of compliance R&D vis-à-vis other R&D. As the row totals show, there are great differences between the different categories. Up to a point, these are caused by the uneven distribution of technological sub-segments, as shown by the intersecting cells. However, comparing mean spending by single and multi-establishment firms shows that the former spent a higher share on compliance R&D. Among multi-establishment firms, spending on compliance R&D was substantially lower in the case of regional or divisional head offices, which is probably due to the internal organisation of R&D in these firms. Another factor that may also matter is focus as firms with only one establishment and branch plants may be more focused than larger corporate units. Accordingly, comparable amounts of R&D spending may show up as differential shares of the respective total R&D budgets, which in turn suggests that although the present measure does provide important information on how the firms were affected by the regulation, it does not reveal whether or to what extent spending on environmental R&D displaced other R&D.

In order to obtain information on this point, firms were asked about the impact of compliance innovations on other R&D projects. More specifically, firms were asked whether other R&D projects had been cancelled, postponed or been entirely unaffected by R&D devoted to the development of compliant products. Table 4 summarises the responses to this question. R&D spending on compliance innovations had the biggest impact on manufacturers of OEM. Almost one in three firms had to cancel and more than half had to postpone other R&D projects. Only two out of the surveyed 13 firms were unaffected. Manufacturers of architectural coatings were slightly less affected. One in four firms had to abandon and another fourth

had to postpone other R&D projects. Printing ink and adhesive manufacturers report a much smaller impact. Only one firm each had to postpone some R&D projects.

Table 4: Impact of compliance R&D on other R&D – Austrian paint, coating, printing ink and adhesive manufacturers (1999)

Other R&D projects were ... Frequency	Cancelled		Postponed		Unaffected		Total
	no.	%	no.	%	no.	%	no.
<i>Product group</i>							
OEM	4	30.8	7	53.8	2	15.4	13
Architectural coatings	2	25.0	2	25.0	4	50.0	8
Printing inks	0	0.0	1	25.0	3	75.0	4
Adhesives	0	0.0	1	33.3	2	66.7	3
All firms	6	21.4	11	39.3	11	39.3	28

Note: OEM stands for Original Equipment Manufacture, which are industrial coatings. n=28

In light of the previous evidence on compliance R&D, these results are entirely expected. Having spent around half of their total R&D budget on compliance efforts, it would be very surprising if other R&D projects of OEM and architectural coating manufacturers had not been affected. Similarly, anything but a limited impact in the remaining segments would have been a surprise. This is also reflected in a Spearman's rho coefficient¹ of 0.55 between the two variables, which indicates a medium strong correlation.

The data confirm the very simple intuition that given limited R&D budgets, firms may no longer have the means to pursue other activities if an environmental regulation requires a big compliance effort. It must be emphasised, however, that this is no valid measure of crowding out. Crowding out only occurs if displaced activities would have been more productive, however defined. Determining the presence or absence of crowding out requires an appropriate productivity measure and counterfactual, both of which are difficult to come by. Instead, Austrian manufacturers of paints, coatings, printing inks and adhesives were asked in the survey whether the VOC emission standards had prevented them from developing or utilising other promising products or technologies. Table 5 reveals considerable variation between the different product groups and an interesting pattern across the different size classes.

Table 5: Displacement of promising products or technologies through compliance R&D – Austrian paint, coating, printing ink and adhesive manufacturers (1999)

Frequency	OEM			no.	Architectural Coatings			no.	Printing inks		no.	Adhesives		no.
	Many	Some	None		Many	None	no.		Many	None		Some	None	
<i>Firm size</i>														
Small	50.0%	0.0%	50.0%	2	100.0%	0.0%	1	100.0%	0.0%	1	0.0%	100.0%	1	
Medium	40.0%	40.0%	20.0%	5	0.0%	100.0%	4	100.0%	0.0%	1	0.0%	0.0%	0	

¹ A nonparametric version of the Pearson correlation coefficient based on the ranks of the data rather than actual values. It is defined by
$$r_s = \frac{\sum_{i=1}^n (R_i - \bar{R})(S_i - \bar{S})}{\sqrt{\sum_{i=1}^n (R_i - \bar{R})^2 \sum_{i=1}^n (S_i - \bar{S})^2}}$$
, where d stands for the rank distance between any two observations and n stands for the number of observations. Possible values range from +1 to -1, indicating perfect correlation.

Large	33.3%	16.7%	50.0%	6	0.0%	100.0%	1	0.0%	100.0%	1	50.0%	50.0%	2
All firms	38.5%	23.1%	38.5%	13	16.7%	83.3%	6	66.7%	33.3%	3	33.3%	66.7%	3

Note: OEM stands for Original Equipment Manufacture, which are industrial coatings.

n=25

Strong displacement is reported by manufacturers of OEM and printing inks, while the respective share is much smaller among manufacturers of architectural coatings and adhesives. These variations are puzzling. From the previous evidence one would expect a fairly high impact on manufacturers of OEM and architectural coatings and rather little impact in the remaining two product groups. Lack of additional evidence prevents an explanation of this unexpected result.

Regarding firm size, the number of firms reporting a displacement of promising products or technologies declines with rising firm size, although the pattern is not totally uniform across the different product groups. However, deviations from the general pattern may be due to the small number of observations where single cases can make a big absolute difference. Two arguments may explain the observed relative decline. *First*, the absolute number of displaced products or technologies may be fairly uniform across the different size classes. However, because of their smaller scope of activities, smaller firms perceive this number as relatively larger. *Second*, the responses may indeed reflect absolute numbers. In this case, displacement is an indicator of technological backwardness as it can only occur if firms fail to foresee future changes and duly adapt their R&D and production plans. Background information from the interviews makes the latter interpretation more likely.

The evidence presented so far does not indicate the presence of innovation offsets. However, environmental regulation may not only cut off promising avenues of technological advance; it may also refocus firms' R&D efforts. If this prompts search in hitherto unexplored areas, it may very well be that firms hit upon some unexpectedly profitable results. With regard to environmental regulation, Ashford *et al.* (1979, p. 179) have coined the term 'ancillary innovation' to describe such unexpected or serendipitous results of regulatory compliance efforts. Moreover, search may not only lead to the development of new artefacts, it may also create new competencies and let firms acquire new technologies that can subsequently be leveraged in other areas.

The best way to collect empirical evidence on these issues are detailed case studies of innovation processes. Since this was not feasible in the present case, Austrian manufacturers of paints, coatings, printing inks and adhesives were instead asked, a) whether compliance efforts had given them fresh ideas for new products (as a rough proxy for the frequency of unexpected discoveries), and b) whether compliance had led to the acquisition of new competencies and technologies, which they would not have acquired in the absence of an environmental regulation.

Table 6 displays a breakdown of the responses to the former question. The bottom line shows that more than half of the 26 respondent firms state that compliance efforts had indeed given them fresh ideas for new products. Interestingly, there are considerable variations between the different technological sub-segments, ranging from a strong majority of OEM and even all adhesive manufacturers to about one in three manufacturers of architectural coatings and printing inks. In contrast, variations between the different size classes are much smaller and mainly due to the dominance of architectural coating manufacturers in the medium-sized category. In other words, the share of firms reporting unexpected insights from com-

pliance R&D is fairly uniform across the different size classes but varies widely between the different product groups.

Table 6: Share of firms obtaining new ideas from compliance R&D – Austrian paint, coating, printing ink and adhesive manufacturers (1999)

	Yes	no.
<i>Product group</i>		
OEM	69.2%	13
Architectural coatings	37.5%	8
Printing inks	33.3%	3
Adhesives	100.0%	2
<i>Firm Size</i>		
Small	60.0%	5
Medium	50.0%	12
Large	66.7%	9
All firms	57.7%	26

Note: OEM stands for Original Equipment Manufacture, which are industrial coatings. n=26

The observed pattern cannot be explained with the available data. One might conjecture that the probability of hitting upon a chance discovery rises with the amount of resources devoted to searching. However, there is absolutely no correlation between the share of firms reporting unexpected insights and the share of total R&D allocated to compliance R&D.

To explore a further dimension of possible serendipitous effects of environmental regulation, firms were asked whether they had obtained knowledge or technologies that they would not have acquired in the absence of the environmental regulations and which could be leveraged in other areas. Table 7 displays a summary of the responses to this question. As the last line shows, more than half of the firms state that compliance efforts had allowed them to acquire at least some new competencies and technologies which subsequently turned out to be useful in other areas. In terms of the different technologies, the results for OEM and architectural coatings resemble the results shown in Table 6. The respective percentages for printing inks and adhesives, however, are almost exactly reversed. In the case of adhesives, this is not unexpected, since previous data had indicated that compliance in this segment had mainly involved the diffusion of existing products. The high share of printing ink manufacturers acquiring competencies and technologies poses a puzzle that cannot be elucidated with the available data.

Table 7: Impact of compliance R&D on knowledge base – Austrian paint, coating, printing ink and adhesive manufacturers (1999)

Compliance R&D helped us acquire new ...	Knowledge/Competencies				Technologies			
	Many	Some	None	no.	Many	Some	None	no.
<i>Product group</i>								
OEM	53.8%	7.7%	38.5%	13	46.2%	15.4%	38.5%	13
Architectural coatings	28.6%	28.6%	42.9%	7	28.6%	28.6%	42.9%	7
Printing inks	66.7%	0.0%	33.3%	3	66.7%	0.0%	33.3%	3

Adhesives	33.3%	0.0%	66.7%	3	33.3%	0.0%	66.7%	3
<i>Firm size</i>								
Small	80.0%	20.0%	0.0%	5	60.0%	20.0%	20.0%	5
Medium	36.4%	9.1%	54.5%	11	36.4%	18.2%	45.5%	11
Large	40.0%	10.0%	50.0%	10	40.0%	10.0%	50.0%	10
All firms	46.2%	11.5%	42.3%	26	42.3%	15.4%	42.3%	26

Note: OEM stands for Original Equipment Manufacture, which are industrial coatings. n=26

In contrast to Table 6, there are sizeable differences between small and larger firms in terms of the share of firms reporting the acquisition of some or even many new competencies or technologies. While the large majority of small firms responds in the affirmative, the respective share of medium-sized and large firms is at most 50 per cent. The most plausible explanation for these differences is once more technological backwardness, as compliance may have forced technologically backward firms to adopt cutting-edge technology that could later be leveraged in other areas.

5. Summary and conclusions

The objective of this paper has been to present some micro-evidence on the techno-economic consequences of Austrian VOC emission standards on Austrian paint, coating, printing ink and adhesive manufacturers that is relevant to the discussion on the 'Porter Hypothesis'. An analysis of the evolution of Austria's revealed comparative advantage in the respective product groups shows that the strictest standards of their kind had no clear, that is neither unequivocally negative nor positive, impact on the competitiveness of manufacturers of regulated products. A similar result also emerges from a survey of Austrian manufacturers of paints, coatings, printing inks and adhesives in which the overwhelming majority of firms declares that its competitiveness has not been affected by the standards. However, firm size seems to matter, as the share of firms stating to have suffered declines with firm size, while the opposite is true of firms who were able to benefit.

There is tentative evidence that the standards have had a dampening effect on import competition, which rose in the aftermath of Austria's accession to the EU in 1995. This implies that competition from abroad would have been considerably stronger in the absence of the environmental regulations. Accordingly, it may not be in the best interest of the Austrian paints, coatings, printing inks and adhesive industry to relax the stricter Austrian rules to the less restrictive limits mandated at the EU level. Rather than leveling the playing field for Austrian firms abroad, as claimed by industry representatives, it might actually further increase import competition in Austria.

Besides reduced import competition, the absence of a negative impact on the competitiveness of regulated firms may also be due to 'innovation offsets' as predicted by the 'Porter Hypothesis'. Survey evidence indeed reveals considerable changes in firms' product range, which also caused the technological environment in the industry to become more dynamic after the implementation of the standards. In other words, the Austrian VOC emission standards appear to have accelerated the rate of product innovation in a formerly rather tranquil industry, a result that has also emerged from comparable industry studies (see Ashford 1993).

R&D spending to develop compliant products is found to be very unevenly distributed. While some firms spent virtually nothing, other firms devoted almost their entire R&D budget to developing compliant products. Differences are mainly due to differences in firms' technological specialisation and to a lesser extent to organisational factors. There is evidence that compliance efforts displaced or postponed existing R&D projects, again with substantial variations by technology.

However, survey evidence also shows that compliance efforts yielded new ideas and allowed some firms to acquire new competencies and technologies which they would not have acquired in the absence of the regulation. Yet rather than indicating the presence of clear benefits of compliance, the latter finding is more likely a result of technologically backward (small) firms catching up.

These results hold a number of lessons for future work. *First*, environmental regulations may affect both exports and imports of regulated goods, a point that should be taken into account when using some measure of net-exports as indicator of competitiveness. *Second*, technological specialisation may have a tremendous influence on the actual impact of environmental regulation. As the survey has shown, even at fairly low levels of aggregation (i.e. SITC or NACE 4-digit and below), firms may be active in entirely different markets. *Third*, even within a fairly homogeneous industry, size effects and organisational factors may be a source of considerable heterogeneity.

Regarding future research, two points emerging from this paper merit further attention. *First*, the analysis points to a systematic difference between smaller and larger firms in their ability to respond to and take advantage of an external shock caused by an environmental regulation. Is this a general result or merely due to case-specific factors? *Second*, in the present case, compliance efforts appear to have redirected firms' search efforts for new technology, which appears to have yielded unexpected new ideas, knowledge and competencies. Future work should examine this process more systematically, especially with a view to clarifying whether these unexpected insights yield knowledge that helps firms to become more competitive or whether it is merely the result of technologically backward firms approaching the current technological possibility frontier.

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