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Direct regulation is an efficient approach to industrial environmental improvement: empirical evidence and perceptions from chemical manufacturers in Ireland and Italy

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1. INTRODUCTION

1.1. Different approaches to environmental regulation

Industrial production is a major source of global pollution, and it is widely recognised that regulation is required to reduce this pollution for the benefit of society. However, there is considerable debate about the most effective approach to environmental regulation, which can be broadly classified according to three main categories of regulatory instrument. Direct regulation comprises standards or commands and prohibitions in relation to inputs, processes and outputs. Economic instruments include duties (e.g. taxes, charges), tradable emission permits (e.g. EU Emissions Trading Scheme for CO_2) and environmental liability (Kuik and Osterhuis, 2008). Finally, soft instruments include voluntary industry agreements, communication and information measures, environmental certification schemes (e.g. ISO 14001, EMAS, EU Ecolabel), and green procurement. Economic theory states that "efficient" regulation necessarily achieves pollution reduction at least cost, but it can be challenging to even quantify the starting point for any assessment of efficiency: regulatory effectiveness.

A considerable body of evidence attests to the general effectiveness of direct environmental regulation. Integrated Pollution Prevention Control regulation (Directive 96/61/EC) is the most widespread and comprehensive example of direct regulation for industry. Numerous studies have found that IPPC licensing has had a significantly positive influence on environmental performance (Silvo et al., 2002; Environment Agency, 2004; Honkasalo et al., 2005; EEA, 2008; Mirasgedis et al., 2008; Styles et al., 2009b). A few studies have demonstrated that the implementation of Best Available Techniques (BAT: http://eippcb.jrc.ec.europa.eu/), as required by IPPC regulation, results in a significant net social benefit with respect to the control of specific pollutants (Clinch and Kerins, 2002; AEA, 2007). However, other studies have questioned the comparative efficiency of IPPC regulation, and its impact on competitiveness (Hitchens et al., 2001; Ederington and Minier, 2003; López-Gamero et al., 2009). Hemmelskamp (1999) notes that direct regulation fails to incentivize continuous pollution reduction below mandated standards for individual operators. There are few ex post cost analyses of IPPC BAT implementation owing to the reluctance of operators to provide cost data (IVM, 2006).

Compared with direct regulation, economic instruments offer a number of potential advantages, including a wider sphere of influence (that includes small enterprises), potentially low implementation costs (e.g. fuel taxes), and provision of an incentive for continuous improvement (Hemmelskamp, 1999). Well-documented theoretical efficiency advantages of market-based instruments, compared with command-and-control instruments, include the least-cost distribution of pollution reduction across installations, and the stimulation of innovation (Jaffe at al., 2002; Requate and Unold, 2003). Experience with cap-and-trade of SOx in the US has partially borne these predictions out (Ellerman, 2003; Burtraw et al., 2005), although California's experience with the RECLAIM NOx emission trading scheme highlights the need for intensive management and careful allowance allocation (SCAQMDS, 2007). Economic instruments are applicable to a limited range of readily quantifiable parameters (e.g. resource use, CO_2 and SO_x emissions). It has also been noted that allocative efficiency advantages of market instruments may be confined in practice owing to sectors and companies being exempted or compensated as a result of competitiveness concerns or targeted lobbying (Ellerman, 2003; Palm and Larsson, 2007).

Soft instruments, in particular accredited Environmental Management Systems (EMS), are often designed to encourage adoption through economic incentives such as the development of intangible assets (e.g. staff training on efficient management of processes) and marketing opportunities associated with certification or product-labelling. Accordingly, studies have assessed the influence of soft instruments on both the environmental and economic performance of firms. Whilst many studies have attributed positive environmental performance effects to EMS adoption (King et al., 2005; Newbold, 2006; Radonjic & Tomic, 2007; Arimura et al., 2008), others have concluded that EMS implementation has no significant influence (Dahlstrom et.al 2003; Barla, 2007). A recent study of 100 firms concluded that well-designed EMS can improve environmental performance through technical and organizational innovations, but there was little evidence of any positive effect on market performance, resource productivity or intangible assets (Iraldo et al., 2009). Detecting and attributing longer-term economic impacts is difficult. It has been suggested that voluntary regulation is more important where direct regulation is weak (Radonjič and Tominc, 2007), although multinational companies with strong corporate social responsibility (CSR) may be less likely to locate in countries with weak direct regulation. Ultimately, it is not just the approach, but the specific design (e.g. standards versus technologies), inclusion of dynamic aspects, coverage (e.g. exceptions, inclusion of old plants, etc), and implementation (flexibility, enforcement, etc) that influence the efficiency of regulation (Kuntze, 1999).

1.2. Assessing the effect of environmental regulation on competitiveness through paradigms

Broadly speaking, the debate about the effect of environmental regulation on production efficiency and competitiveness has been shaped by two competing paradigms. From a traditional economics perspective, environmental regulation exists soley to correct for (internalise) negative externalities, and necessarily has a negative impact on the production efficiency and competitiveness of industry (Gollop and Robert, 1983; Gray and Shadbegian, 1998; Cole and Elliot, 2003; Ederington and Minier, 2003). For instance Gray and Shadbegian (2003) found that more stringent air and water regulations have a significant impact on paper mills' technological choice in the U.S. Their results suggest that regulation diverts investment from productivity to abatement, consistent with the standard paradigm. Furthermore, environmental regulation can have a deterrent effect on foreign direct investment: using a simultaneous model to study the relationship between FDI and final industrial SO_2 emissions in China, He (2006) found evidences for the 'pollution haven' hypothesis.

Meanwhile, a "Revisionist" view suggests that environmental regulation can stimulate competitive advantage through efficiency improvements, innovation, and new "green" market opportunities (Gabel and Sinclair-Desgagné, 1993; Porter and van der Linde, 1995a; Sinclair-Desgagné, 1999). The revisionist view assumes that firms do not necessarily implement the most efficient technology options owing to innovation uncertainty, bounded rationality[1] (Berkhout et al., 2001), and effort discretion (Altman, 2001). Altman argues that, by providing additional incentive to address existing inefficiencies (to offset pollution reduction costs), environmental regulation can achieve social benefit at little or no private cost. In a review of ex-post costs of environmental regulations, IVM (2006) found real-world examples of this for direct regulation (Nitrates Directive and control of ozone-depleting-substances). Wagner (2003) suggests that flexible (voluntary and market-based) regulations are more likely than command-and-control regulations to stimulate the kind of innovation central to the revisionist view proposed by Porter and van der Linde (1995a).

A somewhat intermediate paradigm is the Resource-Based view of firm competitiveness, in which the long-term competitiveness of firms is deemed dependent on their ability to optimise use of available resources (Fouts and Russo, 1997). Crucially, the Resource-Based view expands on the traditional definition of resources to recognise intangible assets such as *know how* (Teece, 1980), *corporate culture* (Barney, 1986), and *reputation* (Hall, 1992). Within this context, well-designed environmental regulation is seen as an incentive and opportunity to achieve private as well as social benefits (Sinclair-Desgagné, 1999). Similarly, expanding the definition of production efficiency to include pollution as an input cost, can redefine regulation as positive driver of production efficiency (Telle and Larsson, 2007).

The aforementioned paradigms have polarised the debate on environmental regulation somewhat, further complicating the already complex and fragmented assessment of regulatory efficiency. Quantitative studies are necessarily restricted in scope. In particular, the econometric models that play such an important role in assessing regulatory efficiency, and comparing different approaches, are usually confined to single parameters (e.g. CO_2 or SOx emissions). In this sense, they diverge from the practice of industry regulation (local authority and IPPC licensing), where the need for an integrated approach to pollution control has long been recognised. In this sense, industry perceptions remain an important, though not unbiased, source of information on the real-world effects of environmental regulation. IVM (2006) note a number of instances where industries substantially over-estimated compliance costs, possibly in an attempt to avert more stringent regulations.

1.3.Study aims

A recent study of Irish IPPC-licensed pharmaceutical manufacturers used an integrated (multi-pollutant), quantitative approach to calculate the pollution avoidance, relative to 1995 eco-efficiency, that was specifically attributable to IPPC and preceding IPC regulation (Styles et al. 2009b). In this paper, we use questionnaire responses regarding the cost and processes influences of IPPC regulation to assess the efficiency of this pollution avoidance. Meanwhile, a recent study of chemical-for-building-products manufacturers in the Padania region of Northern Italy ("Italian building-chemicals sector") has collated data on industry perceptions regarding the influence of different types of environmental regulation on operating practices. In this paper, we draw on the complementary quantitative and qualitative findings of these

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[1] Referred to as paradigm blindness ("what we do is best") in the IPPC reference document on energy efficiency (EC, 2009).

separate studies to assess the effectiveness and efficiency of direct regulation, and posit some conclusions. The main objectives of this paper are to:

1. Report industry perceptions on the effectiveness of direct regulation compared with other approaches
2. Assess the efficiency of direct regulation in terms of public benefit and influence on innovation capabilities

2. METHODS

2.1. Irish and Italian case study sectors

The pharma sector is one of Ireland's main export sectors, dominating the chemical sector that contributes €14 billion per year gross value added to the Irish economy (CSO, 2008). This sector is composed of 36 large installations regulated under IPPC licensing. Multi-national parent companies are image conscious, and operators are generally compliant with IPPC licences (EPA, 2006). Operators engage with voluntary regulation through high levels of formal EMS accreditation and environmental performance reporting in Responsible Care reports (IBEC, 2007). This sector has been subject to direct regulation since the early 1980s, first under Single Media Licensing of air and water emissions, then under Integrated Pollution Control licensing (from 1994 onwards), and now under EU IPPC licensing. It offers valuable insight into the effectiveness of direct and voluntary regulation.

The chemical sector is an important and expanding economic sector in Italy, comprising 23,034 local units employing about 400,000 employees. Sixty-three percent of chemical sector enterprises, and 67% of employees, are based in the Padania region of northern Italy. The segment[2] of chemical for building products represents just a small part of whole sector, comprising approximately 110 companies and employing approximately 12,000 employees in the Padania region (ISTAT, 2005). The building-chemical sub-sector produces intermediate goods such as dyes, paints, glues and insulating materials for the building & construction sector, and is subject to numerous EU environmental regulations that define limits for air and water emissions from process plants (e.g. for heavy metals and chlorinated organics). Within the sector, titanium dioxide producers and choralkali plants are subject to particular regulatory scrutiny. The IPPC Directive has a broad impact on the Irish pharma and Italian building-chemicals industries, requiring authorisation and monitoring of large-scale chemical processes, and compliance with minimum performance standards according to BAT. In Ireland, all IPPC-licensed installations are mandated to implement Environmental Management Programmes (EMP), similar to voluntary EMSs, and report mass annual emissions of major pollutants.

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[2] The sector *chemical for building* is not well defined by the Statistical classification of economic activities in the European Community. The NACE codes that potentially refer to this sector are 20.12.0 Manufacture of dyes and pigments, 20.30.0 Manufacture of paints, varnishes and similar coatings, printing ink and mastics, 20.52.0 Manufacture of glues 22.23.0 Manufacture of builders' ware of plastic, 22.19.0 Manufacture of other rubber products, 22.21.0 Manufacture of plastic plates, sheets, tubes and profiles, 22.29.0 Manufacture of other plastic products

2.2. Irish pharma manufacturers: survey data

Two questionnaires were sent to all 36 of Ireland's pharma manufacturers, addressed specifically to environmental managers where these contact details were available (most instances). In November 2007 Survey 1 (Appendix A) was sent. This questionnaire asked detailed and installation-specific questions about various aspects of IPPC licensing, and included reference to production effects and compliance costs. Following a low response rate to Survey 1 (eight respondents), a second shorter and anonymous questionnaire (Survey 2: Appendix B) was sent in March 2009. This followed from an introduction to the survey, and an overview of study data and objectives, presented to environmental managers at a Pharmachemical Ireland meeting. Twenty responses were received to Survey 2, and quantitative data from it underpin pollution avoidance calculated in Styles et al. (2009b). Integrated licensing was ranked as the most important driver of emissions reductions, followed by corporate social and environmental policy, improved technology and technical knowledge, cost-saving efficiencies, voluntary guidelines for the sector, and EMS accreditation. In this paper, we interpret data provided from both questionnaires.

Previous work collated data for twenty of the most environmentally significant emissions to air and water from Ireland’s pharma sector, and aggregated them based on environmental damage potential[3] so that they could be interpreted as a single index of pollution (Styles et al., 2009a). For the study reported here, we calculated pollution avoidance for 27 core Pharma installations that have been in continuous operation since 1995, and for which compliance costs over this period could be estimated (Fig. 2). The methodology is described in detail in Styles et al. (2009b), where it was applied to the entire sector (36 installations in 2007: Fig. 3)[4]. Crucially, the context of the question in Survey 2 (see Appendix B) used to estimate the specific contribution of IPPC regulation towards quantified pollution avoidance, enabled the additionality of IPPC regulation to be clearly quantified relative to the influence of voluntary regulation (included in "business-as-usual pollution": Fig. 2).

Low and high external cost estimates for the various emissions considered in the pollution index were taken from the literature, primarily from the IPPC BAT assessment reference document (EC, 2006) - these values reflect only crop damage and human health impacts. It was impossible to find external cost data for some emissions (e.g. heavy metal emissions to air and water), so conservative estimates were made for these in relation to other emission costs (Table 4). Low and high aggregated costs of pollution avoided as a consequence of IPPC regulation were thus used to estimate the social benefit of IPPC regulation. This was compared with annualised IPPC compliance costs, derived from responses to Survey 1. Costs for previous years were inflated according to the wholesale price index (CSO, 2009), and all capital investment costs were expressed as annualised depreciation costs assuming a 15 year lifespan. The component of these costs associated with control of air and

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[3] According to life cycle impact assessment methods

[4] Rreported emission data were used to produce an emissions time series from 1995 to 2007. Then, 1995 emissions were extrapolated to 2007 according to constant eco-intensity per volume of production. "Avoided" emissions were calculated as the difference between extrapolated and actual (reported) 2007 emissions. Questionnaire responses (median percentages) from Survey 2 were then used to ascertain that IPPC licensing was responsible for 50% of air emission avoidance and 30% of water emission avoidance (Styles et al., 2009b).

water emissions was identified (Survey 1). These cost data were extrapolated up to the 27 installations that were in operation since 1995, based on the relative contribution of the seven cost-respondents to pollution loading from the 27 installations (23% in 2007: Fig. 3). This was necessary as the emissions, production, and survey 2 data enabled the estimation of IPPC pollution avoidance only at the more aggregate level.

2.3. Italian building-chemicals manufacturers: survey data

Twenty-five detailed interviews were conducted with environmental managers from the building-chemicals sector. The questionnaire on which the interviews were based was designed with reference to the OECD survey[5] "Environmental Policy and Firm-Level Management", and is included in Appendix C. The questionnaire comprised three main sections, designed to obtain critical information pertaining to: (i) organization features, (ii) relevant public environmental policy; (iii) competitive performance, such as business performance, innovation performance, resource efficiency and intangible-related performance. The selection of firms for interview was carried out in three steps: (i) selection of NACE codes relevant to the Italian building-chemicals sector; (ii) identification of all active organizations classified according with the selected codes located within the Padania region – information from the Italian Chamber of Commerce; (iii) randomised selection of 25 organizations for interview.

Since the data from the study were collected using survey techniques, it is important to address the limitations of the survey data. The common method variance (i.e., variance that is attributable to the measurement method rather than to the constructs) is a potential problem in behavioural research There are several causes of method bias. Some sources of common method bias result from the fact that the predictor and criterion variables are obtained from the same source or rater, whereas others are produced by the measurement items themselves, the context of the items within the measurement instrument, and/or the context in which the measures are obtained (Podoskoff *et al.*, 2003). In order to minimize the common method bias that can affect a questionnaire survey, according to the scheme proposed by Podoskoff *et al.* (2003, p:898) we used several procedural remedies in the questionnaire's design[6].

2.4. Italian building-chemicals manufacturers: data analysis

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[5] See http://www.oecd.org/document/37/0,3343,en_2649_34333_2388581_1_1_1_1,00.html for further details.

[6] The procedures can be summarize as follows:

- We created a methodological separation amongst the different measurements of the study. This guarantees a temporal and psychological separation. Furthermore, we used different response formats for the questions.
- In order to minimize the items ambiguity we didn't use ambiguous or unfamiliar terms; we avoided vague concepts or complicated syntax; we kept questions simple, specific, and concise;
- In order to reduce the acquiescence we avoided the use of bipolar numerical scale values (e.g., –3 to _3), providing verbal labels for the midpoints of scales;
- In order to minimize socially desirable, lenient, acquiescent, and consistent bias, all our respondents were guaranteed anonymity

Environmental managers were asked to assess a set of regulatory instruments in terms of perceived influence on their own organization's production activities, including direct regulations (input bans, technology and performance based standards), economic instruments (e.g. emissions and input taxes and tradable emissions permits), and soft instruments (e.g. voluntary agreements, demand information measures, green public procurement). Meanwhile, the stringency of environmental regulation may be quantified in numerous ways: compliance costs, the number of new regulations taking effect, discrepancy between non-constrained emissions and actual emissions, and the number of inspections (Telle and Larsson, 2007). In our study we use the number of inspections as an indicator of regulatory stringency for several reasons. First, this indicator has been used for some time, in a number of studies (e.g. Laplante and Rilstone, 1996). Second, the frequency of inspection is often determined by EU environmental laws (such as the IPPC Directive and the ETS Directive) that target regulate the potentially most environmentally damaging plants. In addition, the perceived degree of regulatory stringency was ascertained from answers to the question "*How would you describe the environmental policy regime to which your facility is subject*?".

Independent quantitative data on competitive performance were not available at the firm level, so we used specific survey questions to establish firm-level competitiveness, in accordance with previous studies. Different dimensions of competitiveness were represented by three key variables: market performance (Levy, 1995, Gray and Shadbegian, 1998), innovation capabilities (Jaffe and Palmer, 1997, Rennings *et al.* 2006) and intangible assets (Halle 1992, Fouts & Russo 1997). Categorised responses to questions regarding competitive performance were assigned scores of 1 (worst performance) to 5 (best performance), whilst responses to questions regarding the importance of different regulatory instruments were assigned scores of 1 (not important) to 3 (very important). This provided for statistical analysis to test for associations between regulatory parameters and competitiveness parameters.

In order to analyze how the environmental policy stringency and direct regulation affect competitive performance and, in particular, the technical innovation of firms in the building-chemicals sector, we applied a two step statistical model. Firstly, a Spearman's correlation test was used to identify any significant associations between the degree of perceived regulatory stringency, the impact of direct regulation, and different measures of competitiveness (business performance, innovation performance, intangible assets). Following confirmation of significant associations between the stringency and the form of environmental regulation on one side, and the competitive performance on the other, we decided to explore these associations in more depth. Regression analyses using ordered probit[7] models were applied in order to test two main hypotheses in relation to the Padania building-chemicals:
H1. How does the environmental policy stringency affect the technical innovation of firms in the building-chemicals sector?
H2. How does the form of environmental regulation (direct regulation) affect the technical innovation of firms in the building- chemicals sector?

[7] The ordered probit is a generalization of the popular probit analysis, used for ordinal multinomial dependent variables.

Results of the correlation tests were used to inform our selection of "investments in technical innovation" as the dependent variable. Independent variables included were the two measures of environmental regulation stringency, and two major direct regulations applied to the investigated sector (input bans and technical-based standards). Finally, we considered the influence of firm size and age (number of years from foundation) as exogenous variables.

3. RESULTS

3.1. Environmental effectiveness

It is clear from both the Irish and Italian case studies that direct regulation was perceived to have had the greatest influence on process modifications (Fig. 1). Technology- and performance- based standards were perceived by 79% and 75% of Italian building-chemicals sector respondents, respectively, to have had a "very important" impact on operations (Fig. 1). Similarly, environmental managers in Ireland's pharma sector perceive integrated licensing to have been the major driver of pollution avoidance, despite widespread participation in voluntary schemes such as ISO14001, EMAS, and CSR initiatives. For the 27 core pharma installations, IPPC regulation resulted in annual pollution loading being reduced by a further 59% relative to BAU and voluntary regulations (Fig. 2). According to ecological damage potential, pollution avoidance attributed to IPPC regulation was dominated by reductions in volatile organic compounds (VOC), SOx and NOx emissions to air, and heavy metal emissions to water (Fig. 2). According to economic damage potential, IPPC regulation resulted in a 76% reduction in pollution relative to BAU and voluntary emission reductions, largely attributable to the reduction in SOx emissions (Fig. 5).

Economic instruments (emissions or effluent taxes or charges, input/output taxes, and tradable emissions permits) were also perceived to have a large influence on operational decisions, though less than direct regulation. Averaged across the four types of economic instrument specified, 53% of Italian building-chemical respondents perceived them to have had a very important influence on operations (Fig. 1). Although most Irish Pharma installations participate in the EU ETS, the 15% CO_2 emission avoidance relative to BAU was low compared with other emissions (Fig. 2).

Italian building-chemicals firms are subject to a wide variety of soft instruments, including voluntary industry agreements, and communication and information measures such as ecolabels. Averaged across the six types of soft regulatory instrument included in the Italian Chem for buildings survey, just 27% of respondents perceived them to have had a very important influence on operations (Fig. 1). Similarly, environmental managers in Ireland's pharma sector ranked voluntary regulation as the least important driver of environmental performance improvement (Styles et al., 2009b). Green public procurement stands out among soft instruments as being perceived to have had a very important influence on operations by 56% of Italian Chem for buildings respondents (Fig. 1).

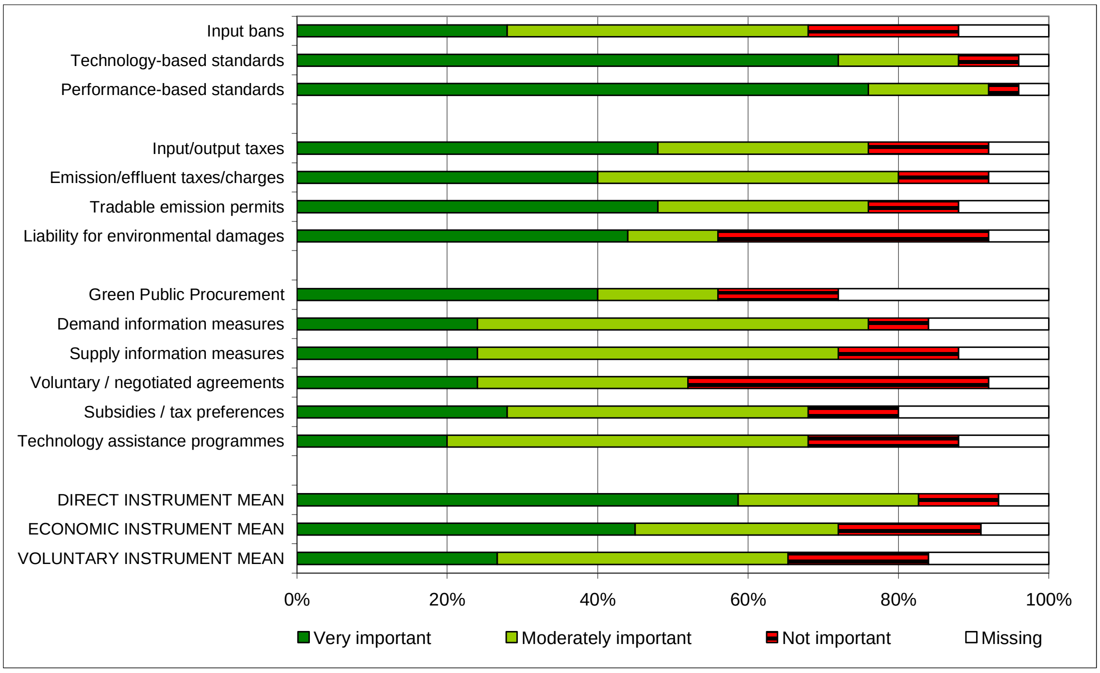

Fig. 1. The influence of specific environmental policy instruments on firm operations, classified according to their relative importance (*n* = *25*).

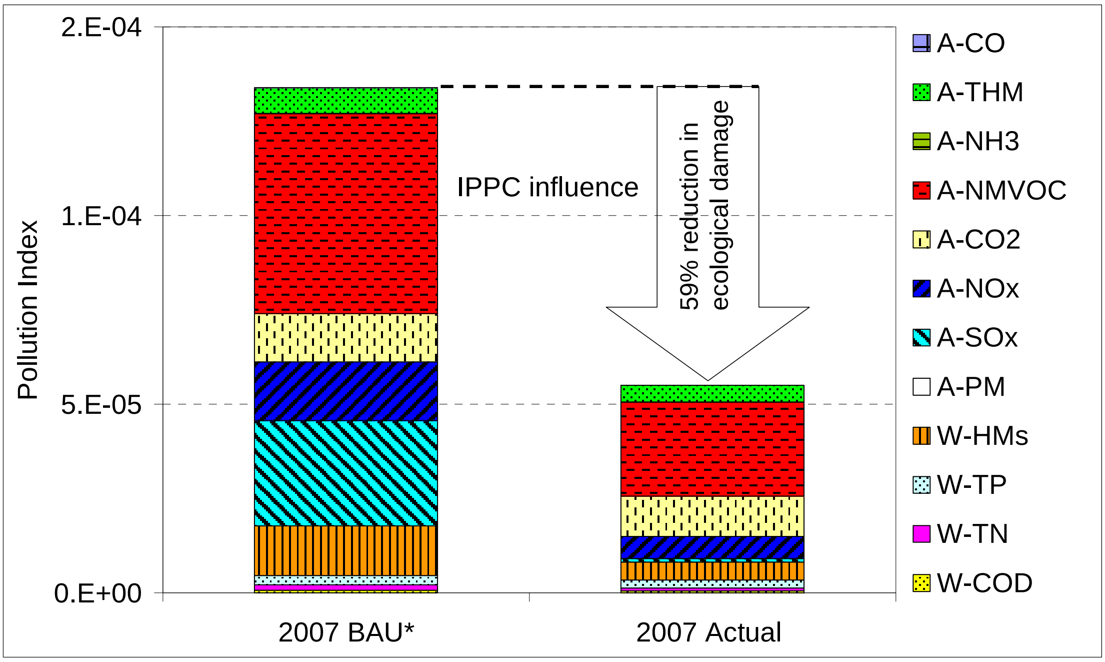

Fig. 2. "Business As Usual" (includes effect of voluntary regulation) and "Actual" 2007 pollution profiles, based on the ecological damage potemtial of emissions, for the 27 core pharma installations. The difference represents the specific influence of IPPC regulation.
*BAU profile based on production-based extrapolation of 1995 emissions, scaled down to acount for median air and water emission avoidances attributed to non-IPPC influences in survey responses.

3.2. Efficiency and competitive effects

As demonstrated in the literature, the concept of competitiveness may be considered from a number of perspectives and at a number of levels. Focusing on direct regulation, we analyze effects on different dimensions of competitiveness at the firm level, represented by three key variables: resource efficiency (cost reduction), innovation capabilities (Jaffe and Palmer, 1997, Rennings *et al.* 2006) and intangible assets (Hall 1992).

Based on information provided by seven Irish pharma respondents to Survey 1, mean IPPC compliance costs were €1.6 million per installation in 2007. Based on a breakdown provided by five respondents, these costs were dominated by operating and maintaining environmental systems (Fig. 4). Respondents apportioned compliance expenditure in the ratios 20%, 30% and 50% to controlling air emissions, water emissions, and waste, respectively. Extrapolated up to the 27 core Pharma installations (Fig. 3), annual expenditure on air and water emission control was estimated at €21.64 million (Table 4). Using lower and higher external cost estimates for emissions, the social economic benefit attributable to emissions avoided through direct regulation ranges from 17.15 to is 49.98 M€ (Table 4). Social benefit is dominated by avoidance of 2485 tonnes of SOx per annum (Table 4; Fig. 5). The basic benefit to cost ratio for IPPC emissions control in the pharma sector ranges from 0.8 to 2.3, with a median value of 1.6. A more comprehensive cost assessment of environmental damage would yield a higher benefit to cost ratio, as indicated by divergence between the ecological (Fig. 2) and economic (Fig. 5) pollution damage profiles[8]. Based on application of median external costs, IPPC regulation has resulted in a net economic benefit of 11.9 M€ per annum. These calculations exclude indirect effects of IPPC regulation on efficiency and competitiveness.

Of the eight Irish Pharma respondents to Survey 1, five had adopted new *process* technologies, and three had adopted new *process* techniques (in addition to simple abatement technologies and techniques) as a result of integrated licensing (Table 1). Four respondents indicated that licensing had a positive influence on operating efficiency (Table 1), and one respondent specifically attributed energy and resource efficiency savings to implementation of extended batch-production campaigns required as part of the installation’s mandatory EMP. Other comments attributed positive effects to the provision of technical guidance documentation and enhancement of corporate image, but also to the implementation of more consistent regulation across competitors, and improved access to markets with strict environmental standards. Conversely, four of the eight respondents to Survey 1 indicated that compliance with integrated licensing had constrained production output (Table 1). Comments suggest that this occurred primarily due to shut-downs required to prevent ELV exceedence on particular occasions (e.g. if abatement systems malfunctioned or became over-loaded). Similarly, whilst eight Survey 2 respondents remarked that IPPC regulation was very effective at driving environmental performance improvements, six complained that it was too bureaucratic, and four thought that it resulted in sub-optimal outcomes (from an economic *and*

[8] The pollution index represents ecological damage potential across six major impact categories (acidification potential, aquatic toxicity potential, eutrophication potential, global warming potential, human toxicity potential, tropospheric ozone formation potential), whilst the economic damage profile is derived primarily from estimates of human health impacts.

environmental perspective). On balance, respondents perceived IPPC licensing to have had a slight positive effect on their competitiveness within Ireland and Europe, but a negative effect on their competitiveness globally.

For the Italian building-chemicals sector, positive relationships were observed between direct regulation in the form of input bans (but not technical standards or any other form of regulation) and innovation (Table 2). Furthermore, some measures of competitiveness were found to be positively correlated with the stringency of environmental regulation, as indicated by inspection frequency and perceived stringency (Table 2 and Table 3). Specifically, the regression analysis (probit model) reveals that more frequent environmental inspections were associated with increased investment in technical and product innovation (the sign of coefficients is positive and significant at 95%). There is tentative evidence that more stringent environmental regulation is associated with stronger business performance generated by green products, though the association is statistically weak ($p < 0.1$: Table 2). Meanwhile, economic and soft instruments, whilst not correlated with innovation, were correlated with intangible assets – most notably soft instruments and reputation (Table 2). Direct regulation in the form of technical standards was weakly associated with technician's competence.

Table 1. Responses to key questions provided in detailed questionnaire returns from eight environmental managers in Ireland's Pharma sector (Survey 1).

Question		Response			
		Yes	No		
Did licensing require…	New process technology?	5	3		
	New abatement technology?	5	3		
	New process techniques?	3	5		
	New abatement techniques?	7	1		
Has licensing had any positive effects through…	Identification of efficiencies?	4	4		
	Provision of BAT information?	6	2		
	Regulation of competitors?	5	3		
	Enhancing corporate image?	7	1		
	Improving access to markets?	4	4		
Were there negative effects in relation to...	Production?	4	4		
	Costs?	8	0		
		Pos	Neg	None	Net
What has been the effect of licensing on competitiveness?	Within Ireland?	3	1	4	2
	Within EU?	3	2	3	1
	Gloablly?	2	4	1	-2

Table 2. Spearman correlation test among Policy stringency measures and competitive performance measure

		Regulation stringency		Regulatory instruments					
				Direct		Economic		Soft	
		Perceiv-ed	Insp. freq.	Input ban	Tech. stand	Input tax	Emiss. tax	GPP	Demand measure
Business performance	Overall performance	-0.13	-.002	0.19	-0.13	-0.15	-0,32	-0.41	-0.01
	"Green Business" perf.	**0.36***	**0.40***	-0.27	-0.12	-0.26	-0,03	-0.13	-0.06
Innovation	Technical innovation	**0.42****	**0.58*****	**0.42***	0.27	0.04	0,1	0.34	-0.02
	Product innovation	**0.43****	**0.47****	**0.44****	0.08	-0.16	0,24	0.06	-0.10
Intangible assets	Reputation	0.12	0.16	0.20	0.11	0.002	0,16	**0.61*****	**0.51****
	Personell motivation	0.29	0.23	-0.10	0.29	0.26	**0.46****	0.26	0.23
	Technicians' competence	0.01	0.53	0.20	**0.38***	0.12	**0.46****	0.40	**0.39***

***$p < 0.01$ **$p < 0.05$ *$p < 0.1$

Table 3. Results of the ordered probit regression model testing for the relationship between the listed variables and technical innovation.

	Coefficient	Std Err.z	*p* value
Policy stringency	**1.70**	**0.83**	**
Inspection frequency	**1.16**	**0.46**	**
Input bans	**1.40**	**0.83**	*
Technical standards	-1.34	1.05	
No. employeees	-0.01	0.01	
Firm age	0.00	0.01	
LR chi^2	20.51		***
Pseudo R^2	0.47		

***$p < 0.01$ **$p < 0.05$ *$p < 0.1$

Table 4. Mass annual emission avoidance specifically attributable to direct regulation (integrated licensing) for 27 core Pharma installations in Ireland. Lower and higher estimates of avoided pollution are compared with extrapolated compliance costs.

Emission	Reg. effect	Pollutant costs		Avoided cost	
		Lower	Higher	Lower	Higher
	$t\ a^{-1}$	$€\ t^{-1}$		$k€\ a^{-1}$	
W-COD	238	1,90[a]	682,7[a]	0,45	162
W-TN	50	10[b]	3 600[c]	0,50	180
W-TP	2,3	590[b]	96 240[c]	1,35	221
W-HMs	0,8	1 180[d]	192 480[d]	0,97	159
A-PM	2,0	26 000[e]	75 000[f]	53	154
A-SOx	2.485	5 600[e]	16 000[f]	13.917	39.764
A-NOx	351	4 400[e]	12 000[f]	1.545	4.214
A-CO_2	33.629	9,5[g]	38[h]	319	1.278
A-VOC	1.344	950[e]	2 800[f]	1.277	3.764
A-NH_3	2,3	11 000[e]	31 000[f]	26	72
A-THM	0,05	52 000[i]	150 000[i]	2,3	6,8
A-CO	28	105[j]	308[j]	3	9
Annual Benefit (k€)				17146	49982
Annual Cost (k€)				21638	21638
Benefit Cost Ratio				0,8	2,3

a = calculated relative to nitrogen based on eutrophication potential (from Guinée et al., 2002)
b = minimum values quoted by O'Doherty and Toll (2007)
c = maximum values quoted by O'Doherty and Toll (2007)
d = estimated at twice TP impact
e = low external cost estimates from BAT-assessment guidance document (EC, 2006), based on Value of Life Year median for PM and ozone mortality, inclusion of health core, crop effects, and sum of means over 35 ppb volume concentration.
f = high external estimates from BAT-assessment guidance document (EC, 2006), based on Value of Statistical Life mean for PM mortality, Value of Life Year mean for O3 mortality, inclusion of health core, health sensitivity and crop effects, and sum of means over 0 ppb volume concentration.
g = half of ExternE estimate (EC, 2005)
h = twice ExternE estimate (EC, 2005)
i = approximated to twice PM cost
j = calculated relative to VOC tropospheric ozone formation potential (from de Leeuw, 2002).

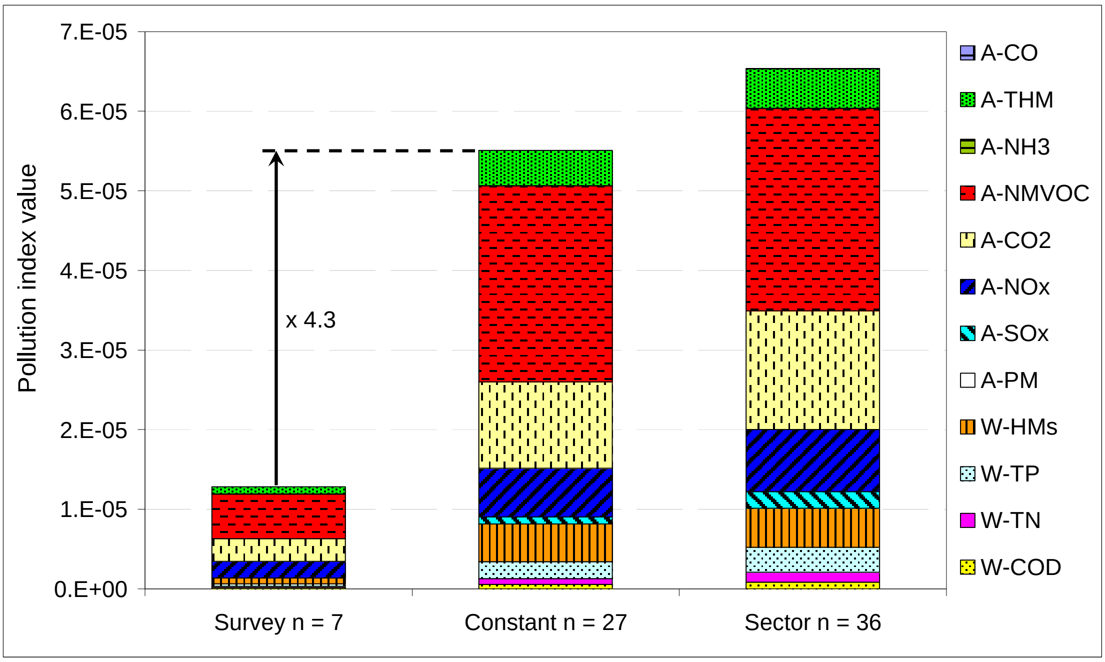

Fig. 3. Aggregate pollution loading for the seven installations that provided compliance-cost data in Survey 1, for the 27 installations that reported throughout 2001-2007, and for the entire sector, based on mass annual emissions in 2007.

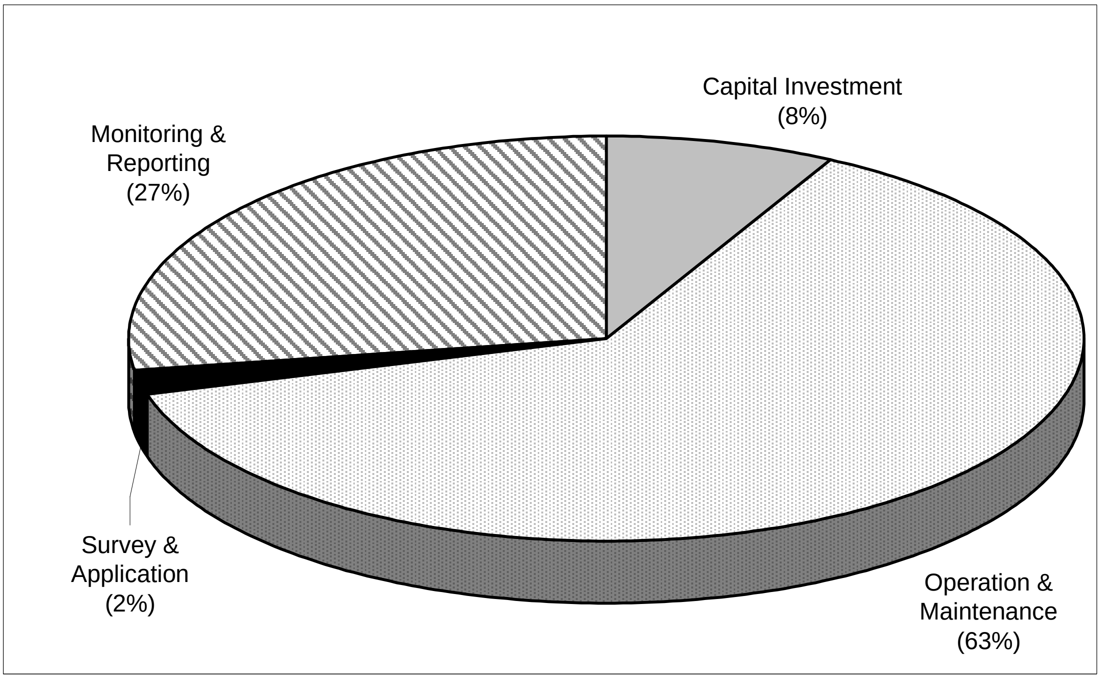

Fig. 4. Average breakdown of annual licence compliance costs between 1995 and 2007 by category, based on detailed questionnaire cost data provided by five installations.

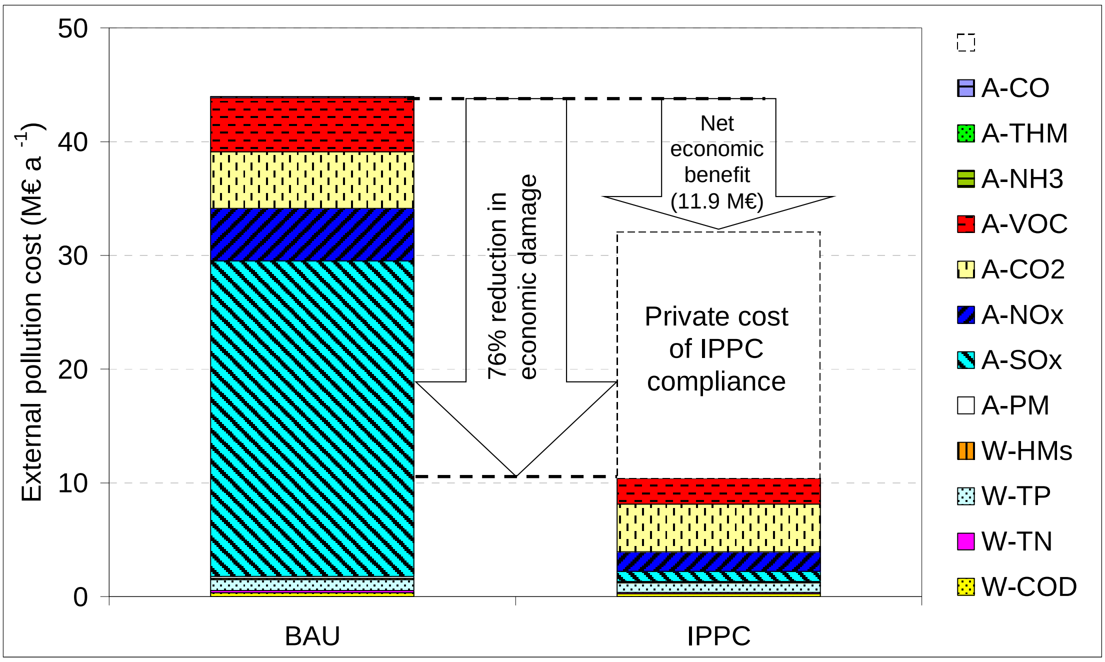

Fig. 5. "Business As Usual" and actual 2007 (IPPC influenced) pollution profiles, according to monetised emission damage, for the 27 core pharma installations.

4. DISCUSSION

4.1. Direct regulation drives pollution avoidance

This paper has emerged from the chance observation at a conference that two entirely separate projects, focussed on the Irish pharma and Italian building-chemicals sectors, appeared to be supporting the same broad conclusions about environmental regulation. Although relatively small in terms of the number of installations studied, these two studies contain lines of complementary empirical evidence that combine to support some important conclusions about environmental regulation, from a multi-pollutant perspective and in the context of existing literature.

It is clear from questionnaire responses that IPPC licensing is seen as the major driver of considerable pollution reductions achieved by Ireland's pharma sector. What wider conclusions can be drawn from this example? On the one hand, the experience of this profitable export-driven and compliant sector could exaggerate the influence of direct regulation, and underestimate the influence on competitiveness (Lee, 2008), for other less compliant (EPA, 2006) and less profitable sectors. On the other hand, the important influence of direct regulation on a sector with a long history of voluntary regulation (EMS accreditation, CSR, voluntary reporting initiative) emphasises the greater effectiveness, and the associated additional social benefit, of direct regulation. Tentative evidence of "over-compliance" with BAT standards (Clinch and Kerins, 2002; Styles et al., 2009b) may reflect a risk-averse approach to future regulation taken by this well-financed sector. However, it may also be explained by the perception that IPPC regulation has driven process innovation beyond BAT, by requiring environmental considerations to be integrated into process management. This would indicate that IPPC regulation is achieving genuine and efficient pollution *prevention* as intended within the original directive (96/61/EC).

Italian building-chemical firm managers also regarded direct regulatory instruments as having the greatest influence on operations, compared with economic and soft instruments. Environmental performance of the Italian building-chemicals sector was not measured directly, so we assume here that it is positively associated with the influence on operations perceived by questionnaire respondents. It is possible that the cumulative influence of the different regulatory approaches differs from the average ratings for the respective instruments. Nonetheless, the overarching finding from the Italian and Irish studies that direct regulation is a major driver of environmental performance is in agreement with other recent studies demonstrating the effectiveness of direct regulations (Silvo et al., 2002; Environment Agency, 2004; Honkasalo et al., 2005; EEA, 2008; Mirasgedis et al., 2008).

4.2. Competitive impacts of direct regulation

Our basic cost benefit assessment indicates that the pollution avoidance achieved by IPPC regulation of Ireland's pharma sector has had a positive net economic benefit over and above the significant business-as-usual improvements that were at least partly associated with voluntary regulation. More complete costing of environmental impacts would increase the benefit attributable to IPPC regulation. Consequently, IPPC regulation has clearly improved the social efficiency of production from a neoclassical economics perspective (Fig. 5). Although other positive assessments of cost-effectiveness have been made for IPPC regulation (e.g. Clinch and Kerins, 2002; AEA, 2007), our finding is important because it is underpinned by highly quantitative and comprehensive data on pollution avoidance that was specifically attributed to IPPC regulation (not approximated to total observed reductions or calculated from a hypothetical BAT effect). The data presented in this paper did not enable a disaggregated comparison of reduction costs for specific emissions between the pharma and other sectors, as would be required for a traditional economic assessment of the comparative efficiency of IPPC regulation. However, we suggest that isolated consideration of abatement costs for individual pollutants can be misleading given the wide range of pollutants that require regulatory control. We conclude that direct regulation drives industry further towards socially 'optimum' pollution levels than voluntary regulation.

There was evidence within questionnaire responses from both Irish and Italian industry that regulation, particularly direct and stringent regulation, can drive innovation and improve production efficiency, as suggested by Poter and van der Linde (1995a;b). Italian respondents indicated that stringent direct regulation may improve realisation of green business opportunities. Specifically, it appears that more stringent regulation can stimulate firms to concentrate on more environmental-friendly products that in turn are commercially successful. These results are in agreement with Costantini and Crespi (2008), who noted a positive association between stringent environmental regulation and technology and innovation investment among Italian firms. However, in our study, efficiency improvements were not perceived to have translated into competitive advantage. Isolating the effect of regulation on competitiveness is known to be challenging (López-Gamero, 2009), owing to confounding factors such as the tendency for larger, more efficient installations to be more responsive to environmental regulations (Hitchens et al., 2001; Radonjič and Tominc, 2007). With regard to EU-level environmental policy, it is notable that Irish pharma respondents perceived competitiveness impacts to be limited overall, and positive at the EU level owing to the creation of a level-playing-field. Significant correlations between economic and soft regulation and intangible assets could lead to longer-term, and thus difficult to attribute, competitive advantages.

Complete assessment of the efficiency of different approaches to environmental regulation is beyond the scope of any single study owing to the range of direct and indirect competitive effects and the scope of environmental performance that should be considered. Results presented here do not represent a quantitative efficiency comparison across approaches, but do offer some insight into the real-world efficiency of direct regulation. Many comparisons of abatement costs across approaches focus on individual pollutants. The pollution index used in this study integrated the major air and water pollutants, but still excluded important environmental parameters that must be controlled, and that should be considered in any complete assessment of regulation (waste generation, land contamination, noise, odour and accident prevention). For many non-readily estimable pollutants (e.g. NOx emissions, heavy metals to water), a verifiable monitoring and reporting framework is required before any form of regulation can be implemented[9]. We suggest that comprehensive command-and-control regulation, such as IPPC licensing, remains essential to these objectives, whilst offering the opportunity to achieve efficiencies through coordinated control of processes and pollutants (Tollefsen et al., 2009). Consideration of sectoral affordability in BAT determination also provides a transparent rationale in which to accommodate the economic / political constraints that often impede the implementation of regulations designed to achieve least-cost pollution reduction (Ellerman, 2003; Palm and Larsson, 2007). Thus, we conclude that stringent and integrated direct regulation is an essential component of industrial pollution control, and the efficiency of this approach relative to economic and voluntary approaches is often underestimated. Although less influential to date, economic and voluntary instruments have important roles to play alongside direct regulation in driving environmental performance improvements, especially for readily-estimable pollutants and across smaller industrial sources.

5. CONCLUSIONS

Empirical evidence from two separate studies emphasises that direct regulation has been the main driver of environmental performance improvements in both the Irish pharma and Italian building-chemicals sectors. It has been considerably more effective than voluntary regulation. From a neoclassical economics perspective, stringent direct regulation implemented through direct (IPPC) regulation has improved the social efficiency of pharmaceutical production in Ireland. In addition, industry perceptions conveyed in questionnaire responses suggested that the direct costs of regulation may be offset somewhat by efficiency and organisational improvements attributable to regulation (in particular to innovation stimulated by direct and stringent regulation). This finding, along with direct questionnaire

[9] For Ireland's pharma sector, emissions monitoring and reporting enforced under IPPC regulation is substantially more complete, and has greater influence, than monitoring and reporting undertaken through voluntary initiatives (Styles et al., 2009b).

responses, suggests that harmful production-efficiency and competitiveness impacts attributed to regulation (e.g. the pollution haven theory) are typically overstated, and in any case less important when regulation is implemented at the EU level. These findings support the Resource-Based view of environmental regulation.

Regulation is required to control a wide range of pollutants from industry, and all forms of regulation require verifiable data regarding pollution quantities. Combined with the above findings, these factors provide a strong rationale for policy-makers and regulators to continue focussing on integrated direct regulation as a central tenet of industrial pollution control. This study did not directly compare the efficiency of different regulatory approaches. Further studies are required to do this within the full context of pollution control (i.e. considering verification of pollution monitoring and reporting, the whole suite of parameters that require regulation, and any stimulated efficiency savings that offset compliance costs).

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