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Squandered Profit Opportunities? Some Historical Perspective on Industrial Waste and the Porter Hypothesis

Pierre Desrochers¹ and Colleen E. Haight²

Abstract:

Despite numerous studies, the ‘Porter Hypothesis’ (PH), which states well-designed regulations can compel manufacturers to develop innovations with both economic and environmental benefits, remains unsettled. We examine two significant cases for which PH claims were once made: the British alkali industry and the (Tennessee) Copper Basin smelting operations. Our conclusions are: 1) the PH is based on a flawed understanding of how ‘win win’ innovations spontaneously emerge in competitive settings; 2) regulatory pressures were only one (and typically minor) factor; 3) “strict and well designed” environmental regulations are unlikely to deliver superior outcomes to traditional property rights-based approaches.

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1. INTRODUCTION

In influential papers, management scholar Michael Porter argues that strict, well-designed (or “flexible”) and properly enforced environmental regulations can trigger ‘win win’ innovations that are both socially and economically beneficial, as they encourage businesses to reduce waste, increase efficiency, and make appropriate use of technological advances. (Porter, 1991, Porter and van der Linde, 1995) Such developments, conditional on the existence of these regulations, allow firms to more than fully offset compliance costs, becoming more competitive and profitable than non-regulated rivals.

Even though Porter’s argument had been anticipated in some form by other scholars in previous years (Ashford, 2000, Ashford et al. , 1979), it has been known for some time as the ‘Porter Hypothesis’ (henceforth PH). It has generated a large and still largely unsettled literature devoted to examining its validity through both case studies and econometric analysis. (Ambec et al. , 2013, Andre et al. , 2009, Antonioli et al. , 2013, Böhringer et al. , 2012, Costantini and Mazzanti, 2012, Jaffe et al. , 2002, Kesidou and Demirel, 2012, Lanoie et al. , 2008, Mohr, 2002, Wagner, 2003) In a recent review of the PH debate Ambec et al. (2013, p.2) state that more than two decades after the publication of Porter’s original article, “we continue to find conflicting evidence concerning the Porter Hypothesis, alternative theories that might explain the Porter Hypothesis, and oftentimes a misunderstanding of what it does and does not say.”

Not surprisingly, as the number of empirical tests of the PH has increased, so have its interpretations that are now typically summarized as “weak,” “strong,” and “narrow.” The first states that regulation-induced innovations might be good or bad for the firm, in the latter case by diverting investment from productivity gains to abatement thus increasing costs and decreasing profits. The “strong” version, by contrast, refers to Porter’s original thinking, i.e., regulation-induced innovations more than offset any additional regulatory costs. The “narrow” version of the PH is more prescriptive and suggests that flexible regulatory policies are more conducive to innovation than more prescriptive approaches. (Ambec et al. 2013) Although widely accepted, the value added

by these theoretical refinements is questionable. After all, every new regulation that mandates improvement upon a firm's current environmental performance must by definition trigger some innovative or adaptive response. Similarly, flexible approaches are also by definition more conducive to experimentation than more prescriptive ones. Only the "strong" version of the PH, we suggest, can be considered meaningful and will therefore be our take on the concept. As we will further argue in our conclusion, the "narrow" version of the PH is also not as straightforward as it may seem, at least inasmuch as its real test should not be between more flexible approaches and so-called "command and control" regulations, but rather between the former and traditional market constraints on polluting activities (i.e., property-rights based litigation). In order to make our case, however, we must first discuss the theoretical underpinnings of the PH as they are now widely understood.

As with present-day environmental economists such as Don Fullerton and Robert Stavins who observe that they "make a living out of analysing [*sic*] market failures such as environmental pollution in which laissez-faire policy leads not to social efficiency, but to inefficiency" (Fullerton and Stavins, 1998 p. 433, Jaffe et al. , 2005, also see Turner, 2000), the PH ultimately stems from a belief in the widespread failure of market forces to factor in environmental impacts, which is further compounded by problems ranging from corporate executives' unwillingness to invest in financially risky research and development whose eventual spillovers might benefit competitors to a lack of relevant information among private sector actors. By providing a level playing field, well-designed regulations are also said to reduce the uncertainty inherent to investments in environmental protection while raising corporate awareness and providing additional pressure on issues that might get lost in daily management routines.³

³ Of course, increased efficiency of manufacturing operations can nonetheless have detrimental environmental impact in the context of open access resources. Because the issue has never been addressed in the context of the PH debate, however, we will refer readers to Ostrom's classic work on ways to govern common access resources (see, among others, Ostrom E. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge: Cambridge University Press; 1990, Ostrom E. *Coping with Tragedies of the Commons*. *Annual Review of Political Science*. 1999;2:493-535, Ostrom E. *Tragedy of the Commons*. In: Durlauf S, Blume LE, editors. *The New Palgrave Dictionary of Economics*. Second ed2008.)

PH sceptics, on the other hand, argue that self-interest within the appropriate institutional context is sufficient to entice manufacturers to invest in the development of innovations that have incidental environmental benefits because of the additional profit those innovations yield. Although PH-type cases may exist, they argue, business people are unlikely to remain systematically oblivious to profit opportunities.

While assessing the specific impact of environmental regulations on the development of ‘win win’ innovations is a challenging task, Porter’s argument effectively implies the widespread existence of waste in manufacturing operations and the incapacity of economic actors to systematically act upon it. As he put it: “Reducing pollution is often coincident with improving the productivity with which resources are used,” but we are currently living in a “transitional phase of industrial history” characterized by companies “still inexperienced in dealing creatively with environmental issues.” (Porter and van der Linde, 1995 pp. 98-99) Any meaningful discussion of the validity of the PH should therefore address the inherent propensity of private sector actors to utilize their inputs ever more fully over time, in the process reducing the amount of residuals released in the environment. Section one illustrates this propensity has been widespread since the beginning of the industrial age (and probably long before), even in the absence of governmental regulations. Additionally, several past authors argued that private property rights and regulations sometimes play a role in this respect. Sections two and three discuss significant historical cases for which PH-like claims were made before Porter resurrected the argument. The first is the nineteenth century British alkali industry and the Alkali Act (1863 and later revisions); the second, (Tennessee) Copper Basin smelting operations and American Supreme Court cases (1907-1915). We find the available evidence in these prominent cases weak at best. Our main conclusion is that although regulations and/or the threat of legal actions based on either common or statutory laws might have occasionally triggered innovative industrial behavior in the past, competitive pressures and self-interested profitability considerations were much more significant. We finally suggest that Porter’s “strict and well designed” regulatory ideal might paradoxically be the traditional property-rights based approach to pollution problems.

2. BACKGROUND AND OVERVIEW

Numerous studies of efficiency of material use over time have convincingly demonstrated that, in a market economy, scarcity-induced price increases dissuade any long-term inefficient use of resources while encouraging reductions in the quantity of inputs needed to maintain, or even increase, output. (Sanbach, 1978, Simpson, 1999) As Jesse Ausubel observes, “the wheels of history [have long been] rolling in the direction of prudent, clean use of resources,” whether one looks at energy, land (for agricultural and timber production), water or materials. (Ausubel, 1998 p. 39) For example, Ausubel documents how the efficiency of generators has gone up from one percent of their apparent limit to about fifty percent in the last three hundred years; that the ratio of weight to power in industrial boilers has decreased almost 100 times in the last two centuries; and that globally, the amount of carbon required to produce the equivalent of energy produced by one ton of oil decreased from about 1.1 tons of carbon in 1860 to about 0.7 tons in 1990.

Not as well documented because of a lack of data, but certainly just as real, is a significant historical trend towards the creation of valuable by-products out of (often polluting) industrial production residuals. In some cases, the process was rather straightforward. In others though, even large concentrations of homogenous materials produced in the heart of manufacturing regions and/or the presence of valuable components within them weren't enough to guarantee profitable development in the short run. While significant successes were achieved over time, the process was often one of painstaking experimentation fraught with failure. Nevertheless, what the following sections illustrate is that entrepreneurial businessmen and creative technicians made “win-win” innovations a reality long before the rise of the modern environmental movement.

2.1 Historical By-Product Literature Review⁴

In the preface to a bulletin on *The Utilization of Wastes and By-Products*⁵, the Chief Statistician for Manufactures of the US Census of 1900 acknowledged, “it is impossible to measure statistically the addition of wealth of the country created by turning to some useful purposes the residues and by-products which were formerly thrown away or left to rot,” but “the volume thus preserved and turned to some useful account must be enormous.” (Kittredge, 1902 p. 1) Another contemporary reflected: “A full account of the various inventions by which the utilization of the bye-products [*sic*] has been brought about would fill a volume, and does in fact actually fill many volumes of technical literature.” (Cornish, 1892 p. 209) Writing in no less an outlet than the *Ladies’ Home Journal*, the well-known essayist William George Jordan observed: “One of the signal advances made by this many-sided century has been in invention and industry. In no way has this progress been more vividly shown than in its conquest of waste.” (Jordan, 1897 p. 8)

As these and several other authors argued, a business’ polluting residuals and emissions often offered some of its most promising profit opportunities through the development of valuable by-products. The most useful sources in this respect are a few reasonably comprehensive books written for a broad audience. (Kershaw, 1928, Koller, 1918, Lipsett, 1963, Razous, 1937, Simmonds, 1876) Despite their status as works of synthesis, their content is simply too overwhelming to be dealt with in any detail. As one of their authors stated over a century and a half ago, the subject was simply “too extensive in its scope to be discussed successfully” in his 420 page and 35 topical chapter book, since

⁴ More detailed or complimentary discussions of this literature include Desrochers P. Industrial Symbiosis: The Case for Market Coordination. *Journal of Cleaner Production*. 2004;12:1099-110, Desrochers P. How did the Invisible Hand Handle Industrial Waste? By-Product Development before the Modern Environmental Era. *Enterprise and Society*. 2007;8:348-74, Desrochers P. Bringing Inter-regional Linkages Back In: Industrial Symbiosis, International Trade and the Emergence of the Synthetic Dyes Industry in the Late 19th Century. *Progress in Industrial Ecology*. 2008;5:465-81, Desrochers P. Does the invisible hand have a green thumb? Incentives, linkages, and the creation of wealth out of industrial waste in Victorian England. *Geographical Journal*. 2009a;175, Desrochers P. Victorian Pioneers of Corporate Sustainability. *Business History Review*. 2009b;83:703-29, Desrochers P, Leppälä S. Industrial Symbiosis: Old Wine in Recycled Bottles? Some Perspective from the History of Economic and Geographical Thought. *International Regional Science Review*. 2010;33:338-61.

⁵ The use of the term “waste” throughout this paper refers to its historic usage in the 19th Century. Although the term “by-products” was common in the late 19th century, many authors used the terms interchangeably at that time.

“any one branch would of itself form a useful and interesting volume.” (Simmonds, 1862 p. 2) Their main message was well summarized in the special Census Bulletin on the issue:

“Nothing in the arts of manufacture is more indicative of economic efficiencies than the utilization of products that have been rejected as wastes or residues in the industrial processes....The refuse of to-day is a source of profit to-morrow; and this has been going on for years and probably will be going on for years to come.... New revelations and new uses are constantly being found for substances of all kinds, whether in their original forms, or in their changed forms due to outside agencies. The world’s increment of wealth is largely dependent upon finding new and more economical uses for materials, however exalted or humble they may be in the industrial scale.” (Kittredge, 1902 p. 3)

More detailed discussions of by-product developments are especially abundant in applied (or industrial) chemistry manuals and professional articles, but more significant for our purpose is that their overall diagnostic was similar. For example, the author of the most important German *Handbook of Chemical Technology* of the period observed that ideally, waste products should cease to exist, leaving only profitable by-products as the result of production. (Wagner, 1877 p. 3) A technological retrospective published ten years later in *The Chemical News* described “the utilization of waste materials and by-products” as a “leading feature of the Victorian epoch.” (Anonymous, 1887a p. 299) The consulting British farm architect and engineer Robert Scott Burn (1880 p. 355) even claimed that it was an axiomatic principle of practical chemistry that those “experiments, or that work only, is perfect when no useless refuse is left as the resultant of the process” and that all progress “in any of the branches of technical or material work” would eventually come through “the progress of economy.”

In an essay on “Chemistry in the United States,” the American “father of geochemistry” F. W. Clarke (1897 p. 126) observed that the main aims of the applied branch of the discipline included not only the discovery of new products, but also the reclamation of waste materials for profitable use and that, as a result of the work of creative scientists

and technicians, industry had become far less wasteful. Almost two decades later, the industrial chemist Gustave W. Thompson (1913 p. 803) wrote:

“Chemistry has been a great help and profit to industry in the control of manufacturing losses, and the business man who fails to recognize its value can not be considered as practical. For the avoidance of such losses, the chemist is peculiarly fitted. Some industries, it is true, can be conducted profitably with large losses of some of the constituents contained in the raw materials, but, in the course of time, these losses must be controlled, for the industry that applies the best control will be the most profitable and the best able to withstand competition.”

In discussing the development of new technologies to create value out of coal waste, an anonymous (1873 p. 360) writer further observed:

“The utilization of waste products adds to the wealth of the entire community. Especially is it a matter of interest where fuel is concerned, whose cost is not only an element in almost every manufacturing and commercial enterprise, but enters into the economy of every householder.”

These insights were not limited to chemists and engineers. In his 1904 address as retiring president of the American Association for the Advancement of Science, the statistician Carroll D. Wright (1904 p. 902) recognized the importance of scientific innovation in the development of new uses for waste materials, a prime example of which was the petroleum industry and its “innumerable products” then being recovered through refining operations. He further observed: “By-products of all kinds are usually the source of profit, and in some cases the chief source of profit, to the manufacturer. This enables him to put out his units of original production at a less cost, and with benefit to the community. Nothing is lost which through scientific methods can be preserved.” (idem) Writing in the *International Journal of Ethics* in 1906, the sociologist Ira Woods Howerth (1906 p. 193) remarked upon the profit motive as a driving force behind the utilization of waste materials by the businessman of his time who, in their attempt to gain “maximum return for minimum expenditure,” was constantly striving to “improve... his organization, perfect... his machinery, utilize... waste products, etc., all for the purpose

of promoting economy from the standpoint of his financial interest... Economy is the law of business.”

This perspective was widely shared by contemporary economists. For example, the most influential mid-nineteenth century American economic textbook, Francis Wayland's *Elements of Political Economy*, stressed that in order to increase profitability, manufacturers should strive to consume entirely “every utility possessed by any substance,” that much care should be devoted to insure that “all the fragments and remnants should be, so far as possible, employed to some valuable purpose,” and that “all the values must be consumed in the most profitable manner.” (Wayland, 1875 pp.118-119) Among other materials, the residuum left over after the extraction of flax seed was a valuable food for cattle and therefore both lessened the price of oil and increased its demand. Similar comments can be found in Alfred Marshall's *Principles of Economics* (Marshall, 1920/1950 pp. 278-279) (the most influential book of this type in the English speaking world at the turn of the twentieth century), in his *Industry and Trade* (Marshall, 1932 pp. 238-239) and in the entry on the “Residual and Waste Products” in the *Palgrave's Dictionary of Political Economy*. (Higgs, 1910)

Interestingly, Karl Marx observed in the third volume of his *Capital* that “with the advance of capitalist production the utilization of the excrements of production and consumption is extended” by finding them uses in other lines of work. He suggested that the “general requirements” for the creation of valuable by-products out of industrial residuals were large volumes along with technical and scientific advances. He further observed that the reworked waste not only serves as inputs to production, but also reduces the costs attributed to new raw materials. Because this reduction in costs increased the rate of profit, Marx deemed industrial waste recovery the “second great branch of economies in the conditions of production” after economies of scale. (Marx, 1909pp. 96, 120)

While the profit motive and the intense competition that doomed stagnant businesses to oblivion were recognized as the primary driving forces behind widespread by-product

development, some authors also addressed the often beneficial impact of legal and regulatory constraints in this respect.

2.2 Impact of Legal and Regulatory Constraints on By-Product Development

Despite a now widespread lack of appreciation of the issue, a host of environmental problems were historically and still are successfully addressed through legal actions based on private property rights. (Pontin, 2012, 2013) In countries of British heritage, parties affected by the emissions of industrial and other activities could seek relief through traditional common law actions of trespass (any entry on the property of another) and nuisance (indirect or intangible invasions - such as odors and noises - or unreasonable interferences with another's use or enjoyment of his property). The legal remedies, if appropriate, were injunctive relief (an order by the court requiring the cessation of offensive activity or specifying corrective action) or compensatory damages, or a combination of the two. (Brubaker, 1995, Meiners and Morriss, 2000) Not surprisingly, manufacturers had strong incentives to avoid property rights-based lawsuits or their threat. Discussing industrial waste reclamation in the French context, the engineer Paul Razous (Razous, 1937p. vii, our translation) thus observed that, apart from their commercial benefits, the development of by-products out of residual materials had the additional benefit of "preserving the healthiness of the neighborhood and to consequently avoid the payment of damages for tort inflicted to surrounding properties."

In some cases writers went a step further and anticipated the core PH argument. Perhaps the first author to do so in some detail was another French engineer (and later prominent politician), Charles de Freycinet, who conducted detailed surveys of public and industrial hygiene practices in Western Europe in the 1860s. He observed that the most flourishing factories inevitably got the most out of their waste and best knew how to bring them back "into the circle of operations," but that industrialists "would have surely remained ignorant a long time still if the necessities of improving sanitation had not directed research in this direction." No matter how one looked at the issue, however, the "natural law that governed sanitary improvements showed that the interests of the manufacturer

were in perfect accord with the general interest” and that “as long as science progresses and industrial procedures improve, harmony becomes more intimate and we can predict a day when, except for rare exceptions, industry will stop putting hygiene in serious danger.” (de Freycinet, 1870pp.7-8, our translation) De Freycinet drew two main lessons from his work:

“On the one hand, public authority would be wrong to abandon regulations for fear of harming production... when these have the goal of stopping serious causes of poor health; on the other hand, manufacturers would be ill-advised to see harmful impediments to their industry in these regulations. They must, on the contrary, tell themselves that the law, while obliging them to improve sanitation, does them a real service most of the time and that for lack of philanthropic considerations, it is in their own interest to respect the security and the well-being of their fellow men.” (1870, p. 8, our translation)

Two generations later, the German-born American economist Erich Zimmermann (1933p. 768) similarly identified “legal action” as a “third factor” leading to a fuller utilization of energies and material substances (after scientific advances and economies of scale triggered by increased competition). As he put it: “Not all business is free to strive from the maximization of profit without social interference” and in some cases “waste elimination may be enforced by law even if it does not pay in the economic sense.” Sometimes, however, “a corporation compelled by legal action to eliminate a waste at great expense, and unable to pass the cost on to the consuming public, may succeed, with the aid of scientific research, in converting the waste products into paying by-products - perhaps, even into a product of major importance.”

De Freycinet, Zimmermann and others’ arguments along similar lines were based on both personal observations and secondary knowledge of well-publicized cases. For example, Simmonds (1876 p. 39) observes that the blood and offal of a Cambridge (MA) pork-packing establishment “had become such an offence to the neighbourhood, that the proprietors were threatened with a perpetual injunction,” but that as a result of such pressures, the owners not only found a way to remediate the problem, but also to earn a profit out of it. Perry (1908) and Clemen (1927) later described similar cases in the same industry while Perry (1908) documented a similar dynamic in the early days of

petroleum refining. As with Porter's original article, however, these authors only devoted a few lines to the idea.⁶ Because the two most prominent cases for which PH-like claims were once made are probably the British alkali industry and copper smelting operations in Tennessee, we now turn to a brief examination of the relevant facts.⁷

3. THE BRITISH ALKALI INDUSTRY AND THE ALKALI ACT

In the British chemical engineer John Baker Cannington Kershaw's opinion, the "most notable example of a recovery process imposed upon the manufacturers by law, which afterwards became a source of large profits, is that of the recovery of hydrochloric acid from the waste gases of alkali works" that followed the adoption of the 1863 Alkali Act. (Kershaw, 1928 p. 3) "The condensation of this gas, and its recovery in liquid form," he argued, "led to the foundation of a new branch of industry." In following years, a "very large share of the profits" made in this line of work would be "derived from the chlorine products, for which the recovered hydrochloric acid served as the source of chlorine." (idem) Legislative efforts pursued at the time of his writings to reduce smoke emissions from domestic and factory chimneys, he argued, would therefore eventually follow the same course and ultimately result in more efficient thermal processes.

Although he did not cite earlier references, Kershaw had been preceded by the geographer Vaughan Cornish (Cornish, 1892p. 208) who argued that "the alkali-maker cared for none of [his externalities] and the Government found it necessary to legislate in order to protect the health and property of the manufacturer's neighbours." Soon after being "compelled to condense and retain fumes" and "being obliged to go to the expense of collecting the hydrochloric acid," the alkali manufacturer "set to work to compensate himself for the outlay involved, by utilizing [this] formerly waste product, which now

⁶ Peter Lund Simmonds was a Danish-born British technology and trade journalist who wrote a compendium on industrial waste recovery and directed a museum exhibit on the topic. George Powell Perry was a pastor while Rudolf Alexander Clemen was a Northwestern University economist and America's best known expert on the by-product development in the meat-packing industry.

⁷ This assessment is based on our own research of such cases. Other potential cases could have included copper smelting in Butte, Montana, and the Swansea Valley, Wales, but they seem less straightforward in terms of PH-like claims. LeCain T. The Limits of Eco-Efficiency: Arsenic Pollution and the Cottrell Electrical Precipitator in U.S. Copper Mining. *Environmental History*. 2000;5:336-51, Newell E. Atmospheric Pollution and the British Copper Industry, 1690-1920. *Technology and Culture* 1997;38:655-89.

became a by-product of the manufacture.” Interestingly, Cornish further observed that later on, as in the case of the “more provident producer of iron... [the alkali-makers] prolonged prosperity has only been attained by minimizing wastefulness as much as the wasteful tendency of all natural change permits.” (idem: 209)

More recent historical accounts of this episode written before Porter formulated his hypothesis make similar claims. For example, the French historian François Crouzet comments: “Belching out clouds of poisonous smoke and turning out dangerous waste-products, [the British soda producing] industry created moon-like landscapes around its works, until government intervention forced it to recover for use as much as it could of its by-products, which turned into a source of profit.” (Crouzet, 1982 p. 224) Similarly, American political scientist John McCormick (1989 p. 5) argues that alkali producers were “unwilling to take action unless their competitors did likewise.” While “farmers and landowners complained... little was done until Lord Derby... took up the matter in the House of Lords... [and] was instrumental in the passage of the Alkali Act of 1863” (idem).

As we will now argue, however, the relevant legal and technological details of what the chemist and politician Lyon Playfair once labelled the “monster nuisance of all” (Parliament of Great Britain, 1862 p. 99) and what would more recently be described as the “archetypal command and control” environmental regulation (Pontin, 1998 p. 663) cast serious doubts on its PH-like interpretation.⁸

To summarize, soda ash obtained from the ash of sea plants such as kelp and potash obtained from land plants such as Northern European and American conifers, collectively termed alkali, were once vital inputs in industries ranging from glass, textile and ceramics to gunpowder, fertilizer, soap and paper. In the late eighteenth century, shipping costs along with insufficient and unreliable supply sources paved the way for the development of substitute products. In 1791, the Frenchman Nicolas Leblanc patented a method to

⁸ For more comprehensive recent discussions of this case, see, among others, Dingle 1982, Pontin 1998 and 2007, and Reed 2008 and 2012.

produce it from common salt, coal, limestone and sulphuric acid, changing the relative importance of the two alkalies by making soda much more plentiful and cheaper than potash. (Haber, 1969)

The Leblanc process eventually led to the development of a large industry that struggled with two very potent waste products, hydrogen chloride gas and a residual mud in which as much as 90 percent of the (then costly) sulphur⁹ used in soda manufacture ended up, resulting in a potent mix of calcium sulphide, unburnt coal, coal ash and sodium sulfide. The acidic gas went up the chimney and had serious detrimental effects upon the surrounding populations, crops and buildings. In the words of one contemporary, “the grass perished, the trees died, crops were ruined, and the birds and insects departed or became extinct.” (Kingzett, 1877 p. 235) One way to reduce complaints from surrounding neighbours was to send this gas up through “chimneys so lofty as to overtop our loftiest steeples, in order to carry away the enemy as far above the region of vegetation as possible”. (Anonymous, 1852 p. 98) It was obvious to all, however, that just as “the best way of destroying an enemy is to make him a friend, so the best way of getting rid of a noxious gas is to find a method by which it may be retained in a useful form”. When this would be done, those chimneys would “remain as so many huge monuments of the ignorance of the past.” (idem.)

For its part, the mud was disposed of in large heaps near alkali works that had required the purchase of large tracts of land or else, also at great cost, “carried away to the dumb fishes of the sea who cannot petition Local Boards or Parliament nor bring a suit for nuisance.” (Mond, 1871 p. 75) Despite being composed of potentially valuable substances, it was a useless product “which nobody can apply to any profitable purpose, nobody will buy, and nobody even accept as a gift”. (Anonymous, 1852 p. 99) The problem with this residual was not only its disposal costs, but that it reacted with rain water loaded with hydrogen chloride gas from nearby plants, producing noxious hydrogen sulfide. When dried, the resulting substance often absorbed tremendous

⁹ In an attempt at consistency, we use “sulphur” vs. “sulfur” throughout. However, both spellings appear as we chose to keep the quotations as the authors intended. As both spelling are acceptable, we chose not to insert [sic] in these instances.

amounts of thermal energy from the sun, caught fire, and released sulphur dioxide. (Roderick and Stephens, 1974, Simmonds, 1876) Furthermore, this residue, “poison[ed] the water of all wells and rivers to which it [had] access”. (Mond, 1863 p. 27) Not surprisingly, chemical manufacturers were then “looking wistfully towards the day when they may perchance save a penny out of this monstrous commercial nothing”. (Anonymous, 1852 p. 99) This is not to say that they were not pro-active in this respect. As one observer put it in 1877:

“No subject has presented more difficulty in treatment than that of [alkali] waste, so that for years it has accumulated, and has evolved poisonous gases into the air, and given off offensive drainings which have polluted many streams. Nevertheless, this nuisance has not existed so long through any lack of investigation; processes upon processes have been devised, but until quite recently none of them have been attended with that success which is essential to a large industry. (Kingzett, 1877 pp. 133-134)

By the late 1820s, air pollution from Leblanc soda works inspired nearby landowners to resort to the common law system for some relief. (Garwood, 2004 p. 101) In some cases, the resulting legal battles against the chemical manufacturers were sufficiently expensive so as to drive numerous firms out of business. (Haber, 1969 p. 19) In others, legal actions resulted in substantial compensations being disbursed by alkali manufacturers, although most payments had typically been agreed upon through voluntary agreements or arbitration. (Dingle, 1982) Vast sums of money were not only expended on disposing of the residual mud and in developing technical solutions to both problems (Roderick and Stephens, 1974), but also on “innumerable attempts to supersede” the Leblanc process with other manufacturing approaches. (Mond, 1863 p. 27)

In the first half of the nineteenth century, when the number of producers was still small and the culprit easy to identify, landowners were successfully able to sue alkali polluters. By the 1850s, however, the growing number of producers, the increased concentration and urbanization of this industry, and the erection of large smokestacks to disperse

emissions made legal actions increasingly difficult.¹⁰ Increased pressure from a campaign organized by prominent land owners, combined with incapacity to mandate the use of effective anti-pollution technology on a minority of reluctant producers, led the leading alkali manufacturers to accept the need for a country-wide legislation that would make at-source condensation of the waste hydrochloric emissions mandatory, provided that it would not impose too great a cost burden on their industry. In the words of a prominent actor at the time:

“The feeling among those who conduct their business properly is they would be *exceedingly glad* to have legislation to compel gas to be condensed, because then those at present doing their work in a slovenly way would conduct their business properly, and those who manage their works a proper way would be relieved from the consequences of the others misdeeds.” (William Gossage in Parliament of Great Britain, 1862 p. 85, our italics)

The British Alkali Act, passed in July 1863 and effective on January 1st 1864¹¹, required the absorption of 95% of the hydrochloric gas emission by whatever method was preferred by the manufacturer, a provision enforced by a new central (but small and staffed by part-time employees) inspectorate headed by Scottish chemist Robert Angus Smith. The initial pollution-reducing steps were accomplished by having the waste gas sent up through a stone tower filled with coke, while water simultaneously trickled down through to absorb the hydrogen chloride. The end product of this process was aqueous hydrochloric acid.

The key point of this legislation - and one which sheds some interesting light on its PH-like interpretation - is that the pollution control technology was originally developed by

¹⁰ The situation in Liverpool, St. Helens and the Midlands was especially problematic, but this was not the case on the Tyneside and Widnes (north-west England) where predominant winds carried the emissions away over a river and mud banks, respectively. Of course, the relocation of some operations to more remote areas had often been done for the explicit purpose of removing nuisances from populated areas. Haber LF. *The Chemical Industry during the Nineteenth Century: A Study of the Economic Aspect of Applied Chemistry in Europe and North America*. Oxford: Oxford University Press; 1969.

¹¹ Later amended were adopted in 1874, 1881, 1892 and 1906, most notably to include conduct-based standards (best practical means) to the early emission limit.

William Gossage in 1836 and was already in widespread use in the early 1860s. As Gossage himself observed at the time: “Almost all of the trade are using it now, some more carefully than others; those who use it more carefully do not do any mischief; those who use it carelessly of course do mischief.” (Parliament of Great Britain, 1862 p. 83) Interestingly, Dingle (1982 pp. 535-537) argues that Gossage first develop his apparatus as a result of lawsuits by wealthy neighbors, while Gossage himself commented that he engaged in this pursuit because his “neighbours began to complain that [he] was destroying crops and so on” (Parliament of Great Britain, 1862 p. 83) perhaps suggesting that he might have done so without judicial procedures. Of course, the threat of lawsuits might have helped focus his mind on the issue...

Be that as it may, a proven pollution control technology not only existed prior to the adoption of the Alkali Act, but was already used by most manufacturers, albeit with varying degrees of success. As Gossage (1871) would point out a few years after the adoption of the Act, some manufacturers’ recovery rates already exceeded 99% around the time of its adoption. The original requirement was thus “well within the technical means then available.” (Hardie and Pratt, 1966 p. 35) Indeed, it was only the existence of a preexisting practical technology that made the legislative control of the alkali industry a possibility. (Dingle, 1982, Williams, 1958) Notably, legislators originally did not target other damaging industrial processes without known practical solutions at the time, such as ‘wet copper’ smelting. (Campbell, 2000)

The mindset of the first alkali inspectors, typically men with previous relevant industrial experience and well-disposed towards manufacturers, was described as emphasizing the education of manufacturers on anti-pollution technology and relegating prosecution to a last resort measure. As Garwood (2004 p. 103) observes, the inspectors’ philosophy amounted to what would now be called a “compliance” or “negotiated compliance” strategy. Freycinet (1912 p. 85, our translation) summarized his own observations of the relationship between inspectors and industrialists as follows:

Commented [p1]: This seems inconsistent with Garwood earlier in the sentence (de Freycinet is repeated within the parenthesis)

“I admired the candor of the relationship established between manufacturers and authorities. Dr. Angus Smith was consulted by them, he spoke to them with complete abandon, he helped them appreciate the science involved and became an amicable guide for them, all the while remaining a conscientious controller. I noted that the industrialists never hid anything from him, nor from his collaborators, few in number but of proven merit. With his personal influence, he obtained much more than through repression; an opinion, a direction on his part was welcomed with eagerness and recognition. This happy state of mind was due to the elevated position of inspectors and to the sense of legality, deeply rooted in the population.”

In spite of the congenial relationship between the inspectors and the industry, inspectors pushed to revise and reinforced the Act in later years as, according to technology historian Peter Reed, its provisions “were grossly inadequate to meet the rising scale of nuisances affecting both the environment and public health.” (Reed, 2012 p. 133) Reed further argues that the Home Office and the Local Government Board chose not to act at that time, thus suggesting that legislators had little interest in imposing more regulations on the industry. Despite this lack of additional regulatory constraint, however, entrepreneurial efforts to reclaim polluting waste and turn it into valuable by-products would ultimately prove successful.

To summarize, although Gossage towers proved effective in lessening air pollution, the technology was less than ideal because the resulting solution was at first too dilute for the preparation of chlorine. While technological advances eventually made the recovery of chlorine from hydrochloric acid more appealing, only about 20% of it could find a lucrative market in the production of bleaching powder in the early 1860s. Most hydrochloric acid captured by Gossage towers was thus released in brooks and streams, endangering (and often killing) the fish residing in these habitats. (Reed, 2008 p. 111, 2012 p. 135) In time, however, advances in the large-scale production of chlorine-based products and the creation of new markets for such products (for instance, the introduction

of Esparto grass in paper making created a new demand for bleaching powder), proved environmentally beneficial. (Campbell, 2000, Hardie and Pratt, 1966) Interestingly, the best agent to decompose hydrochloric acid turned out to be binoxide of manganese, long a residual in another manufacturing process. Indeed, “the demand for manganese oxide was so great and the price so high that a reclamation of the spent manganese was looked upon as desirable... this was accomplished, adding greatly to the resources of the chlorine industry for bleaching.” (Kittredge, 1902 p. 4)

The residual mud, a “problem and a reproach to chemistry” (Anonymous, 1868 p. 352), proved more problematic. As Simmonds (1876 p. 398) observed, the larger alkali works produced between five and six hundred tons of this residual per week. Because sulphur accounted for about 40 percent of the cost of manufacture, the problem was also an economical one. (Haber, 1969 p. 23) Not surprisingly, from the 1830’s onward, several attempts were made at the profitable utilization of this residual. (Simmonds, 1876 p. 398) In the words of the chemist Ludwig Mond (1863 p. 27) some of the most “distinguished chemists and intelligent manufacturers” had devoted countless hours to the development of a cost effective method to recover its potentially valuable sulphur and several manufacturers had “spent thousands of pounds in trying to turn this obstinate substance to advantage.” (Mond, 1871 p. 75)

This research work yielded some valuable products, although these developments only consumed (relatively) minute amounts of this residual. Some of the early commercial markets included the manufacturing of floors, bricks and tiles, antichlor, and a photograph fixing agent. (Simmonds, 1876 p. 399) In 1887, Alexander Chance finally developed a commercially viable process to extract sulphur by blowing carbon dioxide from lime kilns through a suspension of calcium sulphide waste. This liberated hydrogen sulphide gas and left chalk as a by-product. This development, however, had again necessitated much developmental work and expenses - almost £10 000¹² between 1882

¹² According to MeasuringWorth.com, this amount would be equivalent to £747 038 in 2007 using the retail price index.

and early 1884 alone (Weldon, 1884) - and built upon numerous previous failed experiments by other manufacturers. In the words of one contemporary:

“In 1882 Messrs. Chance Brothers perfected Schaffner and Halbig’s process for the recovery of sulphur from alkali waste. So far it was successful, but not commercially. Now Mr. Alexander Chance, after exhaustive experiments, has patented a process whereby the whole of the sulphur in alkali waste is recovered.” (Anonymous, 1887b p. 207)

As Campbell (2000 p. 103) observed, the economics of the Leblanc process became increasingly complex over time:

“As the sources of waste in the Leblanc process were tackled one by one, so the process became too complicated for easy management. An early Leblanc works would have taken in sulphur, salt, limestone, nitre and coal, turning them into a single saleable produce, soda. By 1890 the same works would take in pyrites, salt, nitre, limestone, coal and manganese ore, producing soda, caustic soda, bicarbonates, thiosulphates, bleaching powder, hypochlorites, chlorates, sulphuric, nitric and hydrochloric acids, pure sulphur, sodium sulphide, calcium sulphate and Epsom salts.”

Reviewing early advances, Kingzett (1877 p. 234) observed that during the entire progression of the alkali trade, the industry continually made improvements to utilize waste products more efficiently. “In fact, its history, like that of the English nation, is one of slow progression, in which advancement has been made chiefly by a process of evolution rather than by one of revolution.” In a review of Kingzett’s book, Pattison Muir (1877 p. 181) further observed that while both science and the alkali industry had benefited by the resulting innovations, society had been provided with a clear illustration of what future by-product innovation might hold. Crucial in this process were competitive pressures, for they ensured that:

“if one producer, by the utilisation of a waste product, or by the adoption of an innovation, can enter the market and sell with greater advantage than his compeers, they are generally not slow to follow. It is therefore the object of manufacturers, for the sake of their own purse – with them the strongest argument – to make the most out of a certain outlay, and this can best be done by working with care, and keeping down waste as low as possible. Such waste proves a nuisance as well as an expense.” (Kingzett, 1877 p. 235)

As Clow and Clow (Clow and Clow, 1958 p. 241) would later write, “economics brought about the need for improved processes and attention to the utilization of waste products,” while “social pressures resulted in a demand for the more careful operation of the industry.” As could be expected, however, parallel lines of research brought about a process that finally superseded the Leblanc method, the Solvay or ammonia-soda process, which used carbon dioxide and ammonia (typically obtained as by-products of coal gas and coking operations) as its main inputs. (Clow and Clow, 1958) The Solvay process produced soda more cheaply, created no unpleasant byproducts and, after a few years of developmental work, allowed the recovery of chlorine. As one observer put it at the time:

“... the various proposed new processes... all comply with at least one of the ideas towards which all progress in such matters must henceforth tend. They all possess in common one feature which will certainly be held to be essential to all industrial chemical processes in a not distant future. They are all processes yielding no waste product. They are all processes completely utilizing all the constituents of all their raw materials. Excepting coal and water, nothing would be manipulated in any of them which was not finally yielded either as a commercial commodity, or as regenerated reagent for use again. That way certainly lies the future.” (Weldon, 1884 p. 54)

Indeed, the Leblanc soda works only lasted as long they did (into the 1920s) because of the profitability of bleaching powder and other by-products which made up for the fact that from the late 19th century onwards the price of soda did not otherwise cover the cost of producing it in this fashion. Interestingly, the shift from the LeBlanc to the Solvay process eliminated the chief market for sulphuric acid, thus releasing sulphuric acid for other industries, and created a great demand for ammonia. This change in demand encouraged the shift from (more polluting) beehive to by-product coke ovens because the latter yielded sulfate of ammonia as the primary by-product. Meanwhile, the development of electricity production at the end of the nineteenth century eventually allowed for the electrolytic production of chlorine and caustic soda (sodium hydroxide) from brine. Soon the pulp, paper and textile industries began to manufacture their own chlorine electrolytically, with caustic soda as a by-product that was then sold on the open market, threatening the viability of Solvay plants. In turn, managers of these plants reacted by building their own electrolytic plants where they produced cheap by-product chlorine and caustic soda. (Campbell, 2000, Zimmerman, 1933)

In short, the available evidence seriously undermines the argument that the 1863 Alkali Act triggered a new technological approach or was primarily responsible for the development of residuals. In our opinion, it did at best catalyze outcomes already well under way. We would further suggest that more ancient private property rights approaches to pollution control – such as might have been involved in the development of condensation towers - were probably more crucial if one is to look for PH-like claims. At any rate, new technologies and markets were certainly as crucial. Furthermore, the development of cleaner and more economical alternatives such as the Solvay process seem almost entirely attributable to the search for increased profitability. For this reason alone, in time new and better ways of doing things built on widely available industrial residuals would have spontaneously shut down older and more polluting operations.

4. COPPER BASIN SMELTING OPERATIONS

In a survey of American industrial chemistry written over a century ago, the prominent American chemistry professor Charles E. Munroe (1910 pp. 571-572) discussed the then well-known case of copper smelting air pollution in and around Ducktown,¹³ a small city in the center of the Copper Basin, an area of approximately seventy-five square miles located mostly in Tennessee, but also extending over neighboring Georgia and (to a very small extent) North Carolina.¹⁴ Although “devastating sulphurous fumes” had triggered numerous legal actions in preceding years, they had by then increasingly “been converted into valuable merchandises.” In his opinion, cases such as this illustrated “the operation of a wholesome law in economies” according to which “frequently an urgent reason for saving waste is to suppress a nuisance, for I do not hesitate to assert that the existence of a public nuisance is evidence of the existence of an economic waste.” A year earlier, Johns Hopkins historian James Curtis Ballagh (1909 p. 220) had similarly observed that “denudation of forest and damage of remaining vegetation by acid fumes marked the earlier years of mining” in this corner of Tennessee, but that at the time of his writing “little wood is used for fuel and the poisonous sulphur fumes are condensed into sulphuric acid urgently needed in the Southern states for the preparation of fertilizers from phosphate rock.” In this way “waste and destruction” had been replaced by “an intelligent utilization and conservation of natural resources.”

Four decades later, Stanford chemistry professor Robert E. Swain (1949 p. 2385) would summarize the case by observing that Ducktown smelting operations had run “the entire gamut of injury to vegetation from the early days of heap roasting on through to furnace roasting and low stacks, then to tall stacks, and finally to sulfur dioxide recovery as sulfuric acid” and that it was out of litigation procedures that “a great industrial

¹³ Heinrich (1896), Levy (1912), Quinn (1991, 1993) and Maysilles (2011) are more comprehensive accounts of various aspects of the case while Gerard and LeCain (2001) provide a broader background to legal disputes surrounding American mining operations at the time.

¹⁴ Interestingly, several contemporaries thought sulphurous smoke beneficial for human health (Quinn, 1993, p. 583) while some local residents praised the local environment for its absence of mosquitoes and snakes (Maysilles 2011, p. 5). Quinn (1993, p. 599) further observes: “Turn-of-the-century photographs do show what most now would regard as a bleak industrial landscape... Yet captions contemporaneous with the photographs express no displeasure with the condition of the environment. Moreover, in the midst of such a setting, businesses were thriving and people were going about their daily lives. This landscape was their home, their means of support.”

achievement” came through, “the design, erection, and successful operation of an adaptation of the lead chamber process to convert sulfur dioxide from copper smelting operations to sulfuric acid.” These developments revived the phosphate fertilizer industry and proved beneficial for southern plantations, “many of which had been abandoned except by sharecroppers owing to the exhaustion of soil nutrients.” (idem, p. 2387)

Environmental destruction and by-product development in the Copper Basin were obviously influenced by the nature (copper concentration and presence or absence of sulphur and other elements) and accessibility (proximity to the surface and processing facilities) of local ores, raw material prices, and available mining, smelting and transportation technologies (including advances achieved in distant operations). Some contemporaries, however, singled out the allegedly beneficial impact of air pollution litigation, first in Tennessee courts, who in retrospect appear to have been more consistently pro-industry, and later in the American Supreme Court which threatened to shut down operations. For instance, according to one contemporary university lecturer in metallurgy (Levy, 1912 p. 188) in Ducktown as in other locations with similar production problems, “[legal] interference with the uncontrolled dispersion of then-considered waste products has often proved of ultimate benefit and a source of much profit to their producers” because “the enforced treatment of highly sulphurous furnace gases has in several instances resulted in considerable gain to the copper smelters.”

Industrial advances in the Copper Basin can be summarized as follows. Successful on-site processing of the best deposits began in the early 1850s and lasted about two decades. The large-scale development of less valuable ores, however, had to wait until the 1890s when the building of a railroad, higher prices and technological innovations made their exploitation profitable. Two significant environmental problems resulted from these operations. In the first decades, fuel and construction materials provisioning came from the extensive logging of surrounding forests. While coal supplied by the railroad eventually provided a better alternative to charcoal and cordwood, the Copper Basin flora was severely damaged in the process because of abundant rains that washed out most topsoil and the regular burning of deforested land that had been converted to cattle

ranges. On top of this, the local topography (low hills surrounded on all sides by mountains) and climatic conditions (rainy weather, temperature inversion and abundant natural fog) trapped increasing volumes of sulphur dioxide and other contaminants emitted by smelting operations. By the turn of the twentieth century, about thirty percent of the Copper Basin had been completely denuded of vegetation while the remaining portion had been largely denuded.

Not surprisingly, many early commentators deplored the fact that much sulphur which could be “great importance” for the production of fertilizer was “lost in the present mode of treating [ores].” (Drown, 1873 pp. 37-38) Early experiments, however, could not overcome the fact that the gas produced while smelting copper ore proved too intermittent and too varied to be a suitable input. (Weed, 1918 p. 1301) As Henrich (1896 p. 228) observed, while “no civilized community ought to be afflicted with the nuisance resulting from the continuous dissemination of scores of tons of sulphurous acid gas daily through that part of the atmosphere nearest the surface of the ground,” it was even more painful

“to contemplate the waste of about 20 per cent of sulphur (i.e. of 40 tons of sulphur per day) from each 200 tons of ore roasted. If this sulphur were only present in more concentrated form and capable of economical utilization, its value would greatly exceed that of the copper in the ore; but no practicable method of saving it is now available, and in the present state of our knowledge we can only endeavor to make this unavoidable waste of sulphur as little detrimental as possible to the agriculture and the forests of the surrounding country. To this end the ore must be roasted by a method which permits the collection of the roast gases, or at least the largest part of them, in a chimney that will deliver them at a sufficient height into the atmosphere.” (Henrich, 1896 p. 229)

According to Fulton (1915 p. 7) while emissions were causing “considerable friction between the metallurgical industry and agriculture,” smelting plant owners were

nonetheless “making every effort to devise ways and means to do away with possible damage and annoyance from smoke.” In the Ducktown district, the most significant advance made at the turn of the last century was pyretic smelting. This process smelt raw (‘green’) ore directly without roasting by treating unroasted sulphide ores in a blast furnace whereby the primary source of heat used to smelt the ore was derived from the rapid oxidation of the sulphides themselves. It was believed that this method would be less time-consuming, would lower the amount of carbon fuel (coke) needed in the smelter, reduce air pollution, and lower the cost per pound of the copper produced. The initial adoption of this technology, however, did not live up to the expectations of its proponents. Injurious emissions still escaped into the atmosphere, and since the new process allowed a scaling up of operations, total sulphur dioxide emissions actually increased as a result. (Quinn, 1993 p. 591)

As air pollution problems intensified, lawsuits alleging damage to health and valuable property (primarily commercially valuable forests and orchards) were filed from the mid-1890’s onward. They were first brought in the Tennessee State Court where judges proved disinclined to shutting down the copper smelting operations, arguing that “defendants cannot reduce their ores in a manner different from that they are now employing, and there is no more remote place to which they can remove” and that “the only proper decree is to allow the complainants a reference for the ascertainment of damages, and that the injunction must be denied to them.” (Weed, 1918 p. 159) Through actions from the neighboring state of Georgia, some plaintiffs then sought standing in federal court and a call for a permanent injunction against both Ducktown smelting operations. In 1907, however, the Supreme Court declined to enforce the injunction because the companies were then in the process of constructing sulphuric acid plants for the treatment of their smoke.¹⁵ This method proved successful to a large extent, reducing emissions by half, but insufficient to completely solve the problem.¹⁶ Smelters, however,

¹⁵ US Supreme Court, *Georgia v. Tennessee Copper Co.*, 206 U.S. 230 (1907) available at <http://supreme.justia.com/us/206/230/case.html>. *Georgia v. Tennessee Copper Co.*, 237 U.S. 474 (1915) available at <http://supreme.justia.com/us/237/474/> See Maysilles (2011) for a comprehensive discussion of the litigation process at the time.

¹⁶ The volume of sulphur released was 85.5% without recovery operations and 41.5% with these operations.

had a powerful incentive to improve recovery rates as Ducktown was located in the middle of an agricultural region where the demand for sulphur by the fertilizer industry was important. Indeed, the 1909 annual report of one of the two smelting companies indicated that by-product recovery had doubled the net profit earned per ton of ore. (Quinn, 1993 p. 589) By 1911 Ducktown had become home to the two largest sulphuric acid plants in the world, producing approximately 650 tons of sulphuric acid each day (Emmons and Laney, 1911), a volume which would later go up to approximately 1000 tons a day. (Swain, 1949 p. 2385) For a while, the production of sulphuric acid proved more lucrative than copper, turning the latter material into the *de facto* by-product. (Swain, 1949)

Following the 1907 Supreme Court decision, negotiations began between the State of Georgia and the Ducktown smelter operators for the payment of damages and by 1913 Ducktown operators disbursed an annual sum of \$16,500 to Georgia farmers. (Fulton, 1915 p. 84) However, in 1915, returning to the Supreme Court, lawyers for the state of Georgia asked for the closure of one of the Ducktown smelter operators on the grounds that while the newer recovery technologies were improvements over past practices, they remained insufficient. The chief justice then appointed a Vanderbilt University scientist to spend six months at company expense to study the emissions and the likely effect of new controls. In the meantime, the Court ordered the company to cut back production to further reduce emissions and determined that it would either be allowed to continue operation with additional and more effective anti-pollution equipment, or else would have to shut down. In the end, the firm satisfied the plaintiffs and the Court ended its oversight of the case.

As in the Alkali Act case, a straightforward PH-like scenario in the Tennessee Copper Basin seems unwarranted in light of the available evidence. In his recent comprehensive history of the case, lawyer Duncan Maysilles (2011 p. 7) observes that the “Georgia attorney general... repeatedly delayed or suspended the state’s case in the hope that new technology would preclude the need for an injunction” and that “the many stages of Georgia’s Supreme Court were marked by development of the new pyritic smelting process, the use of high smokestacks for attempted dispersal of sulfur fumes, and the

development of acid condensation plants to cover toxic fumes into marketable sulfuric acid.” Maysilles concludes that, overall, “the Supreme Court litigation *helped* to bring about a thorough transformation of the copper industry in Ducktown,” but that in the end Supreme Court actions “made little difference to either company [because the] case settled quickly on terms that required them *to do nothing beyond* what they were already committed to doing for solid business reasons” (idem, 7 and 122, emphasis added).

Historian Mary-Louise Quinn (1993 pp. 595-596) is similarly nuanced when she observes that:

“A number of sources have treated the manufacture of sulfuric acid from smelter gases in the Ducktown District as a development resulting from the U.S. Supreme Court decision. I contend this is not the whole story. While the court’s decision was handed down in May 1907, both companies had begun construction of sulfuric acid plants in 1906 and had been doing experimental work for some time before that... Clearly, pending litigation was an incentive to the companies to address the problem of escaping fumes. I propose, however, that the quest for improved operations and increased profit was a major driving force as well. Thus, when people write or imply that the sulfuric acid industry was forced on the Copper Basin’s mining/smeltering firms, they are giving too much credit to the role of litigation and no credit to the initiative of the companies themselves.”

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In short, the potential economic gains to be derived from sulphuric acid recovery had long been obvious and much developmental work and building of recovery operations had actually preceded the Supreme Court intervention. While initially these technologies proved only partly satisfactory, it seems almost certain that later higher recovery levels might have been achieved even without litigation.

5. CONCLUSION

In a recent review of the PH debate Ambec et al. (2013p. 2) state that more than two decades after the publication of Porter’s original article, “we continue to find conflicting evidence concerning the Porter Hypothesis, alternative theories that might explain the Porter Hypothesis, and oftentimes a misunderstanding of what it does and does not say.” The historical material covered in this essay contributes to this ongoing debate in a variety of ways.

First, it strongly contradicts Porter's indictment of the alleged passive behavior of past generations of manufacturers towards polluting residuals. Although some individuals were undoubtedly complacent in this respect, many (and certainly a vast majority of the successful ones) were not. The default assumption of environmental economists has traditionally been that profit maximization will lead managers to search for ways to reduce pollution, but only as long as benefits exceed costs. As a result, in the words of Ambec et al. (2013 p. 2): "[t]he traditional view of environmental regulation, held by virtually all economists, was that requiring firms to reduce an externality like pollution necessarily restricted their options and thus by definition reduced their profits. After all, if profitable opportunities existed to reduce pollution, profit-maximizing firms would already be taking advantage of them."

Yet, as Karl Marx and several other past observers understood, competitive pressures and the search for increased profitability have to the contrary always mandated a constant war on industrial waste. Analysis of the impact of environmental regulations on the development of 'win win' innovations must therefore acknowledge this historical reality to claim any validity.¹⁷ This war entails a more dynamic view of green innovations, characterized by intense competition. The firm that does not constantly innovate will cease to exist at some future date. Thus we present in this paper a more endogenous view of technological change than is presented in much of the environmental economic literature.

Second, PH-type arguments have a much longer and more complex history than is now believed to be the case. This can be interpreted as evidence that legal and regulatory pressures have historically provided additional incentives to develop win-win innovations, something which we do not dispute, but it does not tell us about their overall significance. Because of the absence of reliable historical data on the topic, we looked at two prominent cases for which strong PH-type arguments were once made.

¹⁷ A more comprehensive discussion of the environment and centrally planned economies can be found in Desrochers P. Industrial Symbiosis: The Case for Market Coordination. *Journal of Cleaner Production*. 2004;12:1099-110.

As we argued, nothing suggests that the British Alkali Act delivered significant ‘win win’ outcomes, even if one grants that the development of condensation towers (a mitigation rather than ‘win win’ innovation) was partly motivated by property rights-based litigation. While one could always argue that the Alkali Inspectorate might have played a role in diffusing profitable pollution-abating innovations, it would have been ill-advised to divulge trade secrets and we could find no evidence that it played a crucial role in their development. The available evidence also suggests that air pollution litigation in the Tennessee Copper Basin smelting operations was at best one factor among others and that it is not inconceivable that ‘win win’ innovations would have been developed because of economic incentives alone.

Commented [p3]: We sometimes use ‘’ and sometimes ‘’’
I think we should make up our mind on win win

Another issue raised by our evidence is the nature of Porter’s “well designed” environmental regulations. As usually framed by PH proponents, this typically involves replacing cumbersome and ineffective mandates and best available technology or requirements by more flexible taxation, performance and output-based approaches. The key issue in this case is that more directive approach such as “technological standards restrict the choice of technologies or inputs in the production process” while various environmental permits and “fees necessarily divert capital away from productive investments.” (Ambec, Cohen, 2013 p. 3) Even more problematic are rules and regulations that mandate the destruction or increase the potential liabilities of “hazardous wastes” which are essentially similar in their composition to “virgin products,” thus discouraging recovery attempts and promoting the wasteful use of resources. (Byers, 1991, Cheek et al. , 1995)

While the PH supporters’ stance on this issue is well taken, it is nonetheless problematic. As legal scholar Dennis D. Hirsch (2010 p. 1068) argued, the “information costs involved in accurately predicting the amount of pollution or waste reduction” that outcome-based standards could potentially yield “would be extremely high, rendering this approach practically unusable.” For instance, 3M’s Pollution Prevention Pays (3P) program resulted in approximately five thousand small and extremely varied projects throughout

the corporation. As Hirsch observed, “a regulator would find it extremely difficult and costly—if not impossible—to predict in advance the source, nature, and extent of these reductions. Moreover, the cost of measuring and monitoring the reductions achieved – another essential prerequisite for any outcome-based standard – would also prove excessive.” (idem) In the end, he argues, Porter “fails to explain that outcome-based standards will only function properly in limited circumstances and that they will not work to promote much of what we have come to see as green business.” (Hirsch, 2010 p. 1098)

In our opinion, however, the real test of the effectiveness of “well-designed” environmental regulations should be their superiority over traditional common law (or non-regulatory) approaches which gave producers complete freedom to innovate and did not take away resources from them.¹⁸ We simply cannot conceive how distant regulators unfamiliar with day-to-day operations could design regulations in such a way as to deliver a superior outcome. And without being overtly cynical, it hardly needs stating that the political and judicial processes that underlay the formulation of environmental regulations is subjected to regulatory capture, political compromise and faulty judgment that might result in the mandating of inferior or costlier technological alternatives

Though the evidence presented in this paper is not definitive, it suggests that the rational interest of business has never been as far apart from the environmental interest of society as many academics, activists, and regulators currently believe. True, as Porter and his supporters suggest, private sector actors may sometimes lack vision, information, incentives and capital to invest in the development of win-win innovations. It is also probably the case that when a property-rights approach is not feasible, other less flexible approaches must be attempted in order to address pressing problems. However, greater familiarity with the real world history of business and technological development suggests a more positive outlook. Evidence from these case studies suggests that holding corporations accountable while giving them maximum flexibility to explore solutions can be very effective. Greater freedom of entry in markets, profit motive and entrepreneurial

¹⁸ For a summary overview of various approaches to environmental regulation, see Taylor C, Pollard S, Rocks S, Angus A. Selecting Policy Instruments for Better Environmental Regulation: a Critique and Future Research Agenda. *Environmental Policy and Governance*. 2012;22:268-92.

competition provide businesses with strong incentives to continually improve the use of resources through recovery and by-product development. Proper provision and enforcement of private property rights will help the invisible hand develop a green thumb, but expecting a regulatory glove to be the main driver of sustainable development is in the end unrealistic.

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