Innovation, Regulation and the Selection Environment

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I. Introduction

No one doubts the profound impact that technological change has had upon society and the environment throughout history.[1] The internal combustion engine, plastics, microelectronics: these and other innovations have contributed to economic growth, but have also imposed significant burdens on the environment.[2] Yet the relationship between technology, economic growth and environmental quality is both complicated and nuanced. While some may view technological change as the bane of environmental protection, many others consider it to be a critical element of effective environmental policy.[3]

In thinking about environmental policy and technological change, it is helpful to separate the concept of technological change into two parts: "commercial innovation" and "environmental innovation". Commercial innovation refers to the invention, development and ultimate diffusion of new products or processes for commercial purposes, for example to enhance a firm's productivity or competitiveness.[4] Commercial innovation would include such things as the personal computer, the cellular telephone, and the compact disc. Environmental innovation

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[1] See John T. Preston, *Technology Innovation and Environmental Progress, in* THINKING ECOLOGICALLY 136, 136 (Daniel C. Esty & Marian R. Chertow eds. 1997).

[2] Giovanni Dosi, *The Research on Innovation Diffusion: An Assessment*, in DIFFUSION OF TECHNOLOGIES AND SOCIAL BEHAVIOR 179, 179-80 (Nebojša Nakićenović and Arnulf Grubler eds. 1991) (hereinafter "*Assessment").*

[3] *See, e.g.,* DAVID M. DRIESEN, THE ECONOMIC DYNAMICS OF ENVIRONMENTAL LAW __-__ (2003); RENE KEMP, ENVIRONMENTAL POLICY AND TECHNICAL CHANGE1 (1997); Scott R. Milliman & Raymond Prince, *Firm Incentives to Promote Technological Change in Pollution Control*, 17 J. ENVTL. ECON. AND MGMT. 247, 247 (1989); ALLEN V. KNEESE & CHARLES L SCHULTZE, POLLUTION, PRICES AND PUBLIC POLICY 82 (1975) ("[O]ver the long haul, perhaps the most important single criterion on which to judge environmental policies is the extent to which they spur new technology toward the efficient conservation of environmental quality.")

[4] *See* ORGANIZATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT ("OECD), ENVIRONMENTAL POLICY AND TECHNICAL CHANGE 10 (1985) (defining "general business innovation" to be innovations made for commercial purposes); Richard B. Stewart, *Regulation, Innovation and Administrative Law: A Conceptual Framework*, 89 CAL. L. REV. 1256, 1261 (1982) (defining "market innovation" to include innovations the "increase market measures of output per unit of labor or other input and thus increase productivity as measured by traditional national income accounting.")

contemplates product or process innovations intended to reduce or remediate the impacts of human activity on public health and the environment.[5] Environmental innovation encompasses environmentally beneficial technologies, such as pollution control technologies or "clean technologies" that reduce or eliminate the generation of pollution during production.[6]

Environmental innovation offers at least two significant social benefits beyond the obvious potential economic value inherent in technological innovation generally.[7] First, it allows us to keep pace with the increasing flow of environmental issues, providing new responses and solutions to emerging concerns.[8] For example, the same industry that brought us ozone-depleting chlorofluorocarbons also developed non-CFC substitutes when public policy and international accords demanded it.[9] Second, environmental innovation can also reduce the cost of pollution management, making environmental improvement less expensive. Such cost-reducing changes can ease the perceived conflict between environmental

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[5] *See* OECD, *supra*, n. __, at 10 (discussing "compliance innovations" designed to ensure compliance with environmental regulations at the lowest cost); Stewart, *Conceptual Framework*, *supra*, n. __, at 1261 (describing "social innovation" to include new products and processes that are less polluting and safer.)

[6] Environmental technologies typically include (1) pollution control technologies designed to capture and then destroy or immobilize pollutants before they enter the environment, (2) pollution prevention technologies such as process changes, product changes or recycling efforts intended to reduce the creation of pollutants at the source, and (4) remediation technologies intended to clean up the environment after it has been affected by pollutants. NATIONAL ADVISORY COUNCIL FOR ENVIRONMENTAL POLICY AND TECHNOLOGY (NACEPT), REPORT AND RECOMMENDATIONS OF THE TECHNOLOGY INNOVATION AND ECONOMICS COMMITTEE, PERMITTING AND COMPLIANCE POLICY: BARRIERS TO U.S. ENVIRONMENTAL TECHNOLOGY INNOVATION 22 (1991) [hereinafter BARRIERS) (establishing a "hierarchy of technological approaches to environmental improvement," including pollution prevention, recycling, control, and cleanup technologies); KEMP, *supra*, n. __, at 11. "Clean technologies" are a subset of environmental technologies that a technology or process that generates less waste or emissions than the norm. David Allen, *The Chemical Industry: Process Changes and the Search for Cleaner Technologies*, in REDUCING TOXICS ___ (Robert Gottlieb ed. 1995).

[7] OECD, *supra*, n. __, at 9-11 (discussing the vital contribution that technical change makes to economic growth and productivity); Zvi Griliches. *R&D and Productivity: Econometric Results and Measurement Issues* 52, 81(describing research and development as a "major source of economic growth").

[8] *See, e.g.,* GEORGE HEATON ET AL., TRANSFORMING TECHNOLOGY: AN AGENDA FOR ENVIRONMENTALLY SUSTAINABLE GROWTH IN THE 21ST CENTURY 1 (1991); Richard B. Stewart, *Regulation, Innovation, and Administrative Law: A Conceptual Framework*, 69 CAL. L. REV. 1256, 1260-61 (1981) [hereinafter *Conceptual Framework*]; NACEPT, BARRIERS, *supra*, n. __, at 27. The Superfund program provides one striking example of this point. As knowledge of the nature and scope of various forms of environmental contamination grew, government and private researchers began to develop improved and new technologies to address the varied forms of contamination. For example, today there are numerous technologies available to remediating various forms of soil contamination, including soil vapor extraction, in situ thermal treatment and phytoremediation (which uses plants to withdraw contaminants from the soil).

protection and economic development, and thus provide for continued growth in both areas.[10] Consequently, most regulators and commentators conclude that regulation should be crafted so as to encourage and support environmental innovation.[11]

However, policy makers and scholars continue to struggle over exactly how to accomplish that goal.[12] In the legal literature in particular, debate concentrates primarily on whether the dominant "command and control" form of regulation prevents businesses from developing and adopting innovative environmental technologies.[13] Although this debate has produced many helpful insights, its generally myopic focus on regulatory form and standard economic analysis ultimately limits its usefulness. Regulation must operate in the real world, and in the real world regulation is but one of many interrelated factors that affect a business firm's behavior.

In this article, turn attention to the broader socio-economic factors that affect innovative behavior by business firms. A firm's technology choices—and its response to regulations intended to shape those choices—are influenced by other actors (such as suppliers, trade associations, customers, and competitors), by

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[9] *See* KEMP, *supra*, n. __, at 225-230 (discussing the phase out of CFCs).

[10] Timothy F. Malloy, *Regulating by Incentives: Myths, Models and* Micromarkets, 80 TEX. L. REV 531, 541-42 (2002) (observing that innovation can provide the basis for reaching agreement on how to respond to the question of global warming); Adam B. Jaffe & Robert N. Stavins, *Dynamic Incentives of Environmental Regulations: The Effects of Alternative Policy Instruments on Technology Diffusion*, 29 J. ENVTL. ECON. & MGMT. S-44 (1995).

[11] *See, e.g.,* Stewart, *Conceptual Framework*, *supra*, n. __, at 1261; NACEPT, BARRIERS, *supra*, n. __, at 21; OECD, *supra*, n. __, at 81; *Cf.* Ian W. H. Parry et al., *How Important is Technological Innovation in Protecting the Environment?*, at 5, (Resources for the Future, Discussion Paper 00-15) (2000) (observing that in terms of social welfare, promoting technological change may be less important than simply controlling pollution).

[12] S*ee, e.g.,* Malloy, Incentives, *supra*, n. __, at 542-551 (discussing the debate over the use of market-based programs versus traditional regulation to encourage innovation); Stewart, *Conceptual Framework*, *supra*, n. __, at 1364-1373 (presenting a series of proposed regulatory changes); ENVIRONMENTAL LAW INSTITUTE (ELI), INNOVATION, COST AND ENVIRONMENTAL REGULATION: PERSPECTIVES ON BUSINESS, POLICY AND LEGAL FACTORS AFFECTING THE COST OF COMPLIANCE (1999) [hereinafter PERSPECTIVES]; DRIESEN, ECONOMIC DYNAMICS, *supra*, n. __, at __-__.

external social and legal institutions (for example, industry standards and norms) and by the firm's internal structure (such as internal research and development funding policies). Consequently, regulators seeking to encourage technological innovation in a given industry sector must first understand the socio-economic environment created by the network or "system" of actors, institutions, and routines in that particular sector. Regulatory policy designed without this system in mind will often ignore significant relationships and interactions within the relevant system, and consequently fail to produce the behavior it seeks.

Obviously, attempting to catalog and synthesize every factor that affects technology choice is neither feasible nor useful. Rather, we propose to focus on a small set of socio-economic factors—called the "selection environment" by Nelson and Winter and other evolutionary economists—that play a significant role in technology choice. Certainly, the regulatory obligations and constraints facing a firm are a critical part of the selection environment, but the selection environment also includes the mechanisms by which information about the innovation flows to potential adopters; the attributes of the innovation and its value to the potential adopters (i.e., the benefits and costs of adoption); and the strength of pre-existing routines and behaviors exhibited by relevant individuals and organizations.[14] An understanding of the selection environment allows policymakers to do three things: detect systemic barriers to innovation, identify regulatory alternatives that would specifically address those barriers, and anticipate how the system will likely respond to the various alternatives.

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[13] *See* Malloy, *Incentives*, *supra* n. __, at 544-46 (providing overview of debate).

[14] KEMP, *supra*, n. __, at 275-277 (discussing the broad range of technical, economic and institutional relationships that influence the decision of whether to adopt new technology); NELSON & WINTER, *supra*, n. __, at 263 (specifying for elements of the selection environment.)

This article demonstrates the application of the selection environment approach through a case study of the dry cleaning sector in Southern California. Most professional drycleaners use perchloroethylene ("PCE"), a toxic chemical, as their primary cleaning solvent. One non-toxic alternative cleaning technology, known as "professional wet cleaning," has been demonstrated to be both technically viable and economically competitive with the dominant PCE-based technology.[15] Yet relatively few cleaners have adopted wet cleaning technology, despite both the pervasive regulation of PCE dry cleaning and the availability of various voluntary incentive programs in California and elsewhere intended to encourage its diffusion. Recently, the South Coast Air Quality Management District ("AQMD"), the regulatory agency with jurisdiction over air emissions in the Los Angeles region, adopted an even more aggressive approach to encouraging technology change. It revised its air pollution regulations governing dry cleaning operations to prohibit the use of PCE dry cleaning equipment after 2020, and to provide limited financial

[15] Liquid carbon dioxide (CO_2) has also been introduced as an alternative solvent for garment cleaning. By placing gaseous CO_2 under pressure, this equipment makes it a liquid with solvent properties David DeRosa, *Out of Fashion Moving Beyond Toxic Cleaners in the Fabric Care Industry* 16-17 (2001). There is currently one plant in the South Coast utilizing a CO_2 machine. SCAQMD, *Staff Report,* at 1-2. CO_2 machines are quite expensive. The typical cost estimate for the purchase and installation of a CO_2 machine is $150,000. However, cleaners purchasing a machine from Micell, the leading manufacturer, must also pay costs associated with obtaining a franchise from Micell, which can raise capital costs to between $500,000 to $800,000 United States Congress, Committee on Small Business, Subcommittee on Tax, Finance and Exports, *Helping Small Dry Cleaners Adopt Safer Technology: Without Losing Your Shirt*. 106th Cong., 2nd sess. (July 20, 2000) (testimony of Fisher); South Coast Air Quality Management District ("SCAQMD"), *Staff Report for Proposed Amendment to Rule 1421 – Control of Perchloroethylene Emissions from Dry Cleaning Systems* 1-21 (2002) (hereinafter "*Staff Report*").. Micell's CO2 garment cleaning line was purchased by Cool Clean Technologies. *See* wttp://www.co2olclean.com (visited June 3, 2003).

General Electric has also introduced a new silicone-based dry cleaning solvent, marketed under the name Green Earth™ that uses a cyclopentasiloxane mixture as a solvent. However, researchers have raised concerns about the toxicity of the solvent, and about wastes potentially generated in the production of the siloxanes (dioxin and other organochlorine compounds) and from the breakdown of used solvent (formaldehyde). DeRosa, *supra*, n. __, at 17.

incentives to first-movers who adopt wet cleaning or other non-polluting alternatives in the shorter term.[16]

The situation in Southern California raises two basic questions about diffusion of wet cleaning, the answers to which provide policymakers with insights applicable to other technologies as well. First, if wet cleaning is a competitive, commercially viable, non-polluting alternative, why has it failed to spread throughout the sector? Second, what is the most effective policy tool or combination of tools for responding to the apparently slow diffusion of this clean technology? The AQMD took the controversial step of requiring an entire industry to alter its basic production process; would other options such as taxes, stricter regulation of PCE or subsidies have achieved equivalent results with less social cost? We use an analysis of the selection environment to explore these questions.

To gather information concerning technology choice within this sector, we conducted a random sample survey of 202 dry cleaners located in the greater Los Angeles region, and a series of semi-structured interviews of equipment vendors, professional cleaners, and government officials.[17] All surveys and interviews were completed before August 2001, the month in which AQMD first announced its intention to consider a PCE prohibition. This article relies upon the survey and interview results, as well as other publicly available information, to construct a conceptual model of the "professional cleaning" system and the associated selection

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[16] *See* SCAQMD, *Summary of Minutes of the South Coast Air Quality Management District Governing Board* (December 6, 2002).

[17] More specifically, the survey assessed the attitudes of dry cleaners towards technology choice, and towards professional wet cleaning in particular. These topics covered in the survey included: experience as a professional cleaner, familiarity of different garment care technologies, knowledge of professional wet cleaning, factors influencing a decision to purchase professional wet clean equipment, and interest in programs which would reduce the cost of purchasing wet clean equipment. The results, which are reported throughout this article, are accurate to ± 3.5% at a confidence interval of 95%.

environment.[18] It then uses that model and the underlying empirical information to identify the critical barriers to diffusion of wet cleaning, and to examine how different types of policy tools might affect those barriers.

Our analysis of the dry cleaning sector leads to three general conclusions. First, absent some form of intervention, diffusion of clean technology in this sector was likely to be extremely slow for several, interrelated reasons. Information flow within the selection environment regarding the nature and benefits of wet cleaning (and the disadvantages of the dominant technology) is sluggish at best. Also, organizational barriers within the relevant regulatory agency impair the effect of existing air quality regulation on the rate of diffusion. Moreover, the marginal economic benefits to the cleaners of adopting wet cleaning technology are relatively small. The second conclusion is that government-initiated financial incentives and information strategies standing alone are unlikely to successfully increase the rate of diffusion. Third, in the context of this selection environment, direct prohibition of PCE dry cleaning, phased in over time, is likely to lead to a more timely, less costly shift to wet cleaning and other alternative technologies than other policy tools.

Parts II and III of the article provide the background needed to evaluate the influence of the selection environment on technology choice in this sector. Part II

[18] The article thus uses a "systems approach" to expressly incorporate consideration of relevant actors, institutions, and routines into the analysis of technological change. A systems approach is an empirically driven methodology used to analyze complex systems by breaking them into their component parts, and examining how those parts relate to one another and contribute to the functioning of the system. It requires collection of extensive information concerning the system to aid in identifying (1) the scope of the system in question (i.e., which actors, institutions, and routines are relevant), (2) the interests of the system participants, and (3) the manner in which the participants interact. *See* Lynn M. LoPucki, Cornell Article; Lynn M. LoPucki, *Twerski and Cohen's Second Revolution: A Systems/Strategic Perspective*, 94 *Northwestern L. Rev*. 94, __-___ (1999).

defines innovation more precisely, and develops the concept of the selection environment more fully. Part III presents an overview of professional cleaning technology and the dry cleaning sector. With this background in mind, Part IV evaluates the selection environment of the dry cleaning sector, identifying several significant barriers to the diffusion of wet cleaning technology. Lastly, Part V examines the likely effect of various policy responses to the slow rate of diffusion, including the prohibition adopted by AQMD.

II. Technological Change, Diffusion and the Selection Environment

Technological change is commonly described as including three distinct components: invention, innovation, and diffusion.[19] Invention is the creation of a new product, process or concept. Innovation is the conversion of that invention into a commercially viable product or process. Diffusion is the broad adoption of the innovation by the intended end users.[20] While some commentators have questioned the value of trifurcating of the concept of technological change[21], thinking about diffusion as a separate component is a useful construct in analyzing the dry cleaning sector. This is so because wet cleaning is technically mature and commercially viable, and the issue facing regulators is how to encourage adoption of this and other nontoxic alternatives in the short term—a classic question of diffusion.

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[19] *See, e.g.* Nicholas A. Ashford & George R. Heaton, Jr., *Regulation and Technology Innovation in the Chemical Industry*, 46 LAW & CONTEMP. PROBS. 109, 110 (1983); KEMP, *supra*, n. __, at 7-8; Stewart, *Conceptual Framework*, *supra*, n. __, at 1282. The tripartite view of technological change can be traced back to Joseph Schumpeter's seminal work in the field. JOSEPH A. SCHUMPETER, THE THEORY OF ECONOMIC DEVELOPMENT (1974)

[20] Ashford & Heaton, *supra*, n. __, at ___; Stewart, *Conceptual Framework*, *supra*, n. __, at 1282. In practice, technological change is not quite so linear. New products and production processes are often subject to further development as the process of diffusion moves forward. KEMP, *supra*, n. __, at 8-9. For example, even as the early wet cleaning processes were moving to market, further refinements to tensioning equipment were being made, improving the performance of the wet cleaning systems and enhancing diffusion opportunities.

[21] *See, e.g.* NELSON AND WINTER, *supra*, n. __, at 263 (question the usefulness of the distinction between invention and innovation); P.A. Geroski, *Models of Technology Diffusion*, 29 RESEARCH POLICY 603, 623 (2000) (cautioning that "[d]iffusion is as much a process by which new technologies are developed as it is a process by which usage spreads."); Gerald Silverberg, *Adoption and Diffusion of Technology as a Collective Evolutionary Process*, in DIFFUSION OF TECHNOLOGIES AND SOCIAL BEHAVIOR 209, 210 (Nebojša Nakićenović and Arnulf Grubler eds. 1991) (questioning the value of the linear view of technical change introduced by Schumpeter).

The theoretical and empirical literature on diffusion is both voluminous and diverse[22], and a comprehensive summary of that literature is beyond the scope of this article.[23] Nonetheless, diffusion studies in many different industrial sectors support two general conclusions. First, diffusion of new technologies tends to be slow, even for technologies that are clearly superior to the dominant technology in terms performance or cost.[24] Second, although the rate of diffusion varies across technologies, firms, industry sectors, and countries,[25] the pattern of diffusion is fairly consistent across those variables. In particular, diffusion rates tend to rise very slowly at first, then increase rapidly for a time, and thereafter enter another period of slow adoption until most potential users have switched to the innovation.[26]

Diffusion researchers--and economists in particular--have been intrigued by the apparently routine failure of firms to move more quickly to superior

[22] PAUL STONEMAN, THE ECONOMICS OF TECHNOLOGICAL DIFFUSION 3-4 (2002)(hereinafter "TECHNOLOGICAL DIFFUSION"); Jaffe, et al., *supra*, n. __, at __-___. Diffusion research is conducted by a diverse group of scholars, including economists, sociologists, anthropologists, and marketing and management theorists. KEMP, *supra*, n. __, at 71.

[23] For useful surveys of the diffusion literature, see Geroski, *supra*, n. __, at 604-14; KEMP, *supra*, n. __, at 70-94; STONEMAN, TECHNOLOGICAL DIFFUSION, *supra*, n. __, at 29-54.

[24] STONEMAN, TECHNOLOGICAL DIFFUSION, *supra*, n. __, at 25; Geroski, *supra*, n. __, at 604; Dosi, *Assessment*, *supra*, n. __, at 184-85. For example, in a classic study, Mansfield documented the following times for half of the potential adopters to use the new technologies:

Innovation	No. of Years for ½ to Adopt
By-product coke oven	15
Centralized traffic control	14
Industrial robots	12
Diesel locomotives	9
High speed bottle filler	6
Continuous mining machine	3
Tin container	1

Edwin Mansfield, *Industrial Roberts in Japan and the USA*, 18 RESEARCH POLICY 183 (1989)

[25] STONEMAN, TECHNOLOGICAL DIFFUSION, *supra*, n. __, at 12-23.

[26] *Id*. at 12; Geroski, *supra*, n. __, at 604; Dosi, *Assessment*, *supra*, n. __, at 185. Commentators often refer the S-shaped diffusion curve in describing this pattern. When the fraction of potential users who have adopted the innovation is plotted against time, the resulting time path of adoption follows an S-curve. KEMP, *supra*, n. __, at 72-73; Jaffe, et al., *supra*, n. __, at 17.

technologies.[27] There are two leading explanations: "epidemic" models and rational choice models.[28] Epidemic models focus on information flow, essentially assuming that diffusion is constrained by the slow dissemination of information about the innovation. As information reaches more and more firms, the rate of diffusion increases and use of the innovation spreads like an epidemic.[29] Rational choice models concentrate instead on the potential adopters, positing that differences among them—such as size, capabilities, goals—determine the relative value of the innovation to the various firms. Firms switch to the new innovation when the benefits of switching outweigh the costs.[30] As attributes of the innovation change (such as price, reliability, performance, and so on), its value to more and more firms increases, leading to accelerated diffusion.[31]

While both types of models provide powerful insights into diffusion, neither offers a completely satisfying explanation of diffusion patterns or human behavior. For example, for most epidemic models, the major barrier to diffusion is simply a lack of knowledge regarding the existence and capabilities of the innovation. These models generally assume that once the information is received through word of mouth contact, adoption will occur.[32] Little attention is given to the sources, credibility, or accuracy of information, nor to the role of uncertainty or economic

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[27] Geroski, *supra*, n. __, at 604.
[28] KEMP, *supra*, n. __, at 71. Of course, there are other explanations beyond these two dominant models. *See, e,g.,* Stanley J. Metcalfe, *The Economic Foundation of Technology Policy: Equilibrium and Evolutionary* Perspectives, in HANDBOOK OF THE ECONOMICS OF INNOVATION AND TECHNOLOGICAL CHANGE 409 (Paul Stoneman, ed. 1995) (describing evolutionary models of diffusion); Richard R. Nelson, *Recent Theorizing about Economic Change*, 33 J. ECON. LIT. 48, 67-72 (1995) (same); Jennifer Reinganum, *On the Diffusion of New Technology*, 58 REV. ECONOMIC STUDIES 495 (1981)(discussing a game theoretic model); Geroski, *supra*, n. __, at 615-17 (describing a model drawn from population ecology); Brian W. Arthur, *Competing Technologies, Increasing Returns, and Lock-in by Historical Events*, 99 *Economic Journal* 116 (1989) (setting fort a model based on path dependence and information cascades).
[29] Jaffe, *et al*., *supra*, n. __, at 18-19; STONEMAN, TECHNOLOGICAL DIFFUSION, *supra*, n. __, at 29-31.
[30] KEMP, *supra*, n. __, at 79-82; STONEMAN, TECHNOLOGICAL DIFFUSION, *supra*, n. __, at 33-34.
[31] STONEMAN, TECHNOLOGICAL DIFFUSION, *supra*, n. __, at 34; Gersoki, *supra*, n. __, at 610-11.
[32] STONEMAN, TECHNOLOGICAL DIFFUSION, *supra*, n. __, at 29-30; KEMP, *supra*, n. __, at 76-77.

considerations in the adoption decision.[33] The rational choice models face their own limitations, including the assumption of complete information and the failure to consider the impact of routines and search heuristics on behavior.[34]

The concept of the selection environment incorporates the insights of the epidemic and rational choice models into a broader institutional context, examining the role that entities and institutions other than the firm have on the firm's adoption decision. It draws upon the evolutionary theory developed by Nelson and Winter, which posits that diffusion begins when firms engage in "search" routines to identify and evaluate potential changes in their ways of doing things.[35] In a process akin to natural selection, firms whose search routines result in the adoption of a profitable innovation will thrive, and eventually the innovation will diffuse throughout the sector and replace the dominant technology.[36] The features of the socio-economic system in which the firms operate—what Nelson and Winter call the selection environment—determines the path of diffusion over time.[37] For our purposes, the selection environment includes: (1) the nature of the mechanisms by which firms learn about potential innovations, (2) the nature of the costs and benefits considered

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[33] STONEMAN, TECHNOLOGICAL DIFFUSION, *supra*, n. __, at 32; Gersoki, *supra*, n. __, at 609.

[34] *See,* KEMP, , *supra*, n. __, at 83; NELSON & WINTER, supra, n. __, at ___-___. PAUL STONEMAN, THE ECONOMIC ANALYSIS OF TECHNOLOGICAL CHANGE 104 (1983 (hereinafter "TECHNOLOGICAL CHANGE"). Some rational choice models take on the issue of incomplete information directly, using a Bayesian learning rules in which the firm updates its prior information about the technology. *See*, *e.g,* I. Tonks, *The Demand for Innovation and the Diffusion of New Products,* 4 INT'L J. INDUSTRIAL ORGANIZATION 397.

[35] NELSON & WINTER, *supra*, n. __, at 206-07. Nelson and Winter's evolutionary theory characterized firms as "possessing various capabilities, procedures and decision rules that determine what they do in given external conditions." NELSON & WINTER, *supra*, n. __, at 206-07.

[36] NELSON & WINTER, *supra*, n. __, at 262-63. The diffusion can occur through one of two mechanisms. First, the initial adopter will grow absolutely and relatively (in comparison to its competitors) and will make broader use of the innovation in its expanded operations. NELSON & WINTER, *supra*, n. __, at 265; STONEMAN, TECHNOLOGICAL DIFFUSION, *supra*, n. __, at 7 (describing the process of "intra-firm diffusion"). Second, the innovation may spread to

by the firm in deciding whether to adopt the innovation, (3) the nature of the firm's search routines, and (4) the manner in which consumer preferences and government regulation influence what is profitable.[38] We describe each component in more detail below, beginning with information flow.

A. Information Flow Within the Sector

It is clear that information flow is an important component of the diffusion process.[39] In order to adopt a new technology, the potential user must obviously first be aware of its existence, capabilities and costs. The decision to switch also involves consideration of the capabilities and pitfalls of the existing technology. Case studies in a variety of sectors have demonstrated that lack of adequate information concerning the new technology can be a significant barrier to diffusion.[40]

While the epidemic approach highlights the importance of information flow, it provides little help in sorting through the mechanisms and impacts of that flow. Under the epidemic approach, diffusion of wet cleaning would occur as information about its existence and (at least in some variants of the classic model) its performance reached more and more cleaners. Yet the approach does not consider

other firms through imitation, as the other firms attempt to maintain their competitive status. NELSON & WINTER, *supra*, n. _, at 265.

[37] NELSON & WINTER, *supra*, n. __, at 263.

[38] With the exception of the third element, this definition of selection environment relies upon Nelson and Winter's original formulation. *Id.* In recognition of the threshold importance of the firm's internal search routines for identifying evaluating potential innovations, I include such routines as a fourth element that affects the adoption decision. Nelson and Winter treat the search function as a separate part of their model.

In his discussion of technological regime shifts (i.e., radical changes in basic technologies of production, transport and consumption), Kemp uses the concept of selection environment to capture the larger technical and socio-economic system in which diffusion occurs. For Kemp, the selection environment includes (1) the existing technical, economic and institutional interrelationships created by the dominant technology, (2) the mechanisms for the transfer of information needed for the switch to occur, (3) social processes of habitation and taste formation, and (4) existing government policies. KEMP, *supra*, n. __, at 274-76.

[39] KEMP, *supra*, n. __, at 96-98; EVERETT M. ROGERS, DIFFUSION OF INNOVATIONS 17-18 (1995).

[40] *See, e.g.,* KEMP, *supra*, n. __, at 234 (observing that lack of information of the environmental damage caused by high- solvent paints and of the availability of low-solvent alternatives hindered the diffusion of low-solvent alternatives).

quality of the information itself, and thus is of limited use in situations in which inaccurate, negative information about the new technology is circulating within the sector. Moreover, by focusing primarily on word of mouth contact as the mechanism of information flow, the epidemic approach tends to ignore other potentially important information sources such suppliers, trade associations, and regulators.

Analysis of the broader selection environment results in more attention to the substance and sources of the information transmitted. For example, it might seem reasonable to assume that the vendor of a new technology would vigorously spread information about its product or process. Yet in practice, this assumption could easily prove to be false; distributors of the new technology may have their own interest in restricting or even distorting the information that reaches the potential adopter.[41] Analysis of the selection environment also includes consideration of the weight accorded to various pieces of information and their respective sources by the potential adopter. Not all information sources are equal in their eyes. Thus, a potential adopter may discount the value of information provided by the vendor, viewing the vendor's claims about the innovation to be puffery. Likewise, statements by government regulators about new technologies may be viewed with distrust or skepticism. By recognizing these aspects of information flow, evaluation of the selection environment can uncover otherwise unseen barriers to the flow of accurate information, and assist in developing effective policy responses to those barriers.

B. Costs and Benefits of the New Technology

This component incorporates the core concept of the rational choice approach: the firm will adopt the innovation when the benefits of adoption exceed the costs. The value of the innovation to individual firms will vary across the sector, and as the costs of the innovation drop or its benefits increase, more and more firms will switch from the dominant technology.[42] Whatever one has to say about the usefulness of formal theories of rational choice generally, it is difficult to argue with the basic idea that, in the case of business decisions concerning technology choice, cost matters.[43] Nonetheless, this focus on the costs and benefits of adoption does present its own challenges. In particular, it can often be quite difficult to identify the nature and magnitude of the costs and benefits that drive the adoption decision.

On the surface, identifying the types of costs and benefits associated with adopting a new technology may appear to be a relatively straightforward exercise.[44] In practice, however, the analysis of the relative costs and benefits of adoption can be significantly more complicated than it first appears. It is not enough to simply

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[41] KEMP, *supra*, n. __, at 98-99 (suggesting that sales people might advocate against the purchase of new technology where the existing technology results in higher profits of sales commissions.)

[42] STONEMAN, TECHNOLOGICAL DIFFUSION, supra, n. __, at 33-34; KEMP, *supra*, n. __, at 79-80. In formal rational choice models of diffusion, the decision rule is often pegged to a threshold criteria which, if exceeded, causes the innovation to have a net benefit for the firm. For example, firm size is often used as the threshold criteria. Upon introduction, the costs of a new innovation may exceed its value for smaller firms but not for larger firms. As the costs decrease or the value increases, the threshold criteria (i.e., the firm size above which the innovation has net value) decreases, and more and more firms begin to adopt the innovation. *See* KEMP, *supra*, n. __, at 80-83 (describing the probit model which typically uses firm size as the "critical variate"); Jaffe, et. al, *supra*, n. __, at __-__.

[43] Obviously, there is continuing debate over the use of rational choice theory in a variety of substantive areas and across a number of disciplines. For examples of the standard critiques of rational choice theory generally, see ROBYN M. DAWES, RATIONAL CHOICE IN AN UNCERTAIN WORLD 146 (1988); RATIONALITY IN ECONOMICS: ALTERNATIVE PERSPECTIVES (KEN DENNIS ED., 1988); MARY ZEY, RATIONAL CHOICE THEORY AND ORGANIZATIONAL THEORY: A CRITIQUE (1998).

[44] In applying the classic "probit" rational choice model to the diffusion of the labor-saving mechanic reaper in 19th century America, David focused the wage rates and on capital and maintenance costs of the reaper. Paul David, *A Contribution to the Theory of Diffusion* __ (Center for Research in Economic Growth Research Memorandum No. 71 1969). Likewise, in their rational choice model of the adoption of energy –conserving technology, Jaffe and Stavins concentrated on energy costs and the costs of adopting thermal insulation technology. Adam B. Jaffe & Robert N. Stavins, *Dynamic Incentives of Environmental Regulations: The Effects of Alternative Policy Instruments on Technology Diffusion*, 29 J. ENVTL. ECON. & MGMT. S-43, ___ (1995).

know the objective costs and benefits of adoption; one must also understand the magnitude and relative importance of those costs and benefits *as perceived by the potential adopters*.[45]

The potential adopter's view of the costs and benefits can influence the adoption decision in at least three ways. First, uncertainty about the value of a particular cost or benefit, whether based upon an actual absence of information or on impaired flow of existing information, may lead the firm to either discount the cost or benefit or delay adoption until the uncertainty is reduced.[46] Second, behavioral biases may cause potential adopters to give a cost or benefit more or less weight than an objective observer might expect. For example, studies of the diffusion of energy-efficiency technologies have found that adopters tend to give more importance to capital costs than to long-term operating costs in evaluating the financial costs of the new technology.[47] Third, the potential adopter's beliefs or preferences may cause an ostensible cost or benefit to be irrelevant to that firm.

C. Search and Adoption Routines

The first two components of the selection environment fit neatly within commonly held conceptions of the diffusion process. Imagine a small metal

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[45] The analysis is also complicated by the fact that the magnitude of the costs and benefits is a moving target. They will likely vary over time as the firm's experience with the new technology increases, and as the technology itself is improved as a result of feedback received during the diffusion process. Silverberg, *supra*, n. __, at 211-12.

[46] Jaffe, et al., *supra*, n. __, at 40; STONEMAN, TECHNOLOGICAL DIFFUSION, *supra*, n. __, at 54. The uncertainty may rest in the newness of the technology, giving rise to concerns over how it will perform in a particular application. Alternatively, the uncertainty might instead relate to its operating costs. *Id.*

[47] K. A. Hassett and G. E. Metcalf, *Energy Tax Credits and Residential Conservation Investment: Evidence from Panel Data*, 57 J. PUBLIC ECONOMICS 201, ____ (1995);

fabrication firm receiving information through the mass media, equipment vendors, and word of mouth about a new environmentally beneficial coating technology used to paint metal shelves. Perhaps the firm's plant manager reviews the information, collects further data relating to the technology's performance and cost, and ultimately determines that switching to the new process will result in a modest financial benefit for the firm. On the basis of that analysis the firm purchases the new coating technology. This scenario is consistent with much of the modeling of innovation and diffusion that is typically conducted; yet it artificially isolates the firm's adoption decision from the rest of the firm's activities.

The adoption decision looks quite different when viewed in the larger context of the firm's general business operations. At each step, the innovation competes against other firm activities and opportunities for attention and resources. Organizational theory and behavioral science suggest that firms and individuals contending with numerous competing demands for attention and resources often depend upon organizational routines and rules of thumb to sort through the turbulent business environment.[48] To the extent that such routines influence the search and selection activities of firms within a given sector, analysis of diffusion within the sector must include consideration of those routines.

Will the firm's plant manager pay attention to the advertisements and sales calls concerning the new process? To a large extent, the answer to that question depends upon the number and nature of the other items vying for the manager's attention. An individual's capacity to identify and process information is limited, and consequently attention itself is a resource that must be allocated in accordance

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[48] *See* Timothy F. Malloy, *Regulation, Compliance and the Firm*, 76 TEMPLE L. REV. 451, 478-80 (2003).

with some set of decision rules.[49] For example, behavioral scientists tell us that individuals will not engage in search and evaluation activities until they perceive or anticipate a problem to be solved.[50] Stoneman relied on this principle to explain, in part, the slow diffusion of computers in the 1970's, noting, "prior to a change in technique a problem is required."[51] Likewise, Nelson and Winter incorporated this principle into their evolutionary model of technological change, assuming that a firm will not search for innovations if the firm is already "sufficiently profitable."[52]

Even if the manager notices and evaluates the innovation, will the firm purchase it? Again the answer depends upon the other investment opportunities and resource needs facing the firm. The innovation must compete against other projects for capital and other resources.[53] In many firms the competition will be based on such factors as return on investment, consistency with the firm's strategic goals, and the relative power of the sub-units sponsoring the respective projects. Research in this area suggests that these factors systematically disadvantage projects implementing environmentally beneficial innovations.[54]

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[49] HERBERT A. SIMON, ADMINISTRATIVE BEHAVIOR 88-92 (Free Press 4th ed. 1997) (observing that bounded rationality resulting from cognitive and physiological limits restricts the scope of individuals' attention); JAMES G. MARCH, A PRIMER ON DECISION MAKING, 23-24 (1994).

[50] *See, e.g.,* RICHARD M. CYERT & JAMES G. MARCH, A BEHAVIORAL THEORY OF THE FIRM __-__ (1963).

[51] STONEMAN, TECHNOLOGICAL CHANGE, *supra*, n. __, at 140. *See also,* KEMP, supra, n. __, at 83, n. 11 (arguing that bounded rationality may limit adoption because firms will only seek innovations where a problem such as lack of profitability or malfunctioning of machines is present);.

[52] NELSON & WINTER, *supra*, n. __, at 211 (assuming that firms are "satificers" rather than optimizers, and thus will do no searching for innovations at all if the firms are sufficiently profitable). Nelson and Winter's "dumb manager" assumption has been criticized by some as being unrealistic. Vernon W. Ruttan, *Sources of Technical Change: Induced Innovation, Evolutionary Theory, and Path Dependence*, in TECHNOLOGICAL CHANGE AND THE ENVIRONMENT 9, 19 (Arnulf Grubler, *et al.*eds. 2002) .

[53] Malloy, Incentives, *supra*, n. __, at 538.

[54] *Id.* at 571-586.

D. Influence of Existing Regulation

A concrete example is helpful in understanding the potential impact of regulation on diffusion. Assume that Environmental Solutions, Inc. ("ESI") has developed a new, commercially viable pollution control system for capturing and treating hydrogen sulfide emissions from petroleum refinery process units. Unlike existing technologies that use thermal oxidizers, the ESI technology uses a chemical process to treat the hydrogen sulfide. The ESI technology appears to perform as well as or better than the existing technology at a lower cost. Assume also that federal environmental regulation of the process units limits hydrogen sulfide emissions from such facilities. How will that regulation affect the diffusion of the ESI technology?

At the most basic level, the "induced innovation hypothesis" tells us that the hydrogen sulfide regulations should lead to the diffusion of at least some form of environmental technology. That hypothesis posits that an increase in the relative prices of factors of production will stimulate innovation directed at economizing the use of those now more expensive factors.[55] Because it increases the cost of emitting pollution, regulation has the same effect as an increase in factor prices.[56] In our example, faced with regulation, petroleum refineries will seek the most cost effective strategy for reducing hydrogen sulfide emissions, creating a demand for the ESI technology and resulting in its diffusion.[57]

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[55] JOHN HICKS, THE THEORY OF WAGES 124-125 (2ND ED. 1963); Ruttan, *supra*, n. __, at 11.
[56] Richard G. Newell, *et al.*, *The Induced Innovation Hypothesis and Energy Saving Technological Change*, 114 The Quarterly J. Econ. 941, ___ (1999); Malloy, Incentives, *supra*, n. __, at 546.
[57] Rational choice principles suggest that the firm will identify a number of control alternatives, including: (1) using mature technology (such as a thermal oxidizer) to control emissions, (2) using innovative pollution control technology, or (3) modifying the process itself so as to reduce or prevent emissions in the first place. Based on its decision criteria, the organization will then evaluate the alternatives. Malloy, Incentives, *supra*, n. __, at 546, n.51. Obviously, firms with existing controls already in place would also take into account the switching costs into account

But this application of the induced innovation hypothesis is too simplistic. Ultimately the actual impact of any given regulation on innovation depends in large part on two separate aspects of the regulation: its basic structure and the manner in which it is implemented.[58] Much of the existing literature focuses on the first aspect. While recognizing the importance of regulatory form, we seek to direct attention to the second aspect as well.

1. Regulatory Structure

Generally speaking, a regulation can be structured as either a "design standard" or a "performance standard." A design standard mandates the use of a particular pollution control technology.[59] Thus, if the hydrogen sulfide regulation requires the capture and subsequent treatment of hydrogen sulfide emissions with a thermal oxidizer having a destruction efficiency of 98 percent, that regulation would be a design standard. While such a standard would likely lead to broad diffusion of the thermal oxidizer technology, it would severely limit the diffusion of alternative pollution control technologies exhibiting equivalent or superior performance, such as the ESI technology.[60] In other words, the design standard essentially "locks-in" the existing technology, and requires specific, formal action by the regulator before alternative technologies can be used.

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in evaluating the benefits of the ESI technology. Of course, the effects of the regulation may also be limited by other factors in the selection environment, such as inadequate information flow or boundedly rational search routines.)

[58] Of course, the stringency of the regulation is also an important factor. A weak regulation that calls for little improvement in environmental performance is unlikely to encourage significant innovation or diffusion.

[59] Malloy, Incentives, *supra*, n. __, at 546, n.50; Robert W. Hahn & Gordon L. Hester, *Marketable Permits: Lessons for Theory and Practice*, 16 ECO. L. Q. 361, 361 (1989).

However, although a design standard can impair the diffusion of alternative pollution *control* technologies, it could still play a meaningful role in the diffusion of innovative process changes that prevent rather than control pollution. Suppose that the ESI technology actually involved modifications to the standard process units at the refinery so as to prevent the formation of hydrogen sulfide in the first instance. In that case, the hydrogen sulfide regulation is not a barrier to the use of the ESI technology because units using the ESI technology would no longer be subject to the regulation. The very fact that adoption of the ESI technology avoids the application of the hydrogen sulfide regulation theoretically provides an impetus for the diffusion of that technology.

In contrast to a design standard, a performance standard specifies a desired result in terms of an emission limit or other objective goal, but leaves it to the firm to select the technology needed to achieve that result.[61] In our example, a regulation that limits hydrogen sulfide emissions to a concentration of no more than 10 parts per million in the exhaust gas stream constitutes a performance standard. Alternatively, as is often done in permitting for new sources, the firm may be required to achieve the same level of control as is reached by the best available control technology.[62] Under the induced innovation hypothesis, performance standards should encourage diffusion by providing the both the demand for innovation and the flexibility to use alternative technologies.[63]

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[60] *See, e.g.,* Byron Swift, *Barriers to Environmental Technology and Use*, 28 ENVTL. L. REP. 10202, 10213 (1998); Stewart, *Conceptual Framework*, *supra*, n. __, at 1281-82.

[61] Smith, *supra*, n. __, at _____; Stewart, *Conceptual Framework, supra*, n. __, at 1263-69.

[62] *See* 42 U.S.C.A. Section 7503(a)(2) (requiring attainment of lowest achievable emission rate in certain areas under New Source Review).

[63] David M. Driesen, *Is Emissions Trading an Economic Incentive Program?: Replacing the Command and Control/Economic Incentive Dichotomy*, 55 WASH. & LEE L. REV. 289, 302 (1998). Nonetheless, even some types of performance standards can limit the diffusion of innovations in production processes. For example, some performance standards are written so as to require either (a) a specific percent reduction in pollutant mass as

2. Regulatory Implementation

Although the structure of a regulation significantly affects its influence on diffusion, the manner in which the regulation is implemented is also a critical factor in course of diffusion. Implementation of regulatory programs can limit diffusion in at least two noteworthy ways. First, even ostensibly flexible performance standards can be implemented conservatively, and thus transformed into something akin to design standards. For example, critics of traditional regulation often contend that new source review permitting programs, which in theory should allow firms to select any technology that provides the same performance as the best available control technology, in practice are implemented in an excessively rigid manner. They argue that permitting officials are biased in favor of conventional technologies due to the officials' unfamiliarity with new technology, lack of resources, and distrust of the regulated community.[64] Consequently, it is argued, permitting officials are very reluctant to approve the use of new technologies as part of the permitting process.[65]

compared to an uncontrolled emission or (b) a specific reduction in the concentration of the pollutant at the "end of the pipe." Because they focus on the effectiveness of *controlling* pollution after it has been generated, such limits do not recognize the impact of pollution prevention measures that reduce the mass of pollution that would otherwise occur. Suppose that an emission limit required a 90% reduction in pollutant mass emitted from a process unit. A "pollution prevention" measure that prevented 95% of the pollution from ever being created would not meet the limit because there would be no control (i.e., no 90% reduction) of the remaining 5% of pollution that is created and emitted. *See* ELI, PERSPECTIVES, *supra*, n. __, at 10-12. Of course, this assumes that the emission limits incorporate only a single format, such as a percent reduction requirement. In fact, many regulations include alternative formats, including some that take account of process and raw material changes that reduce the mass of pollution generated.

[64] Swift, *supra*, n. __, at 10208-09; NACEPT, BARRIERS, *supra*, n. __, at 10-11.

[65] ENVIRONMENTAL LAW INSTITUTE, BARRIERS TO ENVIRONMENTAL TECHNOLOGY Innovation AND USE 17-19 (1998) (hereinafter "BARRIERS"); Kurt A. Strasser, *Cleaner Technology, Pollution Prevention and Environmental Regulation*, 9 FORDHAM ENVTL. L. J. 57, __-__ (1997); U.S. ENVIRONMENTAL PROTECTION AGENCY, PERMITTING AND COMPLIANCE POLICY: BARRIERS TO U. S. ENVIRONMENTAL TECHNOLOGY INNOVATION 32 (EPA 101/N-91/001 1991).

Second, the intensity of enforcement can affect the strength of the incentives created by regulation for adopting innovative technologies.[66] When enforcement is lax, inspections are infrequent and penalties low, many firms may perceive less pressure to devote attention and resources to compliance. Accordingly, the actual costs of compliance are quite low, and thus have less influence on diffusion.

Before evaluating how the selection environment as outlined may affect the diffusion of wet cleaning, we must understand the nature of the garment care sector, including the professional cleaners, the technology vendors, and the regulatory agency. Section III provides that background.

III. The Garment Care Sector

A. The Competing Technologies: "Dry" and 'Wet" Cleaning Systems

Like penicillin and the dynamite, dry cleaning was discovered by accident. In the early nineteenth century, Jean Baptiste Jolly noticed that some spilled kerosene dissolved a stain on his tablecloth.[67] This observation led to the development of modern "dry cleaning" technology, a process in which a solvent other than water-- usually PCE or a petroleum-based solvent-- is used to clean garments.[68] PCE and petroleum dry cleaning processes are very similar to the process that most of us use in washing and drying clothes at home, except that clothes are washed in the dry

[66] KEMP, *supra*, n. __, at 103 (noting that in the case of traditional regulation, diffusion will depend upon, among other things, "the law enforcement processes, penalties for legal violations, and the law-abiding nature of people and organizations that are subject to environmental laws.")

[67] CHARLOTTE FOLTZ JONES, ACCIDENTS MAY HAPPEN ___ (1996). For a brief history of the garment care industry dating back to 1707, see Kimberly M. Thompson, *Cleaning Up Dry Cleaners*, in THE GREENING OF INDUSTRY 93, 94-98 (John D. Graham and Jennifer Kassalow Hartwell eds. 1997).

[68] *See* United States Environmental Protection Agency ("USEPA"), *EPA Office of Compliance Sector Notebook Project Profile of the Dry Cleaning Industry* 3-4 (EPA/310-R-95-001 1995) ("SECTOR NOTEBOOK")(defining professional dry cleaning).

cleaning solvent rather than in water.[69] In the past, the drying cycle was conducted in a separate machine, causing significant solvent emissions when the clothes were transferred between the machines. Modern "closed loop" machines perform both functions in one machine, and include solvent recovery systems designed to reduce solvent emissions.[70]

Dry cleaning operations expose humans and the environment to PCE through spills and releases of PCE and PCE-contaminated wastes to air, soil, groundwater and surface water.[71] PCE vapors reach the air inside and outside of the cleaning facility from process vents and leaks.[72] In a comprehensive study of toxic air emissions in the Los Angeles air basin, AQMD found that dry cleaners were the leading contributors of PCE emissions.[73] This is particularly significant because PCE is classified by as a probable human carcinogen by the International Agency for Research on Cancer and as a potential human carcinogen by the National Institute of Occupational Safety & Health. Petroleum dry cleaning also causes air emissions. Although petroleum solvents are not classified as carcinogens, they do contribute to the formation of ground level ozone (more commonly known as smog).

In the early 1990's, equipment manufacturers developed professional wet cleaning systems consisting of computer-controlled washers and dryers, specially

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[69] EPA, SECTOR Notebook, supra, n. __, at 3; Due to the higher flammability of petroleum solvents, petroleum machines are also equipped with fire suppressant systems. Some petroleum systems inject an inert gas, such as nitrogen or argon, to reduce oxygen concentration. Other systems use a vacuum system during the operating of the equipment to reduce oxygen concentrations.

[70] *Id.* at ___; SCAQMD, *Staff Report*, *supra* n. __, at 1-1.

[71] USEPA, *Sector Notebook*, at 24-25.

[72] *Id.*.

[73] SCAQMD, MULTIPLE AIR TOXICS EXPOSURE STUDY IN THE SOUTH COAST BASIN (March 2000).

formulated detergents, and finishing equipment to create a cost-effective alternative to dry cleaning.[74] Wet cleaning systems use water as a cleaning solvent rather than PCE or petroleum-based solvents. Researchers have performed numerous case studies of professional wet cleaning at commercial facilities, focusing on the process' technical performance, economic sustainability, and environmental impacts.[75] In terms of technical performance, professional wet cleaners were able to successfully clean the full range of garments normally taken to a dry cleaner.[76] Moreover, wet cleaning operations generated a high level of customer satisfaction.[77] With respect to economic performance, the capital cost for professional wet cleaning equipment was lower than that of dry cleaning equipment, while overall operating expenses were comparable to or even less than those of dry cleaning operations.[78] In terms of environmental impact, no environmental concerns were identified, and a substantial benefit is produced through the elimination of PCE.[79]

B. The Garment Care Industry Actors

1. The Cleaners

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[74] USEPA, *Cleaner Technologies Substitutes Assessment: Professional Fabricare Processes* 2-13 TO 2-24 (EPA 744-B-98-001 1998) (hereinafter *"Substitutes Assessment")*.

[75] Sinsheimer, et al., COMMERCIALIZATION OF PROFESSIONAL WET CLEANING: AN EVALUATION OF OPPORTUNITIES AND FACTORS INVOLVED IN SWITCHING TO A POLLUTION PREVENTION TECHNOLOGY IN THE GARMENT CARE INDUSTRY (2002); ANTHONY STAR AND SYLVIA EWING, REAL WORLD WET CLEANING: A STUDY OF THREE ESTABLISHED WET CLEANING SHOPS CNT 2002) (investigating technical and financial performance at three wet cleaning shops); POLLUTION PREVENTION, EDUCATION AND RESEARCH CENTER (PPERC), POLLUTION PREVENTION IN THE GARMENT CARE INDUSTRY: ASSESSING THE VIABILITY OF PROFESSIONAL WET CLEANING (1997)(investigating technical performance, financial performance and environmental impact of start-up wet cleaner); PETER SINSHEIMER AND ROBERT GOTTLIEB, SUPPORTING POLLUTION PREVENTION IN THE GARMENT CARE INDUSTRY (2000) (nvestigating technical performance and financial performance wet cleaner that converted from dry cleaning technology); JO PATTON AND WILLIAM EYRING, ALTERNATIVE CLOTHES CLEANING DEMONSTRATION SHOP FINAL REPORT (1996) (investigating technical performance and environmental impact of start-up wet cleaner); ENVIRONMENT CANADA, FINAL REPORT FOR THE GREEN CLEAN PROJECT (1995)(investigating technical performance and environmental impact of start-up wet cleaner).

[76] SINSHEIMER, *et al.*, *supra*, n. __, at 4-6 to 4-8

[77] SINSHEIMER, *et al.*, supra, n. __, at 3-1 to 3-22 (assessing customer satisfaction at five wet cleaning facilities); SINSHEIMER & GOTTLIEB, *supra*, n. __, at 2-1 to 2-4 (assessing customer satisfaction at one wet cleaning facility).

[78] SINSHEIMER & GOTTLIEB, *supra*, n. __, at 4-9 to 4-13.

[79] PPERC, *supra,* n. __ at 5-1 to 5-31.

Currently in the United States, 85% of professional cleaners use PCE as their primary cleaning solvent, while approximately 15% of cleaners use petroleum-based solvents.[80] Although wet cleaning is widely used in Germany, diffusion of wet cleaning in the United States has been slow.[81] There are approximately 38 dedicated wet cleaners across the nation; that is, shops using wet cleaning as their sole cleaning technology.[82] As of 2002, Southern California had ten "dedicated" wet cleaners.[83]

The professional cleaning industry is a highly decentralized sector. There are approximately 36,000 dry cleaning shops nationwide, generating approximately $7.2 billion in revenues each year.[84] Of these, approximately 2,618 operate in California.[85] The vast majority of cleaners in the United States and California are very small neighborhood businesses at which cleaning and finishing are performed on the premises. Although the sizes of drycleaners vary, the majority of professional dry cleaners are single facility, family-owned businesses.[86] A typical "mom and pop" shop may have two or three full time employees (including the owner) and often additional part-time help. Most cleaners have fewer than 10 employees and report gross revenues of less than $113,000.[87] Revenues must cover labor costs, rent, debt

[80] USEPA, *Substitutes Assessment*, *supra*, n. __, at 2-17.
[81] SCAQMD, *Staff Report,* at 1-18 to 1-19.
[82] USEPA, Design for the Environment Wetcleaning Directory (EPA 744-B-99-002 1999).
[83] SCAQMD, *Staff* Report, *supra,* n. __, at __.
[84] United States Census Bureau, *1997 Economic Census* (1999).
[85] *Id.* at Table 1a.
[86] http://www.ifi.org/industry/industry-profile.html (visited December 2, 2002).
[87] USEPA, *Sector Notebook*, at 5-6 (1995).

service equipment, regulatory costs, solvents and supplies. Although labor costs are the largest cost category, wages are typically quite low.[88]

2. The Manufacturers and Distributors

To understand the market structure for equipment and supply vendors in the garment care sector, one must first identify the types of equipment that professional cleaners actually use in their process. Dry cleaners typically have two types of cleaning machines: commercial laundry machines (used for cotton shirts, linens and similar garments) and dry cleaning machines (used for other garments that typically carry a "dry clean" label). The two types of cleaning machines are manufactured by two different sets of companies, and distributed by yet a third set (with some limited overlap).

Given the fact that the garment care industry is dominated by PCE dry cleaners, it is unsurprising that manufacturers of PCE dry cleaning systems produce most of the dominate the garment care equipment sector. As new petroleum-based solvents and silicone-based solvents have emerged, those manufacturers have modified their equipment designs to create machines capable of using these newer solvents.[89] Interestingly, none of the PCE machine manufacturers have developed wet cleaning systems. Rather, the laundry machine manufacturers have taken the lead in wet cleaning technology.

In 1991, Meile, Inc., a German appliance manufacturer, introduced the wet cleaning technology as an alternative to dry cleaning.[90] Currently, wet cleaning systems are produced by manufacturers of industrial and domestic laundry systems – including Miele of Germany, Electrolux of Sweden and Denmark (manufacturer of

[88] *Id*.at 5.
[89] Personal interview with James Douglas (April 2001.)

the Aqua Clean system), and IPSO of Belgium (manufacturer of Aquatex system).[91] The two wet cleaning system manufacturers in United States, Alliance Laundry Systems (using the brand name Unimac) and Pellerin Milnor Corporation) are leading industrial laundry equipment manufacturers.[92] With the exception of Miele (which manufactures a wide range of consumer appliances and industrial equipment such as vacuum cleaners, ovens, and parts cleaning systems), the vast majority of equipment sales for each of these firms are of industrial laundry systems.[93]

Six companies currently distribute wet cleaning systems in the United States.[94] Each of these companies also either manufactures or distributes other types of cleaning equipment. For example, Wascomat, the exclusive United States distributor of Aqua Clean wet cleaning systems, claims to be the world's largest manufacturer of industrial laundry equipment.[95] Likewise, Bowe Permac, a distributor of Swiss-made Schulthess wet cleaning systems, manufactures and sells PCE, petroleum and silicone systems.[96]

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[90] Cite to http://www.miele.com/aboutmiele.html; SINSHEIMER, ET AL., *supra*, n. __, at 1-3, n.1.

[91] Center for Neighborhood Technology ("CNT"), Wet Cleaning Equipment Report (May 1997); http://www.miele.com/aboutmiele.html; Diane Ritchey, *Success in Sweden*, 58 APPLIANCE __, __ (February 1, 2001) (discussing Electrolux' role as a world leader in commercial laundry systems). Production of the Aquatex system is actually spread among three companies. While IPSO manufactures the washer, American Dryer produces the dryer in the United States, and Evapoform manufactures the drying cabinet in England. *Id.*

[92] *See, e.g.,* Business Wire, *Alliance Laundry Systems Withdraws Initial Public Offering of Trust Units and Terminates Offer to Purchase* (November 14, 2002); http://www.milnor.com/products0c.asp (visited December 3, 2002); infoUSA.com, US Business Directory, Peelerin Milnor Corp. (November 6, 2002).

[93] Timothy F. Malloy and Peter Sinsheimer, *Pollution Prevention as a Regulatory Tool in California: Breaking Barriers and Building Bridges,* in POLICY OPTIONS 2002 85-86 (Daniel Mitchell ed. 2002) (citing interviews with Daniel Goldman of Wascomat and Robert Eisenberg of IPSO).

[94] *See* CNT, *supra*, n. __, at __-__; Malloy & Sinsheimer, *supra*, n. __, at 85.

[95] http://www.wascomat.com/whoweare.htm (visited December 3, 2002).

[96] Malloy & Sinsheimer, *supra*, n. __, at 85 (citing interview with Tom Tipps of Bowe Permac Garment Care Systems); *see* http://www.bowe-tc.com/products/products.html (visited December 3, 2002); http://www.bowe-tc.com/products/WetCleaningSystems.html (visited December 3, 2002).

C. The Regulator

This case study focuses on rules and activity of the South Coast Air Quality Management District ("AQMD"), the major air regulator of dry cleaners in Southern California.[97] Covering all of Los Angeles and Orange Counties (and parts of several other counties), it is directed by a Governing Board with support of a large professional staff. Much of AQMD's work is directed at establishing and implementing rules that govern the type and amount of air emissions that can be released by sources in the region. The rules are typically incorporated into operating permits issued by AQMD, and enforced by its inspectors and prosecutors. AQMD also plays a role in technology advancement, funding research intended to encourage the development and adoption of new pollution management technologies.

AQMD's operating divisions are primarily organized on a functional basis. Thus, the Planning, Rule Development, and Area Sources division is responsible for drafting new rules and rule amendments. Likewise, various offices within the Engineering and Compliance division are charged with implementation of rules, whether through issuance of permits or enforcement of rules and existing permits. Legal functions are split between the District Prosecutor's office and the General Counsel's office, which handle enforcement and non-enforcement matters, respectively. The Science and Technology Advancement office ("TAO") assists in the development and demonstration of new technologies. AQMD established TAO in 1988 in response to air quality in the Los Angeles air basin that was so bad that new

[97] The dry cleaning industry is regulated by a variety of local, state and federal agencies under a number of environmental and public safety programs. In terms of impact on the selection of dry cleaning equipment and solvent, air quality regulations have generally played the most significant role of all. Both petroleum and PCE dry cleaning are regulated under federal, state and local rules in California and many other states. *See* SCAQMD, *Staff Report, supra* n. __, at 1-1 to 1-5 (describing history of regulation of dry cleaning under California air quality laws; 40 C.F.R. Part 63, subpart M (200_) (regulation of PCE dry cleaning under the federal National Emission Standard for Hazardous Air Pollutant program); 40 C.F.R. Part 60, subpart JJJ (regulation of petroleum dry cleaning under the federal New Source Performance Standard program).

emission reduction technologies would be needed to attain federal standards.[98] From 1995 to the present, TAO has played a significant role in supporting studies of the viability and commercialization of wet cleaning.[99]

IV. Diffusion in the Garment Care Industry

This section tackles the question of why wet cleaning has diffused so slowly over the past decade. In doing so, it focuses upon the selection environment as it existed *prior* to December 2002, the month in which AQMD changed the regulations governing PCE dry cleaning. In that pre-December 2002 period, the AQMD regulations generally resembled those of most jurisdictions: cleaners were permitted to use PCE dry cleaning equipment, so long as the cleaners used certain types of control equipment and followed specific operation, maintenance and inspection practices. Our analysis identified two primary barriers to diffusion, which we summarize here and discuss in greater detail below.

First, dry cleaners exhibit high levels of concern and misinformation concerning wet cleaning that are not overcome by the perceived benefits of the new technology. From the cleaner's perspective, the major perceived benefit of wet cleaning—reduced toxic pollution—accrues to workers or the general public rather than to the cleaner. The economic value of other benefits (such as reduced regulation and lower capital costs) does not appear large enough to overcome the

[98] Personal interview with Chung Lui, Director of TAO (2001.)
[99] TAO has assisted in the funding of (1) the first professional wet cleaning demonstration facility in California, (2) a technical assistance project designed to educate cleaners in the South Coast region about professional wet cleaning, and (3) a grant program to assist eight dry cleaners interested in switching to professional wet cleaning. SINSHEIMER, ET AL., *supra*, n. __, at 1-1 to 1-5.

perceived risk of failure and cost of learning a new technology. Given these concerns and the cleaners' general satisfaction with traditional technology, diffusion of wet cleaning will remain slow unless supported by an external incentive of some form.

Second, there is little evidence that either vendors of wet cleaning equipment or previously existing government regulation would provide that external influence. Given the structure of the market for professional cleaning equipment, most vendors have no strong economic incentive to encourage the diffusion of wet cleaning. Moreover, information barriers, resource constraints and other internal organizational obstacles prevented government permitting and enforcement activities from having any observable growth in wet cleaning. Ultimately, our analysis of the pre-existing selection environment concludes that, absent some new external influence, broad diffusion of wet cleaning technology would not occur in the foreseeable future.

A. Information Flow in the Sector

Emphasis on information flow has significant traction in the context of the dry cleaning sector. On the surface, one might assume that dry cleaners were knowledgeable about wet cleaning technology. Indeed, seventy-five percent cleaners surveyed stated they were either very familiar or somewhat familiar with wet cleaning.[100] However, it appears that cleaners' perceived familiarity with wet cleaning—whatever the level—did not reflect their actual knowledge about the technology. Our survey of dry cleaners in the Los Angeles area concerning

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[100] Out of all respondents, 21% were very familiar with wet cleaning while 54% were somewhat familiar with it. Ninety-three percent of respondents were very familiar with PCE machines.

technology choice indicates that most dry cleaners lacked meaningful, accurate information about wet cleaning.

For example, 74% of the cleaners who considered themselves familiar with wet cleaning believed that wet cleaning causes permanent harm to garments. Yet, it is clear from numerous studies of operating wet cleaning shops that wet cleaning systems using tensioning systems cause no greater damage to garments than the traditional dry cleaning process.[101] This widely held fear of damage to garments is likely a substantial barrier to diffusion; it was identified by the majority of cleaners in the survey as their major concern about wet cleaning.

Nor is misinformation limited to this one issue. For example, fifty-four percent of cleaners who identified themselves as being "very familiar" with wet cleaning believed that a shop that shifts to wet cleaning would lose many customers. Obviously, concern over the loss of customer base would be a critical factor in technology choice for any business. Yet, this concern also appears to be unfounded. Every empirical study of commercial wet cleaning has documented high customer retention rates following a shift to wet cleaning.[102] In fact, one recent study of five wet cleaning facilities reported customer retention rates of between 99 and 100%, with two shops increasing their customer base by 4% or more by attracting customers interested in using non-toxic alternative cleaning systems.[103]

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[101] SINSHEIMER, ET AL., supra, n. __, at 4-6 to 4-9; STAR & EWING, *supra*, n. __, at 17; PPERC, *supra*, n. __, at 3-1 to 3-48;.

[102] *See, e.g.,* STAR & EWING, *supra*, n. __, at 17; PPERC, *supra*, n. __, at 3-33; SINSHEIMER, ET AL., *supra*, n. __, at 4-7 to 4-8.

[103] SINSHEIMER, ET AL., *supra*, n. __, at 4-8.

Clearly, most dry cleaners lack accurate information regarding dry cleaning technology. To some extent, their misconceptions may simply result from out-of-date information. For example, until the introduction of specialized tensioning equipment in the mid-1990's, concerns over shrinkage of clothes did prevent the efficient handling of certain categories of garments. While shrinkage is no longer a problem in wet cleaning, most dry cleaners continue to believe otherwise. Even if these this misconception is based on stale information, the question remains as to why the cleaners are not aware of the more current, accurate information. We can uncover at least part of the answer by examining the most salient source of information within the sector—vendors of wet cleaning equipment itself.

Vendors are in a strong position to influence technology choice among professional cleaners. Fifty-one percent of the cleaners surveyed considered equipment suppliers to be a very important source of information about cleaning technology. One might expect that wet cleaning vendors have strong financial incentive to ensure that their products are marketed to dry cleaners aggressively, yet there is little evidence of such activity.[104] In part, this passive marketing behavior may result from the relatively minor importance of wet cleaning equipment sales within the manufacturing companies. In most of these companies, the production of industrial and laundry systems dwarfs the production of wet cleaning equipment in terms of volume and importance to the company.[105] Indeed, only Miele, a German company without a strong presence in the United States market, relies upon wet cleaning systems for the majority of its sales of professional cleaning

[104] It appears that this phenomenon is not limited to the garment care sector. *See* KEMP, *supra*, n. __, at 237 (describing case study of plating industry which concluded that vendors of new pollution control technology found the sector to be "difficult" and directed their efforts to other more profitable markets.)
[105] Malloy & Sinsheimer, *supra*, n. __, at 85.

machines.[106] And even in Miele's case, professional cleaning equipment is but one of a large and diverse set of product lines manufactured by the firm.

Turning to distributors of wet cleaning equipment, we find similar potential barriers to aggressive marketing where the firms distribute more than one type of cleaning system (for example, selling both laundry equipment and dry cleaning systems). Consider Bowe Permac, which manufactures its own PCE and petroleum dry cleaning systems and distributes wet cleaning systems manufactured by Schulthess in Switzerland. The vast majority of Bowe Permac's equipment sales are of its dry cleaning systems.[107] Bowe Permac's sales agents are paid on commission, and are therefore more motivated to sell dry cleaning systems because such systems are both more expensive and (given the bias against wet cleaning within the sector) easier to sell than wet cleaning systems.[108] Likewise, among firms distributing both wet cleaning systems and commercial laundry equipment, only Wascomat (the U.S. distributor of Aqua Clean equipment) actively promotes the wet cleaning system.[109] Yet even Wascomat promotes its wet cleaning equipment as a "supplement" to dry cleaning, selling the majority of its Aqua Clean system to "mixed" shops that have both wet and dry cleaning machines.[110] Thus, generally speaking, wet cleaning equipment vendors appear to be weak vehicles for information dissemination.

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[106] *Id*. at 85 (citing interview with Jurgen Shaeffer of Miele).
[107] *Id.*. (citing interview with Tom Tipps of Bowe Permac).
[108] *Id.* 86; *see* KEMP, *supra*, n. __, at 99, n.1 (suggesting that sales people may advise *against* the purchase of a clean technology and advocate a product with a higher profit margin).
[109] Malloy and Sinsheimer, *supra,* n. __, . at 86 (citing Daniel Goldman of Wascomat).
[110] *Id.*

B. Perceived Costs and Benefits of Wet Cleaning Technology

At first blush, wet cleaning technology appears to offer significant benefits to dry cleaners at little cost. Two benefits dominate most discussions of the technology: comparable performance at less cost and decreased exposure to a hazardous chemical.[111] However, when viewed from the perspective of many cleaners, these benefits are either illusory or irrelevant. It appears that for many cleaners, the perceived risk of failure and costs of learning the new technology appear to outweigh whatever value the cleaners may place on the putative benefits of switching.

We begin with the issue of cost savings associated with wet cleaning. All other things being equal, there is little doubt that the capital and operating costs of a wet cleaning system are less than those of a comparable dry cleaning system.[112] For example, a 40 pound wet cleaning washer, 75-pound dryer and finishing equipment cost about $35,000. A comparably sized PCE machine ranges in price from $41,000 to $47,000. Overall, operating costs for wet cleaning facilities are comparable to or lower than those for dry cleaning.[113] A recent study of professional cleaners who had switched from PCE dry cleaning to wet cleaning compared three shops' operating costs before and after the conversion. That study found that operating costs per 100 clothes cleaned dropped at all three shops by between 17 and 50 percent after the conversion.[114]

Yet for a majority of the cleaners,' cost differences of this magnitude would not make a switch to wet cleaning more likely. When asked about cost savings associated with wet cleaning, only 8 percent of the cleaners responded that the cost

[111] Freedom from pervasive regulation is also sometimes mentioned as a major benefit of wet cleaning. We believe that this factor is captured by the cost reductions.
[112] This assumes that the systems are of similar capacity and quality. For example, a small, lower end PCE dry cleaning system could cost less than a large, high end wet cleaning system.
[113] AQMD, *Staff Report, supra*, n. __, at 1-25.

differential made them much more likely to purchase a wet cleaning system.[115] This apparent indifference to marginal cost differences is consistent with the responses received when cleaners were asked about the impact of purchase price rebates on their technology choice. As we discuss in more detail in Section IV, it appears that even relatively large financial incentives on the order of $10,000 to $17,500 would not cause most cleaners to shift from PCE dry cleaning to wet cleaning.[116]

Moreover, based on information available to them in the selection environment, the cleaners may simply not believe that the cost savings will occur, or may believe that the technology will not perform as well as PCE dry cleaning. In public testimony before the United States Congress and in public hearings before AQMD, the garment care industry trade associations and individual cleaners consistently took the position that wet cleaning is both more expensive and less effective than dry cleaning.[117] As discussed with respect to information flow within the sector, most cleaners rely on the trade associations and other cleaners for their information concerning cleaning technologies.

In addition, individual cleaners may perceive other costs of switching to be higher. The shift to wet cleaning requires that a cleaner learn a new technology, resulting in some training costs and efforts and, perhaps more importantly, giving rise to concern on the part of the cleaner that he or she may not be able to master

[114] Sinsheimer, *et al.*, *supra*, n. __, at 4-11.
[115] Another 23 percent of the cleaners responded that the lower cost would make them somewhat more likely to buy wet cleaning equipment.
[116] *See* text accompanying notes __-__.
[117] *See, e.g.,* SCAQMD, *Staff Report*, App. A, A-3, A-7, A-8, A-20, A-34, A-44, and A-47 (Comments 2,10, 18, 45(e), 27, 53, 61, respectively).

the new technology. PCE is an aggressive solvent, able to remove many spots and stains without requiring significant skill or knowledge on the part of the operator.[118] Wet cleaning calls for more attention to the nature of various types of stains and techniques for their removal, and entails more technical skill in the operation of the cleaning equipment.[119] Although it is difficult to quantify the economic impact of this concern, it does appear that the effort and risk associated with learning how to wet clean acts limits the willingness to switch of at least some cleaners.[120]

The second major benefit of conversion to wet cleaning is the prevention of exposure to PCE among shop owners, employees and the general public. AQMD estimates that even new dry cleaning machines with state of the art emissions controls will emit an average of 50% of the PCE used in the machines, resulting in excess cancer risks in a range from 15 to 90 in a million to residents and workers in nearby areas.[121] Other studies have documented significant health risks faced by nearby residents and dry cleaning shop employees.[122] Nonetheless, the public health benefits of converting to wet cleaning fare little better than the cost benefits in encouraging cleaners to switch from dry cleaning. The majority of cleaners responding to our survey did not view PCE exposure as a serious problem for their business,[123] and presumably would not view reduced PCE emissions to be cause for converting.

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118 Interview with James Douglas by authors (April 2001).

119 Kenny Slatten, _______, WESTERN CLEANER AND LAUNDERER, __-__ (MARCH 2002)(observing that PCE has spoiled cleaners and that "[n]ow is the time to become better educated in your craft.")

120 In a prior study, two out of five dry cleaners who ultimately converted to wetcleaning reported that the difficulty of learning a new technology was a major concern prior to converting. Sinsheimer, et al., *supra*, n. __, at 3-8 and 3-12.

121 AQMD, *Staff Report, supra*, n. __, at 1-8.

122 Gary Garetano & Michael Gochfeld, *Factors Influencing Tetrachloroethylene Concentrations in Residences Above Dry Cleaning Establishments*, 55 ARCHIVES OF ENVT'L HEALTH 59 (2000); Wan-Kuen Jo & Sung-Hwan Kim, *Worker Exposure to Aromatic Volatile Compounds in Dry Cleaning Stores*, 62 AMER. INDUSTRIAL HYGIENE ASSOC. J. 466 (2001).

123 In our survey, 55% of respondents stated that the hazardous nature of chemicals used in dry cleaning was not a serious problem for their business. Only 14% of the cleaners found the use of hazardous chemicals to be a very

Several factors also appear to contribute to the stickiness of the cleaners' preference for PCE. With respect to reductions PCE exposure, it appears that many PCE dry cleaners are simply not convinced that PCE is not a significant health threat. The International Fabricare Institute ("IFI"), the major garment care trade association, contends that PCE poses no demonstrable cancer risk.[124] Cleaners are more likely rely upon the IFI rather than EPA or AQMD for information on this point. Moreover, cleaners using PCE may be more likely to view the chemical as harmless as a result of certain cognitive phenomena. For example, many cleaners rely upon personal experience in arguing that PCE does not cause cancer, pointing to the lack of cancer in their family or among their peer group.[125] Cognitive psychologists have demonstrated the tendency of individuals to allow such local, anecdotal evidence to bias judgments concerning the probability or frequency of conditions or events occurring in a broader population.[126] Likewise, given the fact the PCE dry cleaner's technology choice exposes the cleaner, his or her employees,

serious problem, while 28% viewed it as a somewhat serious problem. Three percent of the cleaners have no opinion on the matter.

[124] Cite AQMD testimony; http://www.ifi.org/industry/industry-profile.html (visited December 2, 2002). The question of whether PCE causes cancer has sparked controversy for decades. For an overview of the scientific issues and the history of the regulatory battles over the designation of PCE as a probable carcinogen, see Thompson, *supra*, n. __, at 102-128. Ultimately, for purposes of understanding the diffusion of wet cleaning, whether PCE actually causes cancer or should be classified as such is less important than question of how the cleaners view the chemical and its health impacts.

[125] We attended a number of meetings during the SCAQMD rulemaking procedure at which individual dry cleaners noted that neither they nor their families or workers had experienced cancers or other harms from perc exposure.

[126] *See, e.g.,* MAX BAZERMAN, JUDGMENT IN MANAGERIAL DECISION MAKING 18-19 (1998) (describing the impact of the availability heuristic and the "presumed association" bias on judgment of the likelihood of two events occurring together).

family, customers and neighbors to the solvent, the mechanism of cognitive dissonance may encourage cleaners to discount the risks of PCE use.[127]

C. Effect of Regulation

Two AQMD rules are particularly relevant to the dry cleaning sector. The first is Rule 1421, a source-specific rule that applies expressly to all existing and new dry cleaning operations using PCE. (As discussed in Part V, Rule 1421 was amended in December 2002 to prohibit the use of PCE dry cleaning after 2020. In this section, we refer to Rule 1421 as it existed prior to December 2002.) The second is Rule 1401, a permitting provision covering new sources of toxic air contaminants that essentially requires new PCE dry cleaners to use "state of the art" emission controls. Neither Rule 1421 nor Rule 1401 expressly or functionally restricts professional cleaners from adopting wet cleaning systems. Instead, these rules reflect lost opportunities for diffusion rather than affirmative barriers to it. For although in theory each of these rules could encourage the diffusion of wet cleaning by increasing the costs of dry cleaning, in practice they have had no such effect. The following discussion examines several likely causes for the gap between theory and reality in this context.

1. Enforcement of the Source-Specific Rule

Rule 1421 sets forth design and performance standards for PCE dry cleaning machines, and supersedes both state and federal rules applicable to PCE dry

[127] *See* COGNITIVE DISSONANCE : PROGRESS ON A PIVOTAL THEORY IN SOCIAL PSYCHOLOGY, Eddie Harmon-Jones & Judson Mills, eds. (1999).

cleaning.[128] It essentially requires that cleaners use particular types of PCE dry cleaning machines equipped with specified emissions controls.[129] Rule 1421 also includes training, monitoring and record-keeping requirements intended to ensure that the emission controls are operated and maintained properly. For example, cleaners must check for PCE emissions from the cleaning equipment weekly using handheld monitoring equipment, and repair most leaks within twenty-four hours of detection. Excluding the cost of the pollution control equipment (which is part of the capital cost of the dry cleaning machine), annual compliance costs (including training, record-keeping, permit and emission fees, and hazardous waste disposal) range between $5,483 and $8,274 for an average dry cleaner. [130]

Conceptually, enforcement of Rule 1421 should encourage diffusion of alternative technologies by increasing the cost of using existing technology, either by imposing penalties directly for noncompliance or by increasing compliance expenditures by firms in response to the increased risk of detection.[131] In theory, the drive to maximize profits should trigger a cost-effective search for innovative technologies that minimize compliance costs. In reality, the costs of compliance do not appear to be a significant driver of innovation among dry cleaners. This is due in some measure to the fact that most cleaners do not actually incur the full amount

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[128] The California rule, "Air Toxic Control Measure (ATCM)—Emissions of Perchloroethylene from Dry Cleaning Operations," was issued by the California Air Resources Board and became effective in 1994. The Federal rule, promulgated by EPA under the Clean Air Act's National Emission Standards for Hazardous Air Pollutants (NESHAP) program, became effective in 1993. 55 Fed. Reg. 49354 (September 22, 1993), codified at 40 C.F.R. Part 63, Subpart M.

[129] SQAQMD Rule 1421.

[130] *See* PPERC, *supra*, n. __, at 4-13 to 4-27; USEPA, *Substitutes Assessment*, *supra*, n. __, at 10-7. Among process dependent expenses, only energy costs and pressing labor costs are higher . Sinsheimer & Gottlieb, *supra*, n. __, at App. 2-A, 7-11.

[131] *See, e.g.,* Jaffe, *et al..*, *supra*, n. __, at __-__.

of those costs. Compliance audits of drycleaners conducted in five urban areas between 1996 and 1999 revealed astonishing levels of noncompliance with Rule 1421 and similar rules in other jurisdictions. As Table 1 shows, non-compliance rates ranged between 79 and 98% percent, and the percentage of facilities that had PCE emissions or discharges was between 22% and 67%.

Table 1

Compliance Audit Results

Location and Year	Number of Facilities Inspected	Number of Facilities in Compliance	Rate of Noncompliance	Percentage of Facilities with PCE Leaks
Sacramento 1996[132]	30	4	87%	60%
South Coast 1997[133]	208	21	90%	22%
South Coast 1999[134]	340	17	95%	35%
Bay Area 1998[135]	41	9	79%	67%
New York 1998[136]	200	3	98%	No data
Massachusetts 1998[137]	100	6	94%	No data

Historically, the low compliance rates in the South Coast can be traced to at least two factors. First, as a result of reductions in AQMD's enforcement budget,

[132] California Air Resources Board, *An Evaluation of the Sacramento Metropolitan Air Quality Management District's Air Pollution Control Program* (1997).
[133] South Coast Air Quality Management Board, Fact Sheet: Findings from Dry Cleaner Inspections in South Coast AQMD (1997).
[134] Malloy & Sinsheimer, supra, n. __, at 88.
[135] California Air Resources Board, *An Evaluation of the Bay Area Air Quality Management District's Air Pollution Control Program* (1998).

between 1994 and 2000 most of the South Coast's dry cleaners went for five years or more without an inspection.[138] Second, the consequences of noncompliance with Rule 1421 are often minimal.[139] For example, between October 2000 and March 2001, the penalties paid by individual dry cleaning facilities ranged between just $50.00 and $400.00.

2. Implementation of Permitting Rules

Rule 1401 is intended to reduce health risks associated with toxic air emissions from new sources.[140] As part of the permitting process for new sources, Rule 1401 essentially requires the new facility to use the "Best Available Control Technology for Toxics" ("T-BACT").[141] For the dry cleaning sector, AQMD (like many air pollution control districts in California) views PCE equipment having primary and secondary emissions controls as meeting the BACT standard.[142]

AQMD permitting staff has the authority to classify wet cleaning technology as T-BACT. Rule 1401 defines T-BACT as the most stringent emissions limitation or control technique that has been "achieved in practice" for the relevant class of

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136 Drycleaners News, January 1999. Volume 48, No.1 at __-__.

137 Drycleaners News, November 1998. Volume 47, No. 11 at __.

138 Interview of Edwin Pupka of SCAQMD by author and Peter Sinsheimer (December 2000).

139 The District's enforcement policy provides that an inspector can respond to an observed violation in one of two ways. First, for minor violations (i.e., administrative or procedural violations or violations that involve a de minimis amount of emissions) that are not immediately corrected, the inspector issues a notice to comply (NOC). If the facility responds by coming into compliance, no further action will be taken (SCAQMD Rule 112). For non-minor violations or for repeat violations, the inspector issues a Notice of Violation (NOV), which is forwarded to the SCAQMD District Prosecutor's Office. Depending upon the circumstances, the NOV may lead to administrative, civil or criminal proceedings seeking penalties and other relief.

140 Rule 1401 also applies to existing sources that are modified so as to cause an increase in toxic air contaminant emissions, and to existing sources that are relocated. Toxic emissions from existing sources that are neither modified nor relocated are regulated under SCAQMD Rule 1402: Control of Toxic Air Contaminants from Existing Sources.

141 AQMD Rule 1401.

142 *See* SCAQMD Regulation XIII.

sources.[143] Wet cleaning meets the elements of this definition. First, it is clear that wet cleaning provides for the most stringent emission control—there are no emissions of PCE from wet cleaning. The fact that wet cleaning involves a process change rather than the application of a control technology does not prevent it from being T-BACT. The AQMD and other agencies all acknowledge, at least in principle, that changes in production processes can qualify as T-BACT.[144] Second, wet cleaning has been "achieved in practice," a term of art that looks to the commercial availability and viability of technology in question.[145] As discussed in Section __, above, wet cleaning is used as an effective, commercially viable substitute for PCE dry cleaning both in the United States and abroad.[146] Third, the commercial use of wet cleaning has occurred in the same industry sector as PCE dry cleaning: professional garment care. It has been used successfully to clean the same types and range of clothing for the same types of customers as PCE dry cleaning.[147]

Notwithstanding the technical and financial viability of wet cleaning technology, conventional pollution control devices remain T-BACT in the South

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[143] SCAQMD Rule 1401(c)(2).

[144] *See, e.g.,* AQMD Rule 1401(c)(2)(B) (recognizing a process or basic equipment change as an "emissions limitation or control technique.")

[145] Although the term "achieved in practice" is not defined in the rule, elsewhere AQMD has stated that a technology is achieved in practice if it meets four criteria: (a) commercial availability (i.e., it is offered by at least one vendor in the United States for full scale operation), (b) reliability (i.e., it has been installed and operated reliably for at least one year at a comparable commercial operation, (c) effectiveness (i.e., it performs effectively over the range of operation expected for that type of equipment, and (d) cost effectiveness. AQMD, BEST AVAILABLE CONTROL TECHNOLOGY GUIDELINES, PART D (BACT GUIDELINES FOR NON-MAJOR POLLUTING FACILITIES) 27 (2000)(hereinafter "BACT GUIDELINES").

AQMD's definition of achieved in practice is generally consistent with the definition used by EPA, with the exception that AQMD has added a cost-effectiveness criteria. This additional criteria is only applied to determinations affecting "non-major" sources, which would include most dry cleaning facilities. *See* AQMD, BACT GUIDELINES, *supra*, n. __, at Part A, 16 (describing criteria for major sources) and Part D, 27 (establishing criteria for non-major sources). AQMD's BACT Guidelines set forth procedures for determining cost-effectiveness in the standard scenario involving add-on control technology, and are of limited use in the cases of process change. *See* AQMD, BACT GUIDELINES, *supra*, n. __, at Part D, 28-31. Given the fact that wet cleaning is less expensive than PCE dry cleaning, and obviously more effective at reducing PCE emissions, wet cleaning systems appear to meet the cost-effectiveness standard. In its STAFF REPORT regarding amendments to Rule 1421, AQMD performed an economic analysis of wet cleaning and found it to be cost effective using a methodology developed specifically for the case of process changes. AQMD, STAFF REPORT, *supra*, n. __, at 3-2.

[146] The studies of dedicated wet cleaning shops demonstrate that wet cleaning technology is commercially available, reliable, technically effective, and cost effective. *See* notes __-__.

Coast and beyond for PCE dry cleaning. Several interrelated factors appear to contribute to wet cleaning's failure to achieve standing as T-BACT: an agency culture of noninterference, impaired information flow within the agency, and the nature of the permitting managers' task definition.

Agency culture refers to the pervasive and powerful reluctance at the AQMD and other environmental regulatory agencies to "interfere" directly with a facility's production process or other business operations. Historically, environmental regulators consistently relied upon end-of-pipe control and treatment to manage pollution, largely viewing the process that created the pollution as a "black box." Despite hortatory language in statutes, regulations and strategic plans about the value of pollution prevention, many regulators continue to view changes to the production process as beyond their ken. Indeed, at the federal level, environmental groups have turned to the courts to force EPA to implement statutory provisions that called for direct regulation of primary and secondary production processes.[148] For example, a court order was needed before EPA would implement a provision in the Clean Air Act that required the agency to consider potential process changes in establishing "maximum achievable control technology" for purposes of the federal air toxics program.[149]

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[147] *See, e.g.,* SINSHEIMER, ET AL., *supra*, n. __, at 4-6 to 4-8; STAR & EWING, *supra*, n. __, at 18-19.

[148] A primary production process uses raw materials as feedstock, while a secondary process reuses or recycles previously used materials or residuals from a primary process.

[149] National Lime ASS'N V. Environmental Protection Agency, 233 F. 3d 625, 633-34 (D.C. Cir. 2000). In that case, the Sierra Club challenged EPA's failure to set emission standards for several hazardous air pollutants emitted from cement manufacturing plants. EPA argued that under the Clean Air Act, emission standards were to be based on the "maximum achievable control technology" ("MACT") currently in use in the industry. Thus, contended EPA, if no existing sources currently control emissions of a given pollutant, then EPA need not set a "MACT" standard for that pollutant. *Id.* at 630. The court rejected EPA's argument, holding that the absence of an existing control

This reticence to intrude in the business operations of regulated firms was evident in our interviews with AQMD managers, who emphasized that the staff's expertise lay in managing risks created by industrial operations rather than in understanding the underlying production processes and industry settings.[150] Moreover, agency managers view mandatory process changes as riskier for the affected business than add-on control requirements. While a mistake about the feasibility of a new add-on control technology can impose costs on the business, a mistake about the feasibility of a process change could undermine the business' basic viability.[151]

The second factor that contributed to wet cleaning's failure to achieve the status of T-BACT is the uneven distribution of information within AQMD concerning the feasibility of wet cleaning as a substitute technology. As we noted previously, wet cleaners using specialized pressing equipment can clean the full range of garments cleaned by dry cleaners with the same quality. At the time of the interviews in late 2000 and early 2001, staff members in the Planning, Rule Development and Area Sources Division and in Technology Advancement Office

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technology did not relieve the agency of its clear statutory obligation to set emission standards for each hazardous air pollutant emitted from the source. In reaching that conclusion, the court relied in part on a Senate Report that stated:

> The technologies, practices or strategies which are to be considered in setting emission standards under this subsection go beyond the traditional end-of-stack treatment or abatement system. The Administrator [of EPA] is to give priority to technologies or strategies which reduce the amount of pollution generated through process changes or the substitution of materials less hazardous. Pollution prevention is to be the preferred strategy wherever possible.

Id. at 634 (citing S. REP. NO. 101-128, at 168 (1989).

Likewise, the agency began to regulate certain forms of hazardous waste recycling only after losing a judicial challenge to its policies. *See* American Petroleum Institute v. Environmental Protection Agency, 906 F. 2d 729, 740-41 (1990)("API"). The issue in API was whether EPA should have used its authority to regulate hazardous waste to control slag produced from industrial furnaces burning emission control dust from steel manufacturing plants. EPA was reluctant to treat the slag as a hazardous waste because it viewed the recycling process to be "like" a primary production process, and thus beyond the reach of the hazardous waste regulatory program.. For discussion of the API case and its impact on recycling regulation, *see* Timothy F. Malloy, *Once More Unto the Breach*, 7 VILLANOVA ENVT'L L. J. 1, 23-25 (1996).

[150] Interview of Jack P. Broadbent of AQMD by authors (November, 2000); Interview of Chung Lui, Director of TAO (November, 2001).

(TAO) were familiar with the studies that demonstrated this fact. Indeed, TAO has provided financial support for several seminal studies in this area. Yet, managers in the AQMD offices responsible for permitting, engineering and enforcement continued to question the viability of wet cleaning as a substitute technology. In particular, during interviews at that time, AQMD permitting and enforcement managers stated that wet cleaning cannot successfully clean the full range of garments, is more costly, or is otherwise not adequate.[152] Moreover, they were unaware of the AQMD-funded studies that contradicted their conclusions.

There appears to be no mechanism for systematically disseminating information concerning innovative technologies from the TAO to the permitting or enforcement staff. As one official described it, such information moves from TAO to other staff through "ad hoc osmosis."[153] Without access to current information concerning wet cleaning, AQMD staff responsible for making or participating in T-BACT determinations apparently lacked the technical information needed to trigger and conduct an appropriate T-BACT analysis of this technology.

The organizational structure of AQMD also contributed to the continued reliance on conventional control technology as T-BACT. As with virtually every large organization, the work of the District is distributed among a number of specialized sub-units, such as permitting, rule development, enforcement, and

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[151] Interview of Chung Lui, Director of TAO (November, 2001).

[152] Interview of Michael Mills of SCAQMD by author and Peter Sinsheimer (December 2000); Interview of Edwin Pupka of SCAQMD by author and Peter Sinsheimer (December 2000). The lack of information was not limited to staff at AQMD. Personnel at the California Air Resources Board responsible for rule development for the dry cleaning sector also held similar views of wet cleaning in late 2000. Interview of Victor Douglas of CARB by author and Peter Sinsheimer (2001).

others.[154] Sub-unit managers tend to focus on priorities identified by upper management as manifested in the budget, the strategic plan, and other formal and informal communications. Consequently, members of organizations typically avoid activities that do not fit their perception of the organization expects from them, and that divert resources from the sub-unit's priorities.[155] Their task definition—what the organization expects from them—is defined to some extent by formal pronouncements such as job descriptions or standard operating procedures. However, informal signals such as the type of information received by a sub-unit can also influence task definition; if little effort is made to provide a sub-unit with information about a particular issue, the sub-unit is unlikely to view that issue as a priority.[156]

It appears that the permitting staff considers encouraging the diffusion of new process technologies such as wet cleaning to be beyond its mandate, viewing such activity as a role better played by the rule development staff.[157] As discussed above, permitting managers view the choice of process technology to be a business decision, and define the permitting role as limited to identifying appropriate pollution control technologies.[158] Because permitting managers consider choices about process changes (as opposed to choices about pollution control technology) to be business decisions, they direct their staff to avoid involvement in a permittee's

[153] Interview of Peter Mieras of SCAQMD by author and Peter Sinsheimer (December 2000).
[154] *See, e.g.* JOSEPH DIMENTO, ENVIRONMENTAL LAW AND AMERICAN BUSINESS 135-47 (1986)(identifying organizational characteristics of agencies that affect performance, including coordination between sub-units and allocation of resources); JAMES Q. WILSON, BUREAUCRACY WHAT GOVERNMENT AGENCIES DO AND WHY THEY DO IT 101-104 (1989)(discussing competition for resources within agencies).
[155] JOSEPH L. BOWER, MANAGING THE RESOURCE ALLOCATION PROCESS: A STUDY OF CORPORATE PLANNING AND INVESTMENT 50 (2d ed. 1986); HERBERT A. SIMON, ADMINISTRATIVE BEHAVIOR 112 (4TH ED. 1997).
[156] *See* William Ocasio, *Towards an Attention-Based View of the Firm*, 18 STRATEGIC MGMT. J. 187, 194-95 (1997) (discussing influence of communication channels on an individual's perceived task definition); RICHARD M. CYERT & JAMES G. MARCH, A BEHAVIORAL THEORY OF THE FIRM 108-10 (1963) (discussing the impact of information routing rules on the definition of member's roles within the organization).
[157] Interview of Michael Mills of SCAQMD by author and Peter Sinsheimer (December 2000).
[158] See text accompanying note __.

decisions regarding process changes. As one manager put it: "It's not really our place. We just make sure they comply with the rules."[159]

This task definition is supported by the lack of systematic communication between TAO and the permitting division regarding innovative clean technologies.[160] In addition, the permitting division recognizes the organizational costs it would face should it use the T-BACT process to encourage diffusion of wet cleaning. One permitting official acknowledged that wet cleaning probably fits the criteria for T-BACT, but believed identifying it as such would have an unacceptably disruptive effect on the permitting function given the likely vehement reaction form industry and inevitable permit appeals that would follow.[161]

V. Altering the Selection Environment

Having identified systemic barriers to innovation within the selection environment, we now consider potential policy responses. This section examines a series of regulatory approaches aimed at altering the three aspects of the selection environment discussed above; namely, information flow, costs and benefits of the innovation, and regulations. In each case, we anticipate the likely response of the

[159] *Id.*
[160] It is likely that the relationship between information flow and task definition incorporates multiple feedback loops. In other words, the failure to receive information concerning innovative process technologies may buttresses the permitting managers' view that production process issues are beyond the permitting division, while that task definition also inhibits efforts by permitting personnel to seek and obtain such information.
[161] Interview of Michael Mills of SCAQMD by author and Peter Sinsheimer (December 2000).

system to regulatory alternative and consider the potential social costs associated with it.

A. Information Flow to Potential Adopters

Section IV concluded that a substantial majority of dry cleaners lacked accurate information about wet cleaning technology.[162] Research in innovation suggests that demonstration projects and educational outreach campaigns can be effective tools in overcoming such barriers.[163] In a demonstration project, the government sponsors one or more sites at which the new technology is used, providing firms with the opportunity to observe the innovation under actual operating conditions.[164] Outreach activities, including such things as workshops, education campaigns, or information clearinghouses, attempt to teach potential adopters about the technology and perhaps provide technical support to new adopters. Such projects can help create the "social infrastructure" needed to support the diffusion of new technology: skilled personnel to provide technical training; experienced installers, operators and repair technicians; knowledgeable vendors such as distributors; and cooperative relationships among all of those

[162] *See* notes __ and accompanying text.
[163] Jaffe, et al., supra, n. __, at ___; Allen Blackman, *The Economics of Technology Diffusion: Implications for Climate Policy in Developing Countries,* Resources for the Future Discussion Paper 99-42 at ___ (1999). In the agricultural industry and other sectors, the government used such techniques effectively. Shelley H. Metzenbaum, *Information, Environmental Performance, and Environmental Management* Systems, in REGULATING FROM THE INSIDE: CAN ENVIRONMENTAL MANAGEMENT SYSTEMS ACHIEVE POLICY GOALS? 146, 160 (Cary Coglianese and Jennifer Nash eds. 2001) (discussing federal agricultural experiment stations and extensions used to create an information infrastructure to promote innovations in farming techniques); Stephen J. DeCanio, *Barriers Within Firms to Energy-Efficient Investment*, 21 ENERGY POLICY 906, 911-912 (1993) (observing that agricultural experiment stations served as an information clearinghouse for farmers).
California recently enacted SB 998, which establishes the Nontoxic Dry Cleaning Incentive Trust Fund to be used by the Air Resources Board to fund wet cleaning facilities as demonstration projects.

parties. Moreover, demonstration projects can assist policymakers and industry alike in resolving uncertainties about the commercial viability of new technologies.[165]

Yet given the structure of the sector and the relationship between regulators and sector members, demonstration projects and outreach efforts standing alone are unlikely to achieve widespread diffusion of wet cleaning in the near term. The professional cleaning industry is highly decentralized and dominated by small, thinly staffed plants. This creates practical problems for the government in disseminating the necessary information, both in reaching all the cleaners and assuring that they allocate some of their limited attention to the information. For example, it has been reported that in many cases, cleaners will simply throw out correspondence from regulators without opening it.[166] Moreover, cleaners may be highly skeptical of information disseminated by regulators or contractors hired by the regulators.[167] In our survey, only 23% of the cleaners considered information from government regulators concerning cleaning technologies to be very important. Almost 40% of the cleaners found such government information to be not important at all. Not surprisingly, government sources fared worse on this point than three other likely information sources we asked about: vendors, trade publications and

[165]For example, the AQMD's Technology Advancement Office's wet cleaning demonstration project, which contributed to the start-up of ten wet cleaning shops, led AQMD's own rule development staff to conclude that wet cleaning is a viable alternative to dry cleaning. SCAQMD, *Staff Report*, 1-18 to 1-19. The project, which provided outreach, financial support, and technical assistance to participating cleaners, played a significant role in encouraging several dry cleaners to switch. SINSHEIMER, *ET AL.*., *supra*, n. __.

[166] Interview of Nancy Feldman of SCAQMD by author (October 2001).

[167] U.S. CONGRESS, OFFICE OF TECHNOLOGY ASSESSMENT, *Industry, Technology, and the Environment: Competitive Challenges and Business Opportunities* ___ (OTA-ITE-586 1994); Interview of Nancy Feldman of SCAQMD by author (October 2001).

shows, and other cleaners, each of which was found to be very important by almost half of the cleaners.

B. Modifying the Costs/Benefits of Adoption

Section IV also concluded that the perceived risk of failure and costs of learning the new technology appear to outweigh whatever value the cleaners may place on the putative benefits of switching. Below we examine the value in this selection environment of three policy tools intended to directly alter the costs and benefits of the new technology: increased enforcement, excise taxes on PCE and subsidies for adoption of wet cleaning.

1. Enhanced Enforcement of Rule 1421

We stated above that compliance costs with Rule 1421 were too small to encourage a technology switch. While penalty levels certainly could be increased so as to trigger greater diffusion, this would require a substantial change in AQMD policy and regulations, and in California state law governing enforcement.[168] The low penalty numbers reflect the broader compliance assistance approach taken in California towards *all* small businesses under which regulators attempt to educate operators about the existing rules, and gently "nudge" them into compliance.[169]

Even if the enforcement and penalty levels were increased, the “paperwork-based,” self-reporting nature of Rule 1421 itself is a barrier to the effective use of enforcement as a diffusion catalyst. Because comprehensive inspection of cleaners’ compliance with substantive emission limitations and operation and maintenance

[168] Section 42403 of the Health and Safety Code establishes factors to be considered in setting penalty amounts for civil action. Encouraging diffusion of alternative technologies does not easily fit within any of the factors.

obligations is costly and resource intensive, it is rarely done. When the self-reporting form of regulation is coupled with limited enforcement resources in this industry sector, it raises the specter of widespread noncompliance and under-reporting, and ultimately excess emissions.[170]

2. Environmental Excise Taxes

Regulators could attempt to raise the costs of dry cleaning through an excise tax or fee on the purchase of PCE, thus discouraging PCE usage and inducing a technology switch. Economists have identified two general types of "environmental taxes." The first is the Pigouvian tax, which is designed to discourage the taxed activity by imposing the full social cost of the activity on the taxpayer, thus raising the price of engaging in the activity.[171] A Pigouvian tax should in theory prevent future environmental harm by encouraging the adoption of alternative materials or processes.[172] The federal ozone-depleting chemicals tax, which imposed an excise tax on the sale or use of listed ozone depleting chemicals by manufacturers and importers, is an example of such a tax.[173] The second is the "polluter pays"-type tax, which captures the cost of regulation or cleanup from the firm or sector, giving rise

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[169] Interview of Edwin Pupka of SCAQMD by author and Peter Sinsheimer (December 2000).
[170] For example, one experienced inspector noted that in nine years of inspecting dry cleaners, he had yet to see one facility that recorded a PCE leak from their equipment (Rascke, 2001).
[171] Hoerner, *supra*, n. __, at 186; Barthold, *supra*, n. __, at 135.
[172] Hoerner, *supra*, n. __, at 186.
[173] The tax was enacted as part of the Omnibus Budget Reconciliation Act of 1989, CITE. For an overview of the structure and operation of the tax, see Hoerner, *supra*, n. __, at 186-188-95. For a fascinating "behind the scenes" view of the legislative history of the tax, see Brathold, *supra*, n. __, at 136-144. There has been some debate over whether the ozone-depleting chemicals tax is actually a Pigouvian tax given the fact that pre-existing federal regulations also provided for gradually increasing caps on the production and consumption of such chemicals. Some commentators have argued that the tax was a windfall profits tax intended to capture monopoly profits enjoyed by producers as a result of the federal caps. *See* Barthold, *supra*, n. __, at 135, n. 4; J. Andrew Hoerner, *Tax Tools for Protecting the Atmosphere: The US Ozone-Depleting Chemicals Tax*, in GREEN BUDGET REFORM 185, 187 (Robert Gale, et al. eds. 1995).

to the cost.[174] The Superfund tax, used to fund Hazardous Substance Superfund, is an example of the polluter pays approach.[175] The two categories of taxes are not mutually exclusive, and many taxes have elements of both types.[176]

At least ten states have imposed excise taxes on the purchase or use of PCE (ranging from $3.50/gallon in Illinois to $10.00/gallon in Oregon). However, none of these taxes constitute a pure Pigouvian tax.[177] Generally speaking, the existing PCE taxes are not designed to cause a radical technology shift, but rather to fund the cleanup of contaminated dry cleaner sites. In many of the states having such fees, the participating dry cleaners are released from cleanup liability in exchange for both paying the tax and using upgraded PCE dry cleaning equipment and procedures.[178] While the taxes increase the cost of PCE solvent, they decrease the contingent liabilities facing participating PCE dry cleaners and support the diffusion of state of the art PCE equipment. Thus, rather than encouraging a shift to alternative technologies, these programs may actually provide incentives for the *continued* use of dry cleaning processes.

Even a pure Pigouvian-type excise tax program may be of very limited use as a catalyst for diffusion. The annual cost of purchasing PCE is relatively small for most dry cleaners. For a shop processing 200 garments per day (the median daily amount for cleaners in our survey), annual solvent costs would be approximately

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[174]Hoerner, *supra*, n. __, at 187.
[175] *See* the Hazardous Substance Response Revenue Act of 1980, Pub. L. 96-510, 94 Stat. 2796 (Dec. 11, 1980). The polluter pays tax can take at least two forms. In the first, the tax is imposed on a population of actors to fund specific activities by the government necessitated by the activity. Thomas A. Barthold, *Issues in the Design of Environmental Excise Taxes*, 8 J. ECO. PERSP. 133, 134 (1994). This form would include charges on the discharge of wastewaters paid to regulators to finance the costs of purification plants and regulatory oversight. Michiel H H Hötte, et al., *Levy on Surface Water in the Netherlands*, in GREEN BUDGET REFORM 220, 221-22 (Robert Gale, et al. eds. 1995). In the second form, the taxes is essentially an insurance premium in a risk pooling program addressing potential environmental harms that are associated with the taxed activity or material. Barthold, *supra*, n. __, at 135. The federal Superfund Hazardous Substance tax is the best known example of this form..
[176] Barthold, *supra*, n. __, at 135.
[177] State Coalition for Drycleaner Remediation, *State Programs to Clean Up Drycleaners, Table 2: Fee Structures*, http://www.drycleancoalition.org (visited September 4, 2001).

$850.[179] Even applying the largest existing tax of $10/gallon to such a shop would raise total solvent costs by approximately $1,300. The present value of such payments over a ten-year horizon is approximately $9,200. This tax may simply be too small to cause a technology switch. In our survey, most cleaners found a rebate of almost $11,000 insufficient enticement to consider wet cleaning.[180]

Of course, the tax could be raised until the cost of PCE overcomes the barriers to diffusion, but it appears that the level would have to be quite high.[181] Between 1996 and 2001, the solvent tax in Oregon gradually rose from $10 to almost $27/gallon. Yet PCE continued to be the overwhelmingly dominant solvent; there is only one dedicated wet cleaner in Oregon.[182] Moreover, as the amount of the tax is increases, so too do the problems of enforcing it. Rather than switching to alternative technologies, many cleaners may avoid the tax by obtaining "black

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[178] *Id.*

[179] This figure assumes that PCE cost is $0.0136/garment. PPERC, supra, n. __, at App. 4-F. EPA estimates annual solvent costs to be approximately $1,400, based on a facility cleaning 53,333 pounds of clothes annually in a PCE machine with primary and secondary controls, using 210 gallons of solvent each year at a solvent cost $6.83 dollars per gallon. USEPA, *Substitutes Assessment*, *supra*, n. __, at 10-7. At least in the South Coast region where many dry cleaners are subject to annual limitations on PCE usage, the usage rate of 210 gallons appears high. In our survey, when asked how much PCE they need to use to operate their business successfully, only 12% of the cleaners stated that they used more than 120 gallons per year, and only 8% used more than 150 gallons annually. The median usage was 65 gallons per year. Of course, solvent costs will vary depending on the type of machine used and other factors.

[180] There is some risk, however, in assuming that cleaners' views of the value of a purchase price rebate tells us anything about their likely reaction to a PCE excise tax. Research by cognitive psychologists and behavioral economists regarding the so-called "endowment effect" suggests that cleaners may be more concerned about a loss (payment of tax) than about a gain (receipt of rebate). *See* MAX BAZERMAN, JUDGMENT IN MANAGERIAL DECISION MAKING ___-___ (1998). For a critique of the application of endowment effect research in the business context, see Jennifer Arlen, *et. al*, *Endowment Effects Within Corporate Agency Relationships*, USC CLEO Research Paper No. C01-1 (August 2001), available at http://papers.ssrn.com/paper.taf?abstract_id=276110.

[181] *See* Madhu Khanna and David Zilberman, *Incentives, Precision Technology and Environmental Protection*, 23 ECOLOGICAL ECON. 25, 39 (1997) (observing that where the price elasticity of a particular input-use is low and the costs of that input are a small portion of the firm's total production costs, very high taxes would be needed to create meaningful reductions in use of the input.)

[182] Interview with Ellen Glendening of the Oregon Department of Environmental Quality by Timothy Malloy (2001).

market" PCE.[183] Indeed, professional cleaners and state officials report that in states with existing PCE taxes for remediation programs, black markets for PCE already exist.[184] It is extremely difficult for government inspectors to accurately determine the amount of PCE purchased and used by individual cleaners. Also, increasing the excise tax raises the costs of the program for government: as the tax rate goes up, noncompliance climbs, and ultimately the costs of enforcing the tax escalate.[185] Finally, imposition of substantial excise tax could have spillover effects on workers and consumers in the form of lower wages or higher cleaning prices, respectively, as a result of the increased compliance costs or taxes paid by dry cleaners. From a policy perspective, government regulators may determine that such social costs are acceptable. However, these costs could be largely avoided by using the alternative policy tool of a gradual phase-out of PCE dry cleaning, which is examined below.

Undoubtedly, as a theoretical matter, the barriers to an effective excise tax approach could be overcome. For example, the black market problem could be addressed by imposing the tax on the PCE equipment itself rather than upon the solvent.[186] In contrast to the complexity involved in determining the source and amount of PCE actually purchased and used by a facility, it would be quite simple for inspectors to ascertain whether or not a facility is using a PCE machine. Also, the government could reduce the impact of increased tax enforcement costs by allocating tax receipts and nonpayment penalties to support enforcement efforts. Similarly, tax revenues could be redistributed to affected workers or even consumers

[183] *Id.;* John McClaren, *Black Markets and Optimal Evadable Taxation*, 108 ECONOMIC JOURNAL 665, 605-06 (1998). Such was the case with taxation of chlorofluorocarbons (CFCs); taxation during their phase-out led to the development of a black market for CFCs. United States Navy*, Black Market Activity Reminiscent of the Prohibition Era*, CFC/HALON NEWSLETTER ___ (December 1994).
[184] Interview of Victor Douglas of CARB by author and Peter Sinsheimer (2001); Oregon Department of Environmental Quality, Dry Cleaner Advisory Committee, May 16, 2000 Meeting Minutes, http://www.deq.state.or.us/wmc/cleanup/dcmin051600.htm (visited September 6, 2001).
[185] Oregon Department of Environmental Quality, *supra*, n. __.

to offset spillover effects of the excise tax, although accomplishing such redistribution could present significant administrative challenges.[187]

Nonetheless, the taxation alternative still faces two very practical problems that severely undercut its potential viability in this context. First, it would be quite difficult to identify the level of taxation needed to spur the appropriate number of cleaners to switch from PCE use.[188] This could lead to the need for several adjustments to the tax rate over time, creating administrative costs for the government and exposing the tax repeatedly to the second practical problem: political opposition to taxation generally.[189] Under current law, enactment and perhaps even revision of such a tax would require legislative action in California and likely in most other states as well. Like many other forms of taxation, a tax on PCE or PCE equipment significant enough in size to alter technology choice in the sector will likely face substantial political challenges.[190] While economists and others have

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[186] The authors thank Werner Hirsch for suggesting the use of a machine tax to address the black market problem.

[187] R.K. Turner, et al., *Green Taxes, Waste Management and Political Economy*, 53 J. ENVTL. MANAGEMENT 121, 124 (1998).

[188] *See, e,g.*, Turner, et al., *supra*, n. __, at 124 (observing that it is "difficult to establish in advance the tax level that is necessary to achieve a particular environmental objective"); Barthold, *supra*, n. __, at 140 (discussing difficulties involved in determining the rate of tax to impose); STEVEN P. KELMAN, WHAT PRICE INCENTIVES 100-23 (1981) (identifying concern over the ability to calculate the appropriate tax rate as one significant concern about emission taxes among legislators).

[189] Turner, et al., *supra*, n. __, at 124 (noting that efforts to make subsequent corrective changes to the tax rate can take considerable time and face significant political opposition); David Pearce, *The Role of Carbon Taxes in Adjusting to Global Warming*, 101 THE ECONOMIC JOURNAL 938, 942 (observing that some commentators fear that "a carbon tax will be a "hit-and-miss" affair, inducing hostile reaction from industry and consumers as it has to be adjusted in an iterative fashion" but concluding that it is not clear how serious a concern this is.)

[190] In Oregon, a proposal to increase the PCE tax from approximately $27 to $30 caused a profound legislative reaction; the statute was changed to instead cap the tax at $10/gallon. Interview with Ellen Glendening of the Oregon Department of Environmental Quality by Timothy Malloy (2001). There is reason to believe that there would be strong opposition in California as well. In 1995, a state dry cleaner trade group sponsored legislation creating a $20 gallon PCE tax with an associated liability waiver for cleaners. The group withdrew the legislation in the face of withering opposition from PCE manufacturers, environmentalists, and dry cleaners themselves. WALL STREET JOURNAL., *State EPA Finds PCE in Many Wells* (October 2, 1996). Of course, in the California case, parties such as environmentalists may have opposed the tax because of the liability waiver rather than because of any disagreement with the concept of taxing PCE consumption. The point is that tax proposals are likely to result in substantial, vigorous lobbying efforts directed at a broad range of legislators.

long touted environmental taxes as efficient, effective policy tools[191], politicians and regulators in the United States in particular have been remarkably steadfast in their lack of enthusiasm for the use of environmental taxes.[192] There are numerous potential reasons for this reluctance.[193] Many legislators fear that voting for a tax will undermine their political future, and thus prefer to support regulation that ostensibly produces benefits rather than costs.[194] Others may have ideological concerns with the notion of firms "paying to pollute," or may harbor misgivings about the technical challenges of designing and implementing a workable, effective tax program.[195]

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[191] Pigou was apparently the first to identify the efficiency gains that could be obtained through the use of a tax in this way. *See* Robert W. Hahn and Robert N. Stavins, *Economic Incentives for Environmental Protection: Integrating Theory and Practice*, 82 AM. ECON. REV. 464, 464 (1992), citing ARTHUR C. PIGOU, THE ECONOMICS OF WELFARE (1920). Emission charges and other taxes have been championed by economists for decades thereafter. *See, e.g.,* Edwin Mills, *Economic Incentives in Air Pollution Control,* in THE ECONOMICS OF AIR POLLUTION 40, 46-50 (Harold Wolozin ed. 1966); JAMES E. KRIER AND EDMUND URSIN, POLLUTION AND POLICY 303-304 (1977); *but see* Susan Rose-Ackerman, *Effluent Charges: A Critique*, 6 CANADIAN J. ECON. 512, 527 (identifying a series of real world problems that an effluent charge program would face.)

[192] To date, only two federal taxes reflect a Pigouvian approach: the ozone-depleting chemical excise tax and the "gas guzzler" excise tax which varies with the automobiles' fuel economy rating. CITE to taxes; Barthold, *supra*, n. __, at 136. Numerous commentators have observed the reluctance of many legislators, particularly in the United States, to rely upon Pigouvian-like environmental taxes. *See, e.g.,* Barthold, *supra*, n. __, at 136; Robert N. Stavins, *What Can We Learn from the Grand Policy Experiment? Lessons from SO_2 Allowance Trading*, 12 J. ECON. PERSP. 69, 74 (1998); Dieter Cansier and Raimund Krumm, *Air Pollution Taxation: An Empirical Survey*, 23 ECOLOGICAL ECON. 59, 59 (1997); Maureen L. Cropper and Wallace E. Oates, *Environmental Economics: A Survey*, 30 J. ECON. LIT. 675, 689-92 (1992).

[193] *See* Cropper and Oates, *supra*, n. __, at 685-692; Barthold, *supra*, n. __, at 142-145; Stavins, *supra*, n. __, at 71-76 (using a political economy approach to evaluate under-use of environmental taxes).

[194] Barthold, *supra*, n. __, at 143. So-called "green taxes"(also known as "environmental tax reform") may offer an alternative that allows a legislator to support environmental excise taxes while helping the general economy. Environmental tax reform would replace distortionary taxes on labor, income and investment with environmental taxes on socially undesirable activities or materials that cause pollution, waste or resource depletion. Benoît Bosquet, *Environmental Tax Reform: Does It Work? A Survey of Empirical Evidence*, 34 EVNTL. ECON. 1919 (2000) (providing a survey and evaluation of green taxes in Europe); Turner, et al., *supra*, n. __, at 123. Such taxes ostensibly create a "double dividend"—it would produce an environmental benefit by discouraging the polluting activity, but would also provide economic benefits by freeing factors of production from taxation without reducing government revenues. Bosquet, supra, n. __, at 19; Lawrence H. Goulder, *Environmental Taxation and the Double Dividend: A Reader's Guide*, 2 INTL. TAX AND PUBLIC FINANCE 157, __ (1995).

[195] Barthold, *supra*, n. __, at ___; KELMAN, *supra*, n. __, at 101,108; Stavins, *supra*, n. __, at __. Shifting to a tax-based regulatory strategy can create strategic issues within the legislature as well, as the relevant legislative committee in charge of environmental regulation may have to cede control over an environmental issue to the legislature's tax-writing committee. Stavins, *supra*, n. __, at 72. Environmental groups may wish to keep such issues within the environment committees, which frequently tend to be more pro-environment, and away from the tax committees, which are often more conservative. *Id.*; Kelman, supra, n. __, at ___. Barthold relates a story regarding Congressional infighting concerning the 1990 Clean Air Act Amendments that illustrates the relevance of committee jurisdiction. When proposals for the imposition of emissions fees were being considered, the House Ways and Means Committee (which has jurisdiction over taxation) and the Energy and Commerce Committee (which has authority over environmental regulation and enforcement) battled over which committee had jurisdiction over such fees. The parliamentarian ultimately granted jurisdiction to Energy and Commerce. Barthold, *supra*, n. __, at 144.

On balance, an excise tax capable of having a meaningful impact on PCE usage would be administratively complex and (in terms of social costs) potentially very expensive. It would combine two controversial actions (i.e., taxation and regulation of the production process) in one a single policy initiative. Here, where the goal is to supplant the existing technology rather than manage its emissions, it is difficult to articulate any significant advantage to suing an excise tax rather than a direct phase out. However, a PCE tax at lower levels may be a useful tool when used in combination with other policy tools. For example, the tax could be used to make other programs, such as tax credits, demonstration projects or enhanced enforcement, revenue-neutral for the government.

3. Positive Financial Incentives

This section examines the potential value of government subsidies in promoting diffusion of wet cleaning technology, focusing on two points.[196] First, it examines the likely impact of a government subsidy in the selection environment of the garment care industry. While a subsidy program could be a potentially meaningful catalyst for diffusion of wet cleaning, it would also be extremely expensive for the government. Second, it compares the two types of subsidy programs, observing that as between the two, a purchase price rebate is more likely to increase diffusion than an income tax credit of the same magnitude.

[196] Obviously, economic incentive can take many forms, including direct grants or rebates, tax credits, sale tax exemptions, or accelerated depreciation), low interest loans, loan guarantees, and procurement mandates for

Subsidy programs generally attempt to encourage diffusion by affecting the costs of the alternative technology.[197] In the early stages of diffusion, new technologies are often more expensive to purchase or operate than conventional technologies.[198] A subsidy may therefore be used to temporarily offset a price advantage held by the existing technology until the alternative technology becomes more competitive.[199] For example, in 2001, a federal tax credit for the purchase of alternatives to PCE dry cleaning systems was proposed in Congress as a temporary measure designed to reduce costs of new technologies until economies of scale acted to permanently reduce those costs.[200] This justification is misapplied to wet cleaning because wet cleaning systems are already comparable to the dominant technology in

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government agencies. *See* USEPA, EXPERIENCE, *supra*, n. __, at 112. We focus on direct rebates and tax credits because of the prevalence of these two instruments in the literature and in practice.

[197]STONEMAN, TECHNOLOGICAL DIFFUSION, *supra*, n. __, at 184; UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, THE UNITED STATES EXPERIENCE WITH ECONOMIC INCENTIVES FOR PROTECTING THE ENVIRONMENT 20-21 (2001) (hereinafter "EXPERIENCE"); Cropper & Oates, supra, n. __, at 681; Robert W. Lake, *Tax Incentives for Pollution Prevention in New Jersey* 9 *(*1997).

[198] KEMP, *supra*, n. __, at 99; Lake, *supra*, n. __, at 9.

[199] See Hoerner, supra, n. __, at __-___. Tax credits and other financial incentives are also used to reduce the burden of government mandated pollution control on individual businesses, spreading the costs among taxpayers generally. For example, tax benefits have historically been available at the federal and state level for businesses that are required to install pollution control equipment. *See* Barthold, *supra*, n. __, at ___ (listing subsidies of this type); Loren A.Nikolai and Rick Elam, *The Pollution Control Tax Incentive: A Non-Incentive*, 54 THE ACCOUNTING REV. 119 (1979)(demonstrating how tax subsidies for installation of add-controls controls may miss the mark).

Given the fact that capital and operating costs of wet cleaning systems are comparable to or less than PCE dry cleaning systems of similar capacity, it may appear that there are no financial burdens to spread. However, significant burdens may exist depending upon the design of the regulation that leads to the technology switch. For example, suppose that a prohibition on PCE equipment is put in place which is effective immediately. Cleaners with fairly new PCE machines may suffer a significant financial burden if they are unable to recover some or all of their investment in the PCE machine. Thus, for these purposes, the usefulness a tax credit depends upon the type and extent of financial burdens imposed by the regulation upon the affected cleaners.

[200] United States Congress, Committee on Small Business, Subcommittee on Tax, Finance and Exports, *Helping Small Dry Cleaners Adopt Safer Technology: Without Losing Your Shirt*. 106th Cong., 2nd sess. (July 20, 2000) (statement of Rep. Camp). That bill was introduced with strong support from Micell, a major manufacturer of CO2 cleaning systems. The bill ultimately failed to gain passage. In March of 2001, Representative Manzullo introduced the Small Business Pollution Prevention Opportunity Act (H. R. 978), which would provide a 20% tax credit to dry cleaners purchasing qualified dry or wet cleaning equipment. Hazardous solvents such as PCE and petroleum are specifically excluded from coverage. It is unclear whether silicone solvents such as Green Earth™ would be eligible for the credit. The bill did not move beyond committee. Similar efforts have also occurred in California. In 2001, California Assemblyman George Nakano introduced AB 845, which would provide a credit of 50% for the cost of using alternative dry or wet cleaning technology. The purpose of the bill, which was never acted upon by the Assembly, was to make alternative technologies economically feasible.

cost. There is simply no need to use a tax credit to make wet cleaning more affordable for cleaners.[201]

A subsidy could also be used to give wet cleaning a clear cost advantage, so as to overcome obstacles other than the capital or operating costs of the technology. Although the lack of information, the risk of failure, and the burden of learning a new technology are not easily quantified, it is likely that some level of economic incentive could encourage at least some cleaners to pay attention to and ultimately choose wet cleaning. Our survey lends some support to that conclusion.

Respondents in our survey expressed relative indifference to modest tax credits and rebates, but exhibited stronger interest in such programs as the size of the subsidy rose. We asked cleaners whether rebates of various sizes would make them more likely to purchase wet cleaning equipment. As Table 2 indicates, the percentage of cleaners who would be "much more likely" to switch ranged from 2 percent to 15 percent, depending upon the size of the rebate. When we include those respondents for whom a rebate made a switch "somewhat more likely", the percentages roughly double. Thus, 28% of the respondents would be more likely to purchase wet cleaning equipment if a 50% purchase price rebate were available.[202]

Table 2

[201] Clearly, a tax credit would be more useful to promote the use of CO2 technology, which costs as least three times as much as dry cleaning equipment. Analysis of the value and effectiveness of a tax credit for that purpose is beyond the scope of this report. However, it is worth noting two facts. First, even some supporters of CO2 technology question whether CO2 equipment will ever be competitive with PCE equipment on a cost basis. U.S. House, supra, n. __, at 37-38 (testimony of DeSimone). Second, even a 50% tax credit would only reduce the expected cost of a CO2 system to $75,000, a cost that most cleaners would not be willing to incur.

[202] A tax credit equal to 50% of the purchase price would have a similar effect, with 30% of cleaners being either somewhat or much more likely to switch.

Intensity of Likelihood	Percentage Likely to Switch				
	$3,500 Rebate	$7,000 Rebate	$10,500 Rebate	$14,000 Rebate	$17,500 Rebate
Much More Likely	2%	5%	8%	9%	15%
Somewhat More Likely	8%	7%	9%	15%	13%
Much/Somewhat More Combined	**10%**	**12%**	**17%**	**24%**	**28%**

Adoption of wet cleaning by 28% of cleaners would certainly provide a strong foothold for wet cleaning in the sector, and would very likely enhance the dissemination of information concerning wet cleaning among non-adopters.[203] However, it is unclear how accurate the respondents' reported predictions of their own future behavior actually are. Research in cognitive psychology suggests that such predictions should be viewed with caution.[204] Moreover, the experience of Oregon in implementing a pilot tax credit program for PCE dry cleaners suggests that subsidies may not be particularly effective in encouraging the adoption of environmentally beneficial technologies in this sector.[205]

The Oregon Pollution Prevention Tax Credit Program was a four-year pilot program available to several industry sectors from 1996 through 1999.[206] A dry

[203] STONEMAN, TECHNOLOGICAL DIFFUSION, *supra*, n. __, at 184(discussing information spillovers that occur as more firm adopt the innovative technology).
[204] S*ee* Hyde, *supra*, n. __, at 392-394 (discussing psychological research indicating that people lack the ability to identify and articulate their own cognitive and decision-making processes accurately).
[205] There is surprisingly little empirical information available concerning the impact and effectiveness of subsidies on diffusion generally. *See*, Jaffe & Stavins, *supra*, n. __, at S-44. Although a number of states have adopted tax credit programs to encourage pollution prevention generally, research has revealed no published data concerning the extent to which businesses have taken advantage of those generic tax credit programs. *See*, Lake, *supra*, n. __, at __-__ (describing programs in Delaware, Rhode Island, New Jersey and other states).
[206] It was designed to encourage businesses involved in dry cleaning, metal plating and halogenated solvent cleaning sectors to reduce, eliminate or avoid the use of certain toxic chemicals, including PCE. Oregon appears to be one of only two states that adopted a tax credit program specifically targeted at dry cleaning. Beginning in 2000, North Carolina instituted an income tax credit equal to 20% of the cost of equipment that the State Department of

cleaner installing equipment that reduced annual PCE usage to less than 140 gallons/year was eligible for a credit against income or corporate excise tax equal to 50% of the equipment cost. The Oregon credit was not widely used by any of the eligible business sectors. Although credits valued at $2.6 million dollars were available, almost 2 million dollars remained unclaimed at the end of the program. Among dry cleaners, only 24 of the 330 eligible cleaners in Oregon took advantage of it. Of those 24 cleaners, only five purchased wet cleaning equipment. Most cleaners instead purchased either advanced PCE machines (12 cleaners) or petroleum machines (7 cleaners).[207]

It does not appear that the tax credit played a significant role in the technology choices of most cleaners in Oregon, *including* those cleaners who took advantage of it. In responding to a question included in the tax credit application form, almost all of the applicants indicated that they would have made their purchase even absent the tax credit.[208] Nor did the credit appear to significantly affect technology choices of cleaners purchasing wet cleaning systems. During the four-year life of the credit program, nine cleaners purchased wet cleaning systems without seeking the benefits of the tax credit.[209] This result is consistent with a

Environment and Natural Resources (DENR) certifies to be "qualified dry-cleaning equipment." Section 105-129.16C. The statute defines qualified dry-cleaning equipment to mean equipment that is used to "dry-clean clothing or other fabric and does not use any hazardous solvent or any other substance that the [DENR] determines to pose a threat to human health or the environment." As of mid-2001, DENR had yet to receive an application for certification of any equipment. Interview with Bruce Nicholson of DENR by Timothy Malloy (October 2001), DENR had also received no applications or queries from potential wet cleaners, and believed that the tax credit would not be available for wet cleaning equipment given the limitation in the statute to dry cleaning. *Id.*

[207] Oregon Department of Environmental Quality, *Pollution Prevention Tax Credit Application Status* (undated spreadsheet on file with authors).

[208] Interview with David Kauth of the Oregon Department of Environmental Quality by Timothy Malloy (2001).

[209] Interview with Ellen Glendening of the Oregon Department of Environmental Quality by Timothy Malloy (2001).

study of subsidies for environmental expenditures in Germany. In that study, the Organization for Economic Cooperation and Development found that firms typically take advantage of such subsidies only when other regulations require the firms to undertake the expenditures.[210]

Of course it is difficult to draw firm conclusions about the likely effectiveness of a possible subsidy program for dry cleaners from one state's experience. However, one thing is clear: even if subsidies were ultimately effective, they would also be quite expensive.[211] Consider the survey results concerning purchase price rebates. Looking to the mid-range rebate of $10,500 and assuming that 17% of the cleaners take advantage of the rebate over a period of 10 years, the present value of the rebates alone (without any consideration of administrative costs) would exceed 2.5 million dollars.[212] If we assume instead that the rebate is $17,500 and it attracts 28% of the cleaners over ten years, the present value of the rebates will exceed 5 million dollars.[213] These costs are obviously only rough estimates, and would vary with the underlying assumptions adopted; yet there is little doubt that a meaningful subsidy program would involve substantial expenditures by the government. These costs could be avoided by using the alternative policy tool of a gradual phase-out of PCE dry cleaning, which is examined below.

C. Altering Legal Institutions

[210] ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT (OECD), ECONOMIC INSTRUMENTS FOR ENVIRONMENTAL PROTECTION ___ (1989).
[211] *See,* Jaffe, et al., *supra*, n. __, at 61-62.
[212] This years, using a discount rate of 8%. We chose 10 years on the assumption that cleaners would only purchase equipment as the current equipment wore out and, as we discuss below, the useful life of PCE equipment is approximately 10 years.
[213] This assumes that 437 cleaners enter the subsidy program over the course of ten years and that payments of $765,000 are made at the end of each of those years, using a discount rate of 8%.

The potential policy tools discussed thus far attempt to influence technology choice without directly regulating the firm's operations. We now turn to a policy option that alters the regulatory environment in which the firms operate: an outright ban on the use of PCE. As discussed in Section I, regulators have traditionally relied upon pollution control and risk management rather than pollution prevention to address environmental and health concerns raised by industrial activities. [214] Accordingly, product or process bans are fairly uncommon.[215] Federal regulators have banned the use of a limited number of products, such as polychlorinated biphenols (PCBs), DDT, and CFCs for general use.[216] Recently federal and state air quality regulators have prohibited the use of various toxic air contaminants for specific uses, and in each case identified alternative products that were available for the same use.[217]

A prohibition on PCE dry cleaning could be a remarkably effective tool to switch cleaners away from PCE. By directly constraining technology choice within the industry, a prohibition avoids the uncertainty associated with all of the other policy options discussed above. Neither enhanced enforcement of existing regulations nor imposition of a moderately sized PCE excise tax is likely to have a

[214] Indeed, on its face, Rule 1421 reflects a pollution control perspective to environmental policy; that is, the view that the risks associated with PCE usage can be adequately managed through add-on pollution control equipment.

[215] A prohibition can take the form of a ban on existing products or processes, or the "culling" or screening of new ones in which the regulator has some type of prior approval authority. Stewart, *supra*, n. __, at 1296.

[216] Hoerner, *supra*, n. __, at 187.

[217] For example, in 2000, the California Air Resources Board prohibited the use of PCE and two other toxic compounds in automotive consumer products after 2002 based on its judgment that non-chlorinated alternatives are widely available and are as equally effective. California Air Resources Board, *Staff Report: Initial Statement of Reasons for the Proposed Airborne Toxic Control Measure for Emissions of Chlorinated Toxic Air Contaminants from Automotive Maintenance and Repair Activities* (2000). *See also* 40 C.F.R. Part 63, subpart Q (2002)(prohibiting use of chromium additives in cooling towers).

significant impact on the majority of cleaners. Standing alone, positive economic incentives such as tax credits or subsidies would create a windfall for cleaners who would switch to wet cleaning even absent the incentive, while having limited influence on the majority of cleaners who view wet cleaning unfavorably. Moreover, unlike enhanced enforcement of old Rule 1421, imposition of an excise tax, or provision of a direct or tax subsidy, implementation of a prohibition would be relatively straightforward and inexpensive. Presumably, the regulator can identify virtually all PCE cleaners through its permitting database. Inspectors need only check the shops after the effective dates to ensure that PCE machines or solvents are not in use. Thus, social costs associated with enhanced enforcement, an excise tax, or subsidies would be substantially avoided by relying on a prohibition.[218]

In concept, a prohibition can be designed to take immediate effect, and thus cause a swift shift in technology. However, for an existing facility, an immediate prohibition could impose a significant economic burden, depending upon whether or not the facility has recovered its investment in the PCE equipment at the time the prohibition takes effect. In such cases, a gradual phase-out of the existing equipment already in service is more appropriate. The phase-out period plays an equitable role, balancing the need to reduce health and environmental impacts against the social costs of a ban. A phase-out allows temporary continued use of the PCE equipment—perhaps for the remainder of its useful life—and thus reduces the facility's economic loss. In contrast, no phase out period is needed for new facilities beginning operations after promulgation of the prohibition. In fact, because the capital and operating costs of wet cleaning are comparable to those of PCE dry cleaning, a new facility suffers no significant costs as a result of the prohibition.

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[218] *See* text accompanying notes __-__.

In December 2002, the AQMD Governing Board revised Old Rule 1421 to prohibit the use of PCE dry cleaning equipment by any new facilities.[219] Existing facilities (i.e., shops in operation before January 2003) may continue to use PCE equipment until December 31, 2020, subject to the proviso that no shop may operate more than one PCE machine.[220] The AQMD rule represents a significant movement in regulatory policy towards pollution prevention and away from the traditional approach of pollution control. However, it does suffer from two important flaws. First, it fails to implement the phase out in gradual manner. Second, it delays the prohibition effective date beyond the useful life of existing machines.

As currently designed, the AQMD phase out has no mechanism for a gradual movement of existing dry cleaners to alternative technology, but rather simply provides an eighteen year delay before the prohibition takes effect. As the effective date of the prohibition approaches, cleaners with older PCE machines will become less and less likely to purchase a new PCE machine. For example, in 2015, a PCE dry cleaner with a ten-year-old machine will be reluctant to purchase a new PCE machine, as she will only be able to use it for five years. Faced with the immediate choice between buying a new wet cleaning machine and continuing to use an older

[219] With respect to new cleaners (i.e. operations established after January 1, 2003), the Rule 1421 amendments have essentially the same effect as declaring wet cleaning to be T-BACT. Amended SCAQMD Rule 1421(d)(1)(D). The Rule 1421 amendments also have some significant impacts on existing cleaners. For example, although an existing cleaner may replace existing PCE equipment as it wears out prior to the 2020, the cleaner may only operate one such replacement unit. Thus, if an existing cleaner has two PCE units that wear out, it would have to replace the second unit with a non-PCE alternative. Amended SCAQMD Rule 1421(d)(1)(F). Moreover, existing cleaners are required to perform risk assessments and, if the risks exceed certain levels, take risk reduction measures. Amended SCAQMD Rule 1421(d)(1)(F); SCAQMD Rule 1402.

[220] SCAQMD Amended Rule 1421(d)(1)(F). Existing facilities with more than one PCE system may use the additional systems until the end of the extra system's useful life. The restriction to only one PCE machine will affect less than 5% of the facilities in the South Coast region. In addition, all PCE systems must install secondary controls by November 1, 2007. *Id*.

PCE machine, it is likely that many such cleaners will attempt to "get by" with the older machine. As compared to new PCE equipment, the older machines are less efficient in design and more likely to develop leaks. Consequently, they are significant sources of PCE emissions and the associated risks to human health. Likewise, if a substantial number of cleaners wait until the end of the phase-out period to switch to an alternative technology, there may be a shortage of equipment causing a rise in prices and uncertainty. That situation could result in delayed implementation of the prohibition. From a practical and political standpoint, the regulatory agency will be vulnerable if cleaners, vendors and trade associations seek an extension of the phase-out period until the equipment shortage eases.

In addition, the use of eighteen years as the phase out period is excessive from a policy perspective. Asuming that the phase out period is intended to provide existing cleaners with an opportunity to recover the value of their investment in the equipment, the period should be limited to the expected useful life of the equipment. A reasonable estimate of the life span of typical dry cleaning systems is ten years. Industry representatives and government officials have identified “average” useful lives spanning from eight to fifteen years.[221] In identifying ten years, we focused on how long machines can be maintained and operated properly. It is likely that a facility, particularly a small one with limited cash flow, would attempt to keep a machine for as long as possible, putting off expensive repairs and using the machine even beyond the point that its emission controls will operate effectively. Interviews

[221] A representative of the International Fabricare Institute stated in Congressional testimony that depending upon the model and manufacturer, machines may last between “eight to twelve years to fourteen years.” U.S. House, supra, n. 32, (Fisher testimony). EPA assumes a 15-year life. EPA, supra, n. __, at __. In our survey, based on the median age of existing machines and median amount of time cleaners expected to retain their existing machines, it appears that cleaners expect to replace machines after approximately fifteen years of use.

of PCE machine distributors, repair technicians, and a dry cleaner consultant suggest that ten years is an appropriate time period.[222]

The flaws in the AQMD revisions to Rule 1421 could be cured by requiring existing cleaners to replace their PCE machines within ten years (or at the outside fifteen years) from date the machine was first placed in service. The floating phase-out period should even out the rate of replacement across the period, preventing the "bunching" of replacements that might otherwise occur at the end of the period. It will also prevent cleaners from using deteriorating machines well past their useful lives. The revisions to 1421 as originally proposed by the AQMD staff incorporated such a gradual phase out, using a useful life of fifteen years. It appears that the shift to a non-graduated eighteen-year phase out in the final rule resulted from political accommodation and compromise rather than policy analysis. There was no explicit discussion or analysis of the eighteen-year period during the rule making proceedings before the Governing Board.

Standing alone, however, even a prohibition on PCE equipment does not direct the industry towards clean technologies. For example, even modified as

[222] Of the three distributors contacted, one said the expected life of a dry clean machine is 10 years (Interview with Kim Bailey of Iowa Techniques by Peter Sinsheimer (1997)), one said 7-10 years for most machines (Interview with Tom Karman of Western Mutitex by Peter Sinsheimer (1997)), and one said 10-15 years (Interview with Norman Korey of Wyatt-Bennett Inc. by Peter Sinsheimer (1997)). While two of the three repair technicians contacted said that a dry clean machine could last fifteen years, the operator usually would have to practice a significant amount of preventative maintenance, which is costly. Both said that rather than carry out preventative maintenance most cleaners wait until a problem occurs, which leads to more significant problems, more costly repairs, and greater overall deterioration of the machine. Interview with Eddy Centes of Pacific Equipment Company by Peter Sinsheimer (1997); Interview with Art Khaiwara by Peter Sinsheimer (1997). One gave ten years as an average estimate. *Id*. A third repair person said that dry clean machines are not designed to last longer than ten years. He said the maintenance cost of operating a dry clean machine is very low for the first five years, yet becomes very expensive for years five through ten and excessive afterwards. Interview with Steve Trainer of Iowa Techniques by Peter Sinsheimer (1997). The dry cleaning consultant said that ten years is the figure he used for the expected life of a dry clean machine. Interview with Ted Barry of John Barry and Associates by Peter Sinsheimer (1997).

suggested above, the AQMD revisions to Rule 1421 would not prevent cleaners from switching from PCE to petroleum solvents. In fact, the rule revision specifically identifies petroleum dry cleaning as an approved alternative technology. Although existing petroleum and synthetic petroleum solvents do not contain any listed toxic air contaminants, they are sources of VOC emissions and other wastes and industrial wastewaters.[223]

It is unclear just how many cleaners would choose petroleum cleaning over dry cleaning however. In our survey, we asked cleaners which technology would be their first and second choice in the event they had to replace the current machine. As expected, PCE equipment was the overwhelming first choice. However, while 20 percent of those with a preference chose petroleum dry cleaning, 24 percent would choose wet cleaning or CO_2 systems. Forty-five percent expressed no preference for any of the existing alternatives, and 6 percent would select a GreenEarth™ system.

Regulators could adopt at least two different approaches to the issue of PCE substitution. First, given the uncertainty of the likely direction of the movement, regulators could simply track cleaners' the technology choices over the early years of the phase out to determine whether significant movement to petroleum technology is occurring. At the end of that tracking period, AQMD can assess the impact of the prohibition on technology choice, and take further action if required. Petroleum dry cleaning systems require permits, making tracking them relatively straightforward.[224] This tracking approach would allow the regulators to avoid

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[223] *See* text accompanying notes __-__.

[224] Given the fact that toxicity testing of GreenEarth™ systems has not been completed, regulators should also track usage of those systems. GreenEarth™ operators must maintain operating records under SCAQMD Rule 1102, but they need not obtain a permit or otherwise register with SCAQMD or other environmental agencies. Consequently, new registration requirements must be created in order to track GreenEarth™ usage.

further intervention and the associated administrative expense and social costs unless the results of the tracking indicate such action is necessary.

Second, regulators could adopt one of the policy tools discussed above to direct movement away from petroleum dry cleaning. For example, at the same time it revised Rule 1421, AQMD also adopted a financial incentive program under which early adopters of alternative technologies would receive grants from the Air Quality Improvement Fund. The program provides $2,000,000 for grants of up to $10,000 for facilities adopting wet cleaning systems, and up to $5,000 for those adopting CO_2 or GreenEarth™ systems. In light of the uncertain direction of the expected technology shift, it appears that adoption of this grant program may be premature. Allocation of $2,000,000 for these purposes diverts the funds from other, without a clear need for intervention or careful assessment of the appropriate form of such intervention.

V. Conclusion

Which type of regulation leads to more innovation? One cannot answer that question without knowing something about the selection environment. In the case of dry cleaning in the south coast, the selection environment is such that a prohibition is likely to be the most effective, least costly policy choice. However one would expect the nature of the selection environment to vary from industry sector to industry sector.[225] for example, the mechanisms for information dissemination within the chemical manufacturing industry will likely differ from those within the commercial printing sector. So too, routines followed by firms in the microelectronics industry in allocating resources to research and development may also contrast with those of the petroleum refining industry.[226] consequently, the types of barriers to innovation vary across sectors, as will the effectiveness of different forms of regulation. In other words, the relative value of command and control rules and market-based regulation in encouraging innovation ultimately depends on the nature of the selection environment in question.

[225] NELSON & WINTER, *supra*, n. __, at 265-66.
[226] *See* Malloy, Incentives, *supra*, n. __, at 598; David J. Teece, *Firm Organization, Industrial Structure, and Technological Innovation*, 31 J. ECON. BEHAV. & ORG. 193, 211-14.