2011-01-31

The effect of technology type on the adoption and effectiveness of global environmental standards

Ben William Lewis
blewis@byu.edu

Glen W. S. Dowell
Cornell University, gwd39@cornell.edu

Original Publication Citation
Dowell, Glen and Ben Lewis. 2011. "The effect of technology type on the adoption and effectiveness of global environmental standards." In Subhash C. Jain and Ben L. Kedia (eds.), Enhancing Global Competitiveness through Sustainable Environmental Stewardship.

THE EFFECT OF TECHNOLOGY TYPE ON THE ADOPTION AND EFFECTIVENESS OF GLOBAL ENVIRONMENTAL STANDARDS

Glen W. S. Dowell
Johnson Graduate School of Management
Cornell University
350 Sage Hall
Ithaca, NY 14853
gwd39@cornell.edu
(607) 255–3800

Ben W. Lewis
Johnson Graduate School of Management
Cornell University
201K Sage Hall
Ithaca, NY 14853
bwl33@cornell.edu
(480) 385–9563

INTRODUCTION

Fitting with the theme of this volume, we are interested in explaining firms' environmental performance, and factors affecting firms' abilities to improve that performance. We investigate the role of technology as a factor in influencing firms' environmental strategies. We also consider whether a firm's primary technology type is a moderating factor between its global environmental strategy and its financial performance.

Much of the prior literature on corporate environmental performance has considered the link between environmental performance and profit (see Orlitzky, Schmidt, and Rynes, 2003 for one of many reviews of this topic). If the broad message from the numerous studies of environmental and financial performance is that it can pay to be green (or perhaps, that it does not have to cost to be green), the bigger question that remains may be "when does it pay to be green?" Embedded in that question, we believe, is the question of which organizations will have a greater ability to improve their environmental performance, and what role does a firm's industry and core technology play in its ability to improve its environmental performance (Schaltegger & Synnestvedt, 2002).

We argue that understanding environmental performance is, by itself, important for organizational scholars. That is, we need to understand the factors that affect environmental performance regardless of the link between financial performance and environmental factors. Margolis and Walsh (2003) argue forcefully for this perspective, as they suggest that the emphasis on understanding how social responsibility affects profit "leaves unexplored questions about what it is firms are actually doing in response to social misery and what effects corporate actions have, not only on the bottom line but also on society (p. 278)."

Below, we describe the role of technological change and technology type in affecting environmental performance. We argue that one of the key constraints on a firm's ability to improve its environmental performance is the technology in which it is embedded. We develop hypotheses regarding the influence of technology type on a firm's global environmental strategy, and test these hypotheses using a panel of MNEs. We find that technology type does influence a firm's global environmental strategy, and the financial return associated with using a global environmental standard.

TECHNOLOGY TYPE

In this chapter we follow the model proposed by Tushman and Rosenkopf (1992) and conceptualize technological complexity as a typology of products ranging from simple to complex. This typology includes four product types as shown in Table 5.1: (1) non-assembled products; (2) simple assembled products; (3) closed systems; and (4) open systems.

(Insert Table 5.1 here)

Non-assembled products consist of raw materials that are transformed through a series of sequentially linked steps or manufacturing subprocesses (such as chemical, thermal, or machining). Examples of non-assembled products include aluminum, steel, glass, and petroleum. Because of their simplistic nature, the performance of such products are evaluated on relatively simple unidimensional scales of efficiency and value (such as price/ unit or price/performance). While technological progress can be made through process or product improvements, such decisions are largely made at the managerial level with minimal sociopolitical influence.

Simple assembled products are made up of distinct subsystems that fit together through a set of interlinked steps that are sequentially ordered. Examples include stoves, guns, skis, and books. Like non-assembled products, the performance criteria for simple assembled products are clear and easily measured (such as price/unit or price/performance). Technological progress occurs through process innovation or product substitution as technical considerations dominate organizational considerations in the quest for superior alternative processes or inputs.

Composed of various subsystems, assembled systems are much more complex than non-assembled or simple assembled products. Assembled systems can be conceptualized into two distinct classes: closed and open systems. Closed systems are bounded and often produced by a single organization whereas open systems are unbounded and produced by networks of organizations. Examples of closed systems include watches, automobiles, and airplanes. Because there are multiple subsystems, performance evaluation is much more complex as the overall system performance depends on the subsystem performance and interface technologies. Unlike non-assembled or simple assembled products, the subsystems of closed systems are not necessarily of equal importance – some subsystems are more central, others play a more peripheral role. For example, the engine is a core subsystem that plays a central role in the overall performance and technological progress of the automobile, whereas the wheels, brakes, and steering are peripheral subsystems that are highly dependent on the engine's characteristics. Because the closed system is composed of several subsystems, technical progress occurs at the subsystem level with each subsystem having its own unidimensional path of progress largely driven by process and/or product innovation at the non-assembled or simple product level. Like simple assembled products, a dominant design emerges through technical competition of alternative processes and subsystems.

Open systems are composed of a set of closed systems linked together through interface technologies. Examples of open systems include railroads, television, the Internet, and other telecommunication networks. While each closed subsystem evolves independently, the system as a whole is composed of a network of highly interdependent systems that is inherently complex and subject to a variety of sociopolitical forces. Technical progress generally occurs at the component and subsystem level until a dominant design can be achieved. Yet because of the high interdependency between the components and subsystems, technical progress of the overall system can be slowed as various organizations and other social and/or political institutions compete for the optimal design. In summary, the more complex the technological type, the greater the social and technical uncertainty and the influence of social and political processes on the nature and path of technical progress. In the following section, we develop hypotheses that address the role of technology type on environmental performance.

GLOBAL ENVIRONMENTAL STANDARDS AND ENVIRONMENTAL PERFORMANCE

Managing a firm's environmental performance is complicated by the plethora of regulatory regimes to which a firm has to attend. This process is difficult for firms that have operations distributed through a single country, but becomes even more complex for MNEs. Some corporations, with operations spread across very different jurisdictions, face not simply different regulations, but significantly differing levels of environmental requirements, with some jurisdictions requiring relatively stringent environmental performance, and other, so-called pollution havens allowing firms a wide latitude in their environmental impacts.

Meyer (2004) reviews the academic literature that addresses MNEs' effects on the environment. He discusses the arguments that MNEs have two potential environmental effects in their host-countries. First, firms may bring state-of-the-art environmental technology to jurisdictions that previously did not enjoy such technologies. Second, firms may take advantage of lax regulations and behave in ways that are not allowed in more stringent jurisdictions. Such behavior might include emitting more pollution or producing products that have been banned due to their environmental impact.

Anecdotal evidence of both chasing pollution havens and employing state-of-the-art technologies exists. More interesting, for the purposes of this chapter, is understanding when one strategy is more likely than the other, and how using one or the other strategy affects firm performance. Broadly speaking, firms have two choices. First, they can allow subsidiaries to meet local environmental standards, whether those standards are strict or lax. Second, the corporation can mandate that all subsidiaries follow the same standard, even if that standard exceeds what is required in the local jurisdiction.

Dowell, Hart, and Yeung (2000) review the arguments for and against employing a global environmental standard. The benefits, they suggest, fall into three categories. First, employing a single global standard facilitates knowledge sharing among the firm’s subsidiaries. Second, firms can enjoy reputational benefits from adhering to strict standards even when the standards are not mandated. Third, if countries’ standards tend to become stricter as they develop, going beyond currently-mandated requirements can preempt the need to improve performance to meet improving standards later.

The costs of employing a global standard arise because many solutions to environmental issues impose added production costs to companies (Newton & Harte, 1997; Walley & Whitehead, 1994). The degree to which stringency imposes added costs may depend upon how the stringency is achieved, however, as pollution prevention can involve efficiencies as firms find ways to avoid pollution altogether, rather than to involve costly treatment (Hart, 1995). Even so, there is evidence that not all forms of pollution prevention are profitable (King & Lenox, 2002), and that firms may need to develop complementary assets in order to profit from pollution prevention (Christmann, 2000). Thus, on average, going beyond environmental requirements may force firms to incur costs they would not otherwise experience.

Rather than argue whether, overall, global standards have net benefits for firms, it is more instructive to consider conditions that might affect the relative benefits of such standards. That is, we wish to outline contingencies in the global standard–profit relationship. While a number of internal and external contingencies are possible, we focus on the influence of technology type on both the probability that a firm will attempt to implement a global standard, and the profitability of doing so.

HYPOTHESES

We follow Dowell et al. (2000) and consider an MNE to have two broad choices in its global environmental practices. First, it can alter its environmental practices in its various international operations, so that in stringent jurisdictions it practices greater environmental stewardship than it practices in less stringent jurisdictions. Second, the firm can attempt to enact a single, global environmental standard in all jurisdictions in which it operates. While there are potential benefits to either of these strategies, Dowell et al. (2000) find that the market values of those firms that we a global environmental standard are significantly higher than the values of those firms using the host country standards.

In considering their results, we ask what we believe to be a fundamental question: why, if global environmental standards are associated with higher value, do all firms not pursue such standards? There are, of course, a number of internal and external factors that could affect a firm’s ability to enact and derive value from a global environmental standard. Christmann (2000), for example, demonstrates that firms are better able to profit from environmental best practices if they also possess complementary assets such as capability for process innovation.

While internal factors such as complementary assets are likely to be important for firms deriving value from global standards, we focus here on the role of a firm's technology type on its ability to (a) enact a global standard and (b) realize value from such a standard.

Global firms face a confusing array of regulations and standard practices in the varying jurisdictions in which they operate (Hebb & Wójcik, 2005; Stiglitz, 2002). While it may be tempting to consider global standards to be a ready solution to these differences, we argue that, in fact, global standards are difficult to enact, particularly in the presence of legacy investments (Lundan, 2003). The legacy investments place constraints on a firm's attempts to produce in the same way in all jurisdictions, which means that a firm that uses proactive pollution prevention technologies in more modern plants may be forced to use pollution control techniques in older facilities.

Taking the difficulty of enacting a global standard as given, the question remains whether and how technology type might affect a firm's ability to enact a standard. At first glance, it might seem that systems technologies are naturally more conducive to enacting global environmental standards, we argue that, in fact, they are the most difficult technologies in which to do so. As described above, systems technologies are particularly prone to political influence, and thus standards and practices can differ greatly between jurisdictions. The increased political influence on these standards means that deviance from a practice in a given jurisdiction is particularly circumscribed.

The case of television illustrates the difficulty of enacting a global standard in an open systems technology. In the mid-1980s the US began to consider adopting a standard for high definition television, and though Japan had already created high definition broadcast capabilities, political processes (fueled by anti-Japanese sentiment due to the loss of US competitiveness in electronics) led to the Federal Communications Commission (FCC) creating a standards competition, which eventually settled on a series of standards, none of which were compatible with the Japanese system (Brinkley, 1997). The standards in television broadcasting remain different across jurisdictions today.

The well-known Intel strategy of "copy exactly," in which equipment and processes are duplicated precisely across its global factories, might seem to contradict our contention that open system technologies exacerbate the difficulty of creating global standards. Certainly, microprocessors are components of an open system technology in computing. We offer two observations of the situation for Intel that, we believe, reduce its power as a counter-example. First, it is notable that though Intel completed adoption of its "copy exactly" strategy in 1996, it remains an iconic, perhaps unique, example of such a strategy, which to us underscores the difficulty of enacting this strategy. Second, Intel reports that implementing the strategy, even in its high capital-turnover industry, took over a decade, which suggests that for firms lacking Intel's resources and capital replacement cycle (meaning, of course, nearly all other firms in the world), it would take even longer and be even more difficult to create payback.

Our contention, then, is that firms that operate in less complex technological spaces will have an easier time enacting global environmental standards. We expect, therefore, that firms in non-assembled and simple assembled technology industries will be more likely to enact global environmental standards, and that the relationship between global standards and market value is stronger for such firms:

Hypothesis 1a: The probability that a firm will use a global environmental standard is lower if the firm primarily uses an open or closed system technology than if it uses a non-assembled or simple assembled technology.

Hypothesis 1b: The market value of firms using global environmental standards is lower for those firms that primarily use open or closed system technologies compared to those that use non-assembled or simple assembled technologies.

DATA AND METHODS

For hypotheses 1a and 1b, we assess a firm's global environmental standards using the Investor Responsibility Research Center (IRRC) survey data of S&P 500 firms. These data and the global standard measure specifically, were used in Dowell, Hart and Yeung's (2000) study of the relationship between environmental standards and market value. The data, gathered by IRRC surveys, are available from 1994–97, so they cover a limited time period, but one in which there was an ongoing managerial debate over the profitability of going beyond compliance in environmental efforts, thus making this an important period for analysis.

Each firm in the IRRC data set indicates whether it uses the host country standard in each country in which it operates, attempts to use US standards around the world, or has an internal global environmental standard that it attempts to apply throughout its operations. Dowell et al. (2000) find that firms that use global environmental standards had significantly higher market values, as measured by Tobin's Q, than firms that used either the US standards or the host country standards. From the IRRC survey, we create an indicator variable that takes on the value of 1 if the firm uses an internal global environmental standard, and 0 otherwise.

Our second key variable is the firm's technology type. To construct this variable, we begin by assigning each four-digit Standard Industrial Classification (SIC) code that is represented in our sample to one of the Tushman and Rosenkopf (1992) classifications. We performed this classification prior to examining the IRRC sample, so that the technology classifications would not be biased by knowing which firms in our sample were in which SIC. The IRRC data include the firm's main SIC, and we assign each firm to a technology category based upon that SIC designation. Many of these companies are diversified, but the data do not allow us to divide their operations among multiple SICs, so we use the SIC category that the firm considers its main industry classification. The equations that we employ for hypotheses 1a and 1b are:

$$(1)\ Global\ Standard_{it} = \beta_1 TechType_{it} + \beta \boldsymbol{X}_{it} + e_{it}$$

$$(2)\ Tobin_{it} = \beta_1 TechType_{it} + \beta_2 Global\ Standard + \beta_3 TechType \times Standard_{it} + \beta \boldsymbol{X}_{it}$$

In equation (1), *Global Standard* is the indicator variable described above. The *TechType* is a series of indicator variables, each taking on a "1" if the firm's industry is classified as a given type, and **X** is a vector of control variables. Hypothesis 1a is assessed by the coefficients on the indicator variables in *TechType*. In equation (2), Tobin is the firm's Tobin's Q value in year t.[1]

Global Standard and *TechType* are as described above. Hypothesis 1b is assessed by the coefficient β_3, which is the coefficient for the interaction of *Global Standard* and *TechType*.

Control variables

For equations (1) and (2), we follow Dowell et al. (2000) in our choice of control variables. For equation (1), we include a firm's size, measured by its assets and the degree to which its operations are multinational (percent of foreign assets). Larger, more international firms may have to expend greater efforts to manage a global environmental standard, but the ensuing benefits may also be greater for such firms. For equation (2), we include size (assets), research and development intensity, advertising intensity, and degree of leverage, as these variables have been shown to affect the firm's Tobin's Q (Dowell et al., 2000; Morck & Yeung, 1991). We also include an indicator variable that takes on a value of 1 if the firm operates a production facility in a low-income country, as prior work suggests that low-income countries have lower

[1]Tobin's Q is a measure of the market value per dollar of replacement cost of tangible assets. We use the market value of a firm's common stock at year end and the replacement costs are calculated using values from Compustat.

environmental standards (Grossman & Krueger, 1995), and the benefits of using global environmental standards might differ for firms that operate in such jurisdictions.

Methods

For hypothesis 1a, we use a logistic regression with random effects at the facility level. The dependent variable, as described above, is 1 if the firm uses a global environmental standard in a given year, and 0 if it uses a host country standard or uses the US standard. For hypothesis 1b, we again use regression with random effects at the facility level, with the firm's Tobin's Q as the dependent variable.

(Insert Table 5.2 here)

RESULTS AND DISCUSSION

Table 5.2 contains the descriptive statistics and correlation coefficients for the variables. The correlation results suggest that there are significant differences between firms, depending upon the technology type in which they operate. For example, firms in systems technologies (both open and closed) tend to be larger, and open system technology firms tend to spend more on research and development and less on advertising than other firms, but have a lower percentage of assets in foreign countries.

(Insert Table 5.3 here)

We now turn to the questions posed in hypotheses 1a and 1b. Does technology type affect the likelihood of a firm using a single, global environmental standard? Does it affect the return from doing so? We begin by exploring the data. Table 5.3 shows the frequency of global environmental standards by technology type. The results show support for the argument that technology type affects the likelihood of using a global environmental standard, though the pattern may be a little more complex than hypothesis 1 suggests. It appears that companies that primarily operate in industries characterized by non-assembled technologies are most likely to use global standards, as we predicted. Likewise, those companies that are in industries classified as open systems technologies have the lowest likelihood of using global standards. The t-test of the difference in the proportion of non-assembled and open systems firms using global standards is significant (t-value = 5.41, p = 0.000). Those firms that are in industries classified as closed system technologies, however, are equally likely to use global standards as the firms in non-assembled technology industries are, while those using assembled systems have a moderate probability of using global standards.

Overall, the results of Table 5.3 suggest that technology type may play an important role in affecting a firm's likelihood of using a single, global environmental standard. The analysis in Table 5.3, however, does not allow us to control for other factors that might affect the probability of employing a global standard. For example, if it is more complex to implement a global standard when the firm has a higher proportion of its assets outside the US, and more of the open systems firms have a higher proportion of international operations, the results in Table 5.3 could reflect this, rather than being driven by technology type. To attempt to control for possibilities such as this, we turn to regression analysis.

(Insert Table 5.4 here)

Table 5.4 contains the results of random-effects logistic regression analysis where the dependent variable takes on a 1 for firms that use a global environmental standard. Model 1 contains the control variables. The results indicate that larger firms and those with a greater proportion of international operations are more likely to use a global standard.

Model 2 adds the indicator variables for technology type. The omitted category is non-assembled technology, so the coefficients on the technology type variables represent the increase or decrease in probability that a firm in an industry characterized by a given technology uses a global standard, relative to a firm in a non-assembled technology industry. The results indicate that firms in open systems technology industries are significantly less likely to use global standards than are those firms in non-assembled industries. In fact, testing the equality of coefficients shows that the firms in open systems technologies are significantly less likely to use global standards than firms in closed systems or simple assembled technologies as well.

(Insert Table 5.5 here)

The results thus far provide strong evidence that a firm's core technology type does affect its likelihood of using a global environmental standard. We now turn our attention to whether the return to employing a global standard differs depending upon the technology type, as predicted in hypothesis 2. In Table 5.5, we present the results of random-effects regression of a firm's Tobin's Q on the control and independent variables described above. Model 1 contains the control variables. This model replicates the findings of Dowell et al. (2000), and demonstrates that firms with more intangible assets, as represented by research and development and advertising intensity, have higher Tobin's Q ratios. The key finding from Dowell et al. (2000) is also demonstrated, as firms that use internal global environmental standards have significantly higher Tobin's Q ratios.

In Model 2 we add the indicator variables for technology type (non-assembled technology is again the omitted category). We also add the interaction between technology type and global environmental standards. Hypothesis 2 suggests that the coefficient on Global Standard X Open System should be negative and significant, reflecting the difficulty of enacting a global environmental standard in an open system technological environment. The results do not support hypothesis 2, as the coefficient on the interaction between global standards and open systems is positive but insignificant.

DISCUSSION AND CONCLUSION

By their very size and pervasiveness, MNEs have a massive impact on not only the global economy, but also on the natural environment. Understanding the factors that affect these corporations' impact on the environment, therefore, is an important research question. In this paper, we have taken a small step forward in advancing our understanding of these factors, by exploring the relationship between technology type and global environmental strategy.

We find that technology type, as measured by the Tushman & Rosenkopf (1992) typology, is related to the likelihood that a firm undertakes an internal global environmental standard. Those firms that operate in industries characterized by open systems technologies are significantly less likely to use an internal global standard, compared to firms that are in non-assembled technology sectors. For firms in the open systems sectors, coordinating the practices across multiple jurisdictions is a complex undertaking, as an open systems technology is characterized by the presence of multiple, interacting subsystems. In such an environment, a firm cannot make a decision to modify its practices independent of the other parties involved in the open system, which makes global coordination difficult for a firm. This difficulty is amplified by the MNC's operations that may span vastly different political and technical environments.

We find no evidence that the return on employing a global standard differs depending upon the technology type. Though this contradicts our prediction that open systems technology firms would have a lower return on employing a global standard, it suggests that the managers are acting rationally. That is, firms are not employing global standards in situations in which such standards reduce their financial returns. Within the sectors characterized by open systems technologies, therefore, it is likely that there are some firms for which it is easier to manage globally coordinated processes, and these firms are the ones that are doing so. With our data, we are not able to determine what might affect the firms' abilities to manage global standards, but one candidate is experience with global operations, as experience has been shown to increase firms' abilities to deal with complexity (Dowell & Killaly, 2009).

Taking our key findings together, we believe that our results provide evidence that firms' abilities to proactively manage their interactions with the physical environment are positively related to their overall quality of management. This relationship has been discussed at least since Cairncross (1991), who argued that "Companies that take the environment seriously change not only their processes and products but also the way they run themselves (p. 279)." Dowell et al.'s (2000) results are consistent with this argument as they suggest that companies that use a global standard rather than ratcheting down to a host country standard were better-run companies. Our results further this 'green management is good management' hypothesis, as we find that some companies are better able to overcome technical restrictions and profit by doing so.

Overall, our results have several implications. First, they point to the importance of understanding the external context in targeting firms and industries for environmental improvement. Christmann (2000) and others have shown the importance of understanding context in assessing environmental performance. Our findings suggest that the external context, which we represent here by the technology in a firm's core industry, is also important.

Our results also speak to research that seeks to understand the leap from pollution prevention to sustainability. If we take as given that the leap to sustainability is even more complicated than the greening attempts we have observed, then we need to have a strong understanding of the barriers to companies becoming more sustainable. This link is important not only for academics studying environmental performance, but also for managers seeking to understand the task of organizational change involved in enacting better environmental performance.

Finally, the results have implications for public policy. As policy experts look to find the right combination of carrots and sticks to enable firms to move to more sustainable positions, it is important to understand how to fit the policy to the technology. The results of our global sample indicate that firms in complex technologies, for example, may react differently to legislation than firms that are in less complex situations.

This research should be seen as exploratory. Many other issues to consider and control variables could be important, but could not be incorporated in this initial attempt to understand the relationships. We believe that this is the first attempt to understand how technology type affects environmental performance, and indeed is one of the few attempts to date to really try to assess the role of technology type in organizational change in any setting. Our results are likely to create more questions than answers in our quest to understand how to move to a more sustainable world.

REFERENCES

Brinkley, J. (1997). Defining vision: The battle for the future of television. New York, NY: Harcourt Brace.

Cairncross, F. (1991). Costing the earth. Cambridge, MA: Harvard Business School Press.

Christmann, P. (2000). Effects of "best practices" of environmental management on cost advantage: The role of complementary assets. *Academy of Management Journal, 43*(4), 663-680.

Dowell, G., Hart, S., & Yeung, B. (2000). Do corporate global environmental standards create or destroy market value? *Management Science, 46*(8), 1059-1074.

Dowell, G., & Killaly, B. (2009). Effect of resource variation and firm experience on market entry decisions: Evidence from U.S. telecommunication firms' international expansion decisions. *Organization Science, 20*(1), 69-84.

Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *The Quarterly Journal of Economics, 110*(2), 353-377.

Hart, S. L. (1995). A natural-resource-based view of the firm. *Academy of Management Review, 20*(4), 986-1014.

Hebb, T., & Wójcik, D. (2005). Global standards and emerging markets: The institutional-investment value chain and the CalPERS investment strategy. *Environment and Planning, 37*(11), 1955-1974.

King, A., & Lenox, M. (2002). Exploring the locus of profitable pollution reduction. *Management Science, 48*(2), 289-299.

Lundan, S. M. (2003). Multinationals, environment, and global competition: A conceptual framework. In S. M. Lundan (Ed.), *Multinationals, Environment and Global Competition* (pp. 1-22): Emerald Group Publishing Limited.

Margolis, J. D., & Walsh, J. P. (2003). Misery loves companies: Rethinking social initiatives by business. *Administrative Science Quarterly, 48*(2), 268-305.

Meyer, K. E. (2004). Perspectives on multinational enterprises in emerging economies. *Journal of International Business Studies, 35*(4), 259-276.

Morck, R., & Yeung, B. (1991). Why investors value multinationality. *The Journal of Business, 64*(2), 165-187.

Newton, T., & Harte, G. (1997). Green business: Technicist kitsch? *Journal of Management Studies, 34*(1), 75-98.

Orlitzky, M., Schmidt, F. L., & Rynes, S. L. (2003). Corporate social and financial performance: A meta-analysis. *Organization Studies, 24*(3), 403-441.

Schaltegger, S., & Synnestvedt, T. (2002). The link between 'green' and economic success: environmental management as the crucial trigger between environmental and economic performance. *Journal of Environmental Management, 65*(4), 339-346.

Stiglitz, J. E. (2002). Globalization and its discontents. New York, NY: W.W. Norton.

Tushman, M. L., & Rosenkopf, L. (1992). Organizational determinants of technological change: Toward a sociology of technological evolution. *Research in Organizational Behavior, 14,* 311-347.

Walley, N., & Whitehead, B. (1994). It's not easy being green. *Harvard Business Review, 72*(3), 46-51.

Table 5.1 Technology types

Technology type	*Examples*	*Process*	*Performance Criteria*	*Influences on Change*
Non-assembled	Aluminum, steel, glass, gears, paper, fibers, petroleum, springs	Chemical, thermal, machining – sequentially inter-linked steps	Unidimensional based upon price/ performance	Adoption as price/ performance of new process or product exceeds existing.
Simple assembled	Stoves, hoses, cans, skis, containers, guns	Assembly	Unidimensional based upon price/ performance	Adoption as price/ performance of new process or product exceeds existing.
Closed system	Watch, bicycle, car, airplane	Assembly at subsystem and system level	Multidimensional depending upon subsystem performance and linkages	Change at subsystem or system level; political processes important.
Open system	Computer, power generation, television	Assembly at subsystem and system level	Multidimensional depending upon subsystem performance, linkages and technological interdependencies	Inherently political – competition between systems and subsystems with multiple performance criteria available

Table 5.2 *Descriptive statistics and correlation coefficients*

Variable		Mean (Std Dev)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1)	Tobin's q	2.98 (2.82)	1.000									
(2)	Size (ln assets)	8.91 (1.21)	-0.023	1.000								
(3)	R&D intensity	0.04 (0.04)	0.240	-0.224	1.000							
(4)	Advertising intensity	0.02 (.04)	0.375	-0.050	0.018	1.000						
(5)	Leverage	0.18 (0.11)	-0.278	0.159	-0.486	-0.156	1.000					
(6)	Percentage of foreign assets	0.28 (0.17)	0.206	-0.068	0.386	0.134	-0.323	1.000				
(7)	Global environmental standard	0.37 (0.48)	0.325	0.246	0.108	0.092	-0.077	0.154	1.000			
(8)	Non-assembled technology	0.39 (0.48)	0.103	0.034	-0.089	0.048	-0.082	0.158	0.181	1.000		
(9)	Simple assembled technology	0.21 (0.41)	0.128	-0.208	-0.037	0.197	0.010	0.054	-0.042	-0.415	1.000	
(10)	Closed systems technology	0.14 (0.35)	-0.113	0.133	0.030	-0.053	0.066	-0.030	-0.015	-0.326	-0.209	1.000
(11)	Open systems technology	0.18 (0.38)	-0.092	0.159	0.142	-0.140	0.008	0.188	-0.146	-0.376	-0.242	0.190

Table 5.3 *Frequency of global environmental standards by technology type*

Technology Type	***Internal global standard***	***Other***	***Total***
Non-assembled	151	161	312
	(48.4%)	(51.6%)	
Assembled	111	56	167
	(33.5%)	(66.5%)	
Closed system	44	68	112
	(39.3%)	(60.7%)	
Open system	32	111	143
	(22.4%)	(77.6%)	
Total	283	451	734
	(38.6%)	(61.4%)	

Table 5.4 *Effect of technology type on probability of using a global environmental standard*

Variable	**Model 1**		**Model 2**	
Constant	-11.580		-11.000	
	(2.247)		(2.128)	
Size (ln assets)	1.015	***	1.059	***
	(0.227)		(0.218)	
R&D intensity	4.177		9.860	*
	(5.841)		(5.863)	
Advertising intensity	1.049		-0.091	
	(5.435)		(5.204)	
Leverage	-1.526		-1.259	
	(1.979)		(1.933)	
Percentage of foreign operations	0.050	***	0.035	**
	(0.016)		(0.016)	
Assembled technology			-0.613	
			(0.615)	
Closed system technology			-0.873	
			(0.687)	
Open system technology			-2.549	***
			(0.736)	

Notes: All models have 734 observations. ***, **, *: significant at 0.01, 0.05, and 0.10 respectively.

Table 5.5

Effect of technology type on relation between global environmental standard and Tobin's Q

Variable	Model 1		Model 2	
Constant	-0.458		-0.848	
	(1.224)		(1.244)	
Size (ln assets)	0.256	*	0.326	**
	(0.133)		(0.136)	
R&D intensity	9.159	***	10.470	
	(3.439)		(3.513)	
Advertising intensity	19.610	***	18.640	
	(3.450)		(3.455)	
Leverage	-2.401	**	-2.528	**
	(1.110)		(1.107)	
Percentage of foreign operations	0.018	**	0.013	
	(0.009)		(0.009)	
Assembled technology			0.473	
			(0.459)	
Closed system technology			-0.623	
			(0.537)	
Open system technology			-0.569	
			(0.500)	
Global environmental standard	0.977	***	0.985	***
	(0.158)		(0.222)	
Global standard X assembled			0.127	
			(0.400)	
Global standard X closed system			-0.696	
			(0.453)	
Global standard X open system			0.407	
			(0.477)	

Notes: All models have 734 observations. ***, **, *: significant at 0.01, 0.05, and 0.10 respectively.