Environmental Regulation, Globalization, and Innovation: Integrating Industrial, Environmental, and Trade Policies

This paper analyses the relationship between industrial and environmental regulation and sustainable development in the context of a global economy. It is argued that industrial policy, environment policy and commercial initiatives should be integrated and should act jointly. Particular emphasis is also placed on the promotion of technological innovation. Consolidated national regulations can thus act as a stimulus for technological, organisational and social innovation, which would entail commercial advantages for those pioneering firms that are the first to come into line with regulations, enabling them to become leaders and displace rivals that offer sub-optimal products

Lan honetan industria- eta ingurumen-erregulazioaren, eta berrikuntzaren eta garapen iraunkorraren arteko harremanak aztertzen dira, betiere ekonomia globalaren testuinguruan. Bertan aipatzen da industria-politika, ingurumen-politika eta merkataritza-ekimenak integratuta egon behar direla, eta elkarrekin jardun. Gainera, bereziki azpimarratu nahi izan da berrikuntza teknologiaren sustapena. Horrela, erregulazio nazional sendotua suspergarria izan daiteke teknologia, antolakuntza, erakunde eta gizarte alorretako berrikuntzarako, eta horrek merkataritza-abantailak eragingo ditu araudia modu berritzailean betetzen duten enpresa aitzindarientzat, enpresa lider bihurtu ahal izango direla, optimoak ez diren produktuak eskaintzen dituzten beste enpresa batzuk ordezkatuz.

Este trabajo analiza las relaciones entre la regulación industrial y medioambiental, y la innovación y el desarrollo sostenible en el contexto de una economía global. Se sostiene que la política industrial, la política medioambiental y las iniciativas comerciales deben estar integradas y actuar conjuntamente, además se hace especial hincapié en la promoción de la innovación tecnológica. De esta forma una regulación nacional consolidada puede ser el estímulo para la innovación tecnológica, organizativa, institucional y social, y ello va a suponer ventajas comerciales para las empresas precursoras que cumplen el reglamento de forma innovadora pudiendo convertirse en empresas líderes y desplazando a otras empresas que ofrecen productos no óptimos.

Nicholas A. Ashford*
Massachusetts Institute of Technology

INDEX

Keywords: economic development; employment; environment; innovation; health and safety; policy integration; regulation; system changes; sustainability; sustainable development; trade.

JEL classification: O31, O32, Q55,Q56.

1. **INTRODUCTION**

This essay explores the complex relationship between environmental regulation, innovation, and sustainable development within the context of an increasingly globalizing economy. It will be argued that industrial policy, environmental policy, and trade initiatives must be integrated, with a deliberate focus on stimulating technological innovation, if trade and globalization are not to undercut progress in sustainable development.

Health, safety, and environmental regulation —herein collectively referred to as 'environmental regulation'— addresses failures of the free market to internalize many of the social costs of an industrialized or industrializing economy by requiring the adoption of measures to protect the environment, workers, consumers, and citizens. Regulation is criticized and resisted by many industrial firms[1] who argue that such measures force sometimes unnecessary 'non-productive' investment that could be better directed to developing better goods and services and to expanding markets. Further, one of the complaints

* This chapter draws heavily from Nicholas A. Ashford and Ralph P. Hall (2011), *Technology, Globalization and Sustainable Development,* Yale University Press, and an article based on that book available at http://www.mdpi.com/about/openaccess/.

[1] Here the term 'industrial firms' is broadly defined to include those engaged in the extraction of energy and material resources, manufacturing, transportation, agriculture, and services.

made by trading firms in industrialized nations is that such measures are not required in industrializing countries that enjoy the competitive advantage of free-riding on the environment and conditions of work[2]. A more modern view of the effects of regulation on the economy that results in competitive advantage resulting from regulation-induced innovation derives from the work of Michael Porter and Claas van den Linde (1995a and b), Martin Jaenicke and Klaus Jacob (2004), Jens Hemmelskamp *et al.* (2000), and Ashford (1979, 1985, 2000), among others. They argue that there are 'first-mover' advantages to firms —and to nations— that comply innovatively with regulation, become pioneers in lead markets, and in some cases displace suboptimal products, processes, and firms.

Globalization has indeed changed the economic landscape. It connects the national economies in new ways and denationalizes access to information, technology, knowledge, markets, and financial capital. It has also opened up two distinct pathways by which a national sector or economy can compete in international markets: (1) by producing more innovative and superior technology that may or may not be first deployed in niche markets (Kemp, 1994, 1997) and (2) by adopting cost-cutting measures that involve increased economies-of-scale, by shedding labor, and by ignoring health, safety, and environmental hazards (see Charles and Lehner, 1998). While some have argued that globalization also increases the demand for more protective environmental and labor measures worldwide (Vogel, 1995; Bhagwati, 1997), others have cautioned about a 'race to the bottom' and an ever-increasing tendency to trade on environmental (and labor) externalities (Ekins *et al.,* 1994).

The author and his colleagues have long argued, from the empirical evidence of regulation-induced innovation in a national context, that significant, rather than marginal, environmental advancements require the displacement of incumbent firms and their technologies (Ashford *et al.,* 1979 and 1985). This article takes that argument further into the realm of sustainable development where nations operate in a globalized economy which challenges not only the achievement of environmental improvements, but also satisfaction of demands for economic growth and employment. System changes are necessary for sustainable development and they require dramatic realignments of economic actors, government institutions, and societal demand. A more extensive treatment of policies needed to transform the industrial state are the subject of a book in press (Ashford and Hall, 2011).

Thus, we see that there are not only two drivers of economic growth, technology and trade, but that trade itself can take two diametrically-opposed directions, innovation-driven competition and traditional cost-cutting competition (Charles and Lehner, 1998).

Health, safety, and environmental regulation is the means by which industrial development is forced to become more sustainable, but the absence of strong international regulatory regimes changes the balance between industrialization and environment. This paper argues that strong national regulation can spur technological, organizational, institutional, and social innovation resulting in trade advantages that

[2] The author argues elsewhere that the three pillars of sustainable development include competitiveness, environment, and employment. See Ashford (2000).

exceed shorter term gains from cost-cutting and trade expansion that would otherwise weaken environmental protection, and it can result in better environmental quality as well. However, more than the 'greening' of industry is needed. Creative destruction in the Schumpeterian sense is required (Schumpeter 1939; 1962).

2. INNOVATION IS THE KEY TO IMPROVEMENTS IN BOTH COMPETITIVENESS AND ENVIRONMENT

Technological change is a general —and imprecise— term that encompasses invention, innovation, diffusion, and technology transfer. Technological innovation is the first commercially successful application of a new technical idea. It should be distinguished from invention, which is the development of a new technical idea, and from diffusion, which is the subsequent widespread adoption of an innovation beyond those who developed it[3].

As industrial societies mature, the nature and patterns of innovation changes (Abernathy and Clark, 1985; Utterback, 1987). New technologies become old technologies. Many product lines (e.g., washing machines or lead batteries) become standardized or increasingly 'rigid,' and innovation becomes more difficult and incremental rather than radical.

Using language that is familiar to traditional innovation scholars, an *incremental innovation* involves a step-by-step co-evolutionary process of change, whereas *radical innovations* are discontinuous and possibly involve the *displacement* of dominant firms and institutions, rather than evolutionary transformation (Moors, 2000; Luiten, 2001; Ashford *et al.,* 2002; Partidario, 2003). Christensen (1997) distinguishes the former as *sustaining innovation* and the latter as *disrupting innovation*, rather than 'radical.' He argues that both sustaining and disrupting innovation can be incremental, moderate, or radical. Unfortunately, the term 'radical' in the literature is used in these two different ways and is a source of confusion.

However, another issue is in need of clarification: *sustaining or disrupting of what?* Christensen uses the term disrupting in the context of a *customer* base which values certain product attributes, and whose changing desires can change the markets for technological variants in products. The context in which we will use the term pertains to the product —and also other technological or system changes— from a *technological*, as well as a customer-based desirability-of-attribute perspective. In this regard, our use of the term disrupting is more in line with Chris Freeman's (1982) use of the term 'radical' or Nelson and Winter's (1977) idea of shifting 'technological regimes'(see below). Since we take Christensen's point that the term 'radical' should be reserved to describe the *rate* of change rather its type, we will generally avoid the term as a synonym for disrupting. But more is needed. From a technological perspective, disrupting innovations can be *intrinsic* or they can be *architectural.* The former is a dramatically different way of achieving functionality, such as the transistor replacing the vacuum tube;

[3] The distinction between innovation and diffusion is sometimes hard to draw, however, because innovations can rarely be adopted by new users without some modification. When modifications are extensive, i.e., when adoption requires significant *adaptation*, the result may be a new innovation (Ashford and Heaton, 1983).

the latter may combine technological ideas in a new artifact, such as the hybrid electric-internal combustion engine. Christensen *et al.* (1998) stress the latter and focus on product technology. Utterback and Acee (2005; pp. 15-16) observe that "[i]nnovations that broaden the market create new room for firms to start" and "[t]he true importance of disruptive technology … is not that it may displace established products. Rather, it is a powerful means for enlarging and broadening markets and providing new functionality." The problem with restricting one's analysis to the market determinants of technological change is that it neglects the fact that markets may not respond adequately to sustainability concerns. For example, consumers may well be concerned with product safety but are likely to be less concerned by the safety of the manufacturing process affecting the workers who made the product. More is needed than matching the technological capacities of firms with current societal demands. Our inquiry will distinguish between sustaining innovation and disrupting innovation in a broader technological and societal context.

Product lines/sectors that are well-developed, and that have become standardized, experience incremental innovation for the most part. Here, changes are focused on cost-reducing production methods —including increasing the scale of production, displacing labor with technology, and exercising more control over workers— rather than on significant changes in products. Gradually, process innovation also declines as manufacturing or production processes are standardized. The term refers to an individual product line that is defined by certain boundaries for technological progress and by directions or trajectories in which progress is possible and worth doing (Nelson and Winter, 1977).

Sometimes, however, the dominant technologies (such as the vacuum tube and mechanical calculator) are challenged and rather abruptly displaced by significant disrupting innovations (such as the transistor and electronic calculator), but this is relatively rare, although very important (Kemp, 1994; Christensen, 1997). We will argue that disrupting innovations may be what is needed to achieve sustainability. As industrial economies mature, innovation in many sectors may become more and more difficult and incremental, regulatory and governmental policies are increasingly influenced, if not captured, by the purveyors of the dominant technology [regime] who become more resistant to change. However, occasionally, traditional sectors can revitalize themselves, such as in the case of cotton textiles[4].

Other sectors, notably those based on emerging technologies, may experience increased innovation. The overall economic health and employment potential of a nation as a whole is the sum of these diverging trends, and is increasingly dependent on international trade. Whether nations seek to increase revenues based on competition in technological performance or alternatively rely on cost-cutting strategies can have an enormous impact on both employment and the environment. As will be discussed below, health, safety, and environmental

[4] Under the economic threat of more stringent worker protection standards for cotton dust exposure, the leading US textile firm decided to redesign and modernize its technology to reduce occupational exposure to both cotton dust and noise and to improve production efficiency. It stands out as one of the rare instances where an industry reinvented and replaced itself.

regulation, structured appropriately, as well as new societal demands, can also stimulate significant technological changes that might not otherwise have occurred at the time (Ashford *et al.,* 1985).

A technological innovation can be characterized by its *motivating force*, by its *type*, and by its *nature*. The motivating force behind technological change can be the result of an industry's main business activities or it can evolve from the industry's efforts to comply with or respond to health, safety, or environmental regulations and pressures (Ashford *et al.,* 1979). Regulation, market signals, and anticipated worker or consumer demand can affect any of the characteristics of innovation. There is ample evidence that the most significant driving force for technological change identified by business managers is environmental legislation and enforcement (Ashford and Hall, 2011).

Concerning the *type* of innovation, four different levels of technological change need to be considered: [1] product changes, [2] process changes, [3] shifts from products to product-services, and [4] more far-reaching system changes. The last level of change includes not only include technological innovation, but also effects on employment, the organization of the firm, and societal demands. Innovation can be a product-oriented type, meaning that it involves changes in the design of the final product or service. It can extend further, to include shifts to *product-services*, in which the firm envisions delivering a desired service or benefit to the customer in creative new ways, with a goal of minimizing resources, energy use, and pollution. An example is selling copier services to customers —in which the copier company owns the machine and performs all maintenance and service on it while in use— instead of selling copy machines. Technological innovation can also be a process-oriented type, meaning that it can occur as part of the *production process* of a product or the delivery of a service.

System changes are the deepest and broadest form of technological changes. They extend outside the boundaries of the firm to include many actors, including suppliers, competitor and collaborator firms, and new firms to the the economic activity, government authorities, and civil society. They involve the reconceptualization and reordering of entire production chains and stakeholder networks, for example, shifting from non-local industrial agriculture to locally-grown organic food systems, or simultaneously altering production, employment, distribution, and transportation regimes to move people and deliver goods more efficiently, with less energy use and pollution. Another interesting example is a system change involving the merger of on-site housing construction with factory-made modular housing units resulting in less waste, safer practices, higher wages, and faster, less expensive construction (Ashford *et al.,* 2002).

In the context of product change, the *nature* of a technological innovation can be evaluated according to whether it serves either to *sustain* or *disrupt* established product lines and value networks of customers with well-defined demands (Christensen, 1997). Christensen's concept of a 'value network' is "the context within which a firm identifies and responds to customers' needs, solves problems, procures input, reacts to competitors, and strives for profit." In Christensen's formulation, sustaining innovations occur when established firms "push the

envelope" to continue to satisfy existing consumers with improved products within the prior but expanded technological trajectory. Disrupting innovations cater to different, perhaps not yet well-defined, customers with product attributes different from those in the established producer-consumer networks[5]. Alternatively, the distinction between sustaining and disrupting innovation might be focused on the technological nature of the change, a distinction that invites incentives focused on not only product changes (which may be the main driver in market-pull innovation), but also changes involving process improvements, shifts to product services, and wider system changes. This is not to downplay the importance of consumer demand, but to put it in a proper context, since many desirable technological changes will need to come from more interventionist and regulatory approaches if sustainable development is to be achieved in a timely fashion. We explore these ideas further in the next section.

Another way of comparing sustaining and disrupting innovation is to depict three different pathways that innovation could take. In Figure 1 below, the various performance levels of an existing technology regime (for example, various internal combustion automobile engines with different fuel efficiencies) is shown as a function of cost. The most efficient *existing* engine is represented by point 'A' at cost C_1. New improvements (sustaining innovations) to internal combustion engines can be developed within the same technological regime in several different ways. First improvements could be made, extending the performance of existing technology, but at higher cost, as depicted by the dashed line. Secondly, a significant innovation could occur within the same technological regime, giving rise to new performance-cost relationships as depicted in the second curve, shifted to the right in Figure 1. Thirdly, a power system based on a different concept of innovation (a disrupting innovation) could be developed, represented by the 'future technology' curve, depicted by the right-most curve. At some point, fuel efficient engines can be developed that provide the best old engine efficiency at a lower cost C_2 (represented by point 'C') or better efficiency can be achieved at the same cost C_1 (represented by the point 'B'). Anywhere in between on the future technology curve represents a 'win-win' situation over the sustaining innovations on the dashed line.

Both evolutionary and revolutionary innovation can occur without government intervention, but the time periods over which these changes are expected may be too long to address the environmental and employment crises which are upon us. For this reason, it is important to address the importance of government intervention.

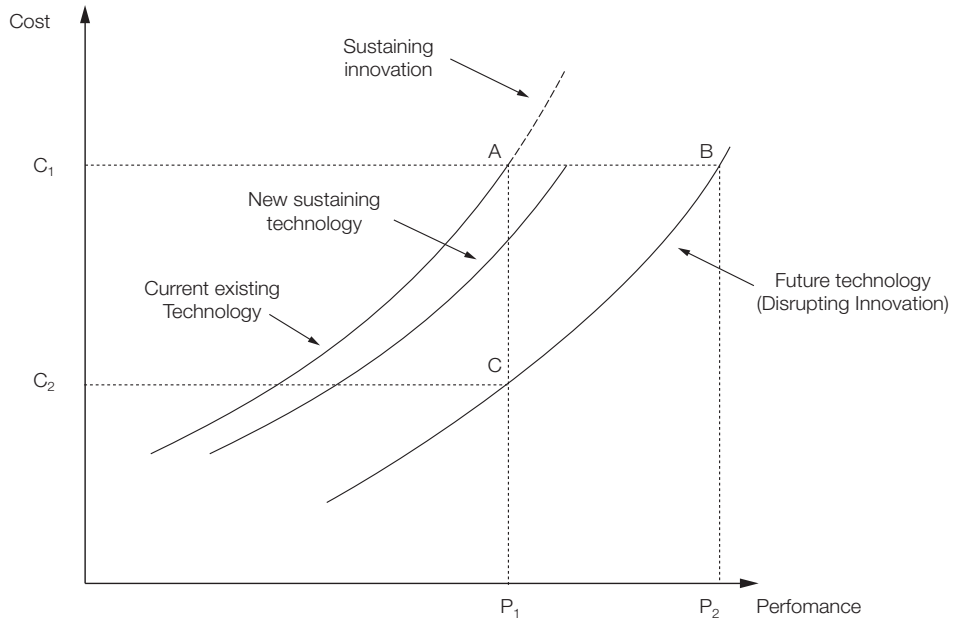
3. REGULATION CAN STIMULATE INNOVATION THAT BENEFITS BOTH THE ECONOMY AND THE ENVIRONMENT

The author and his colleagues have argued previously that regulation —properly fashioned— can transform products and processes which confers both economic and health, safety, and environmental benefits (Ashford *et al.,* 1979 and 1985).

[5] The creation of new products in this case is not a wave built upon prior waves of technological advance, but rather occurs in an entirely new trajectory, often creating a new market.

Figure 1

The Efficient Frontier for Current and Future Technology Contrasting Sustaining and Disrupting Innovation



Source: Own elaboration.

In contrast, classical economic analysis of the relationship between health/safety/environmental regulation and competitiveness has argued that stringent regulation increases production costs, diverting resources from R&D, and consequently hinders innovation (Jaffe *et al.,* 1995; Rennings *et al.,* 2003). This assumption was challenged first in the late 1970s at MIT (Ashford, Heaton and Priest, 1979) and made popular in 1991 by the so-called 'Porter hypothesis.'

Based upon his research into the competitive advantage of nations, Porter (1990; p. 168) claimed that "[*s*]*trict environmental regulations do not inevitably hinder competitive advantage against foreign rivals; indeed, they often enhance it. Tough standards trigger innovation and upgrading.*" He continues, "[*p*]*roperly constructed regulatory standards, which aim at outcomes and not methods, will encourage companies to re-engineer their technology. The result in many cases is a process that not only pollutes less but lowers costs or improves quality. … Strict product regulations can also prod companies into innovating to produce less polluting or more resource-efficient products*

that will be highly valued internationally" *(ibid,* p. 168). Porter's essential hypothesis is that firms which respond to stringent regulation by developing new technologies have a 'first mover' advantage and can capture the market for their products/services. A recent comparison of national competitiveness with good environmental governance and private sector responsiveness supported the Porter hypothesis (World Economic Forum *et al.,* 2002). It states that "*good economic management and good environmental management are related*" and that "*firms which succeed in developing innovative responses to environmental challenges benefit both environmentally and economically*" *(ibid,* p. 17).

Earlier work on this concept, along with empirical evidence, dates back some twelve years before Porter's work to research undertaken at MIT (Ashford *et al.,* 1979; Ashford and Heaton, 1983; Ashford, Ayers and Stone, 1985; Ashford, 1993). This work showed how stringent and focused regulations in the U.S. chemical producing and using industries had the effect of stimulating fundamental product and process innovations (Ashford *et al.,* 1985). The MIT studies revealed that environmental and health and safety regulation —if appropriately designed, implemented, and complemented by economic incentives— can lead to radical technological developments that can significantly reduce exposure to toxic chemicals in the natural and working environments, and in consumer products (Strasser, 1997). Examples include regulation-induced replacement of poly-chlorinated biphenyls used in transformers by a silicone oil, a new polymerization process for polyvinylchloride, and textile weaving innovation eliminating the need for a formaldehyde-containing resin that imparted permanent press properties to cloth (Ashford and Heaton, 1983; Strasser, 1997).

A weakness of Porter's hypothesis is that its focus is on how incumbent firms respond to more stringent regulations, ignoring the important dynamics of new entrants (Van de Poel, 2000). Porter and van den Linde (1995a' 1995b) argue that regulation, properly designed, can cause a regulated firm to undertake innovations that not only reduce pollution —which is a hallmark of production inefficiency— but also save on materials, water, and energy costs, conferring what Porter calls 'innovation offsets' to the innovating firm (and what Ashford called "ancillary benefits."). This can occur because the firm, at any point in time, is sub-optimal. If the firm is the first to comply with regulation in an intelligent way, other firms will later have to rush to comply and do so in a less thoughtful and more expensive way. Thus, there are 'learning curve' advantages to being first and early.

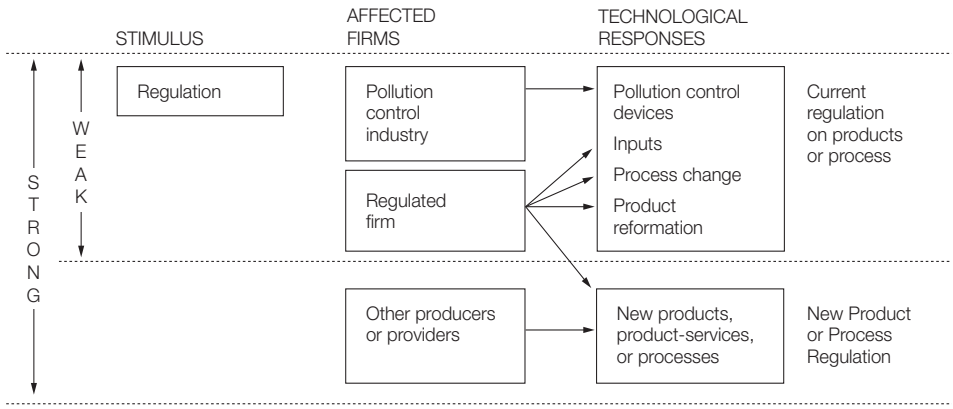
Porter's focus on 'innovation offsets' —i.e., the cost savings due to induced innovation that could exceed the cost of the regulation (Porter and Van den Linden, 1995a, 1995b)— indicate that he is mainly concerned with the costs to incumbent firms. From this insight, it is possible to differentiate between 'weak' and 'strong' forms of the regulation-induced innovation hypothesis (Ashford, 1999) -- a distinction that Porter does not make. In its weak form, Porter argues that firms subject to more stringent regulation respond with incremental (or sustaining) product and process innovations. Thus, while environmental and worker health and safety improvements may be realized, the offending products and processes remain intact, albeit in a greener, more efficient state.

In the strong form of the regulation-induced innovation hypothesis, Ashford [ref] argues that stringent regulation could stimulate the entrance of entirely new products and processes into the market, thereby displacing dominant technologies. In this situation, unless incumbent firms have the willingness and capability to produce and compete with the new forms of technology, they too are likely to be displaced from the market (Christensen, 1997). Figure 2 provides a simple diagram of the likely technological responses to the strong and weak forms of the regulation-induced innovation hypothesis. Empirically-based examples were researched by Ashford and colleagues in their work.

While some question whether environmental regulation does generate a positive effect on innovation (Jaffe and Palmer, 1997; Robinson, 1995; Walley and Whitehead, 1994), their analyses tends to miss the essence of the 'strong' form of the regulation-induced innovation hypothesis. Although it is likely that stringent regulation will not stimulate technological innovation in most firms, some firms are likely to rise to the challenge and become technological leaders in the process. Hence, the "*evidence is necessarily anecdotal*" (Ashford, 1999; p. 3). The Schumpeterian notion of "waves of creative destruction" leading to succeeding advances in technological development describes the process by which dominant technologies are being continually displaced as new technologies become available. The design challenge facing government is how existing undesirable technologies can be retired (or displaced) through a combination of regulation and market incentives. These

Figure 2

A Model for Regulation-induced Technological Change for 'Weak' (Porter) and 'Strong' (Ashford/MIT) Forms of the Regulation-induced Innovation Hypothesis



Source: Adapted from Ashford (2000).

ideas thus challenge the notion that incumbent firms can reinvent themselves in a significant way and should have a major role in setting the targets for future regulation. Incumbents will not set targets they expect not to be able to meet.

For a contrasting view on the 'strong' form of the regulation-induced innovation hypothesis, see Gunningham and Sinclair (1999). They argue that "the most appropriate role for governmental regulation lies in nudging firms at the margin toward cleaner production, heightening their awareness of environmental issues, and encouraging the re-ordering of corporate priorities in order to reap the benefits of improved environmental performance" *(ibid,* p. 883). Gunningham and Sinclair (1999) disagree with the argument that more stringent regulation is the best way to encourage the development of environmental technologies, and present a series of less-intrusive policy options than regulation. Under their policy framework, the use of regulation is only supported as a last resort, when covenants between industry and government and pressure from environmental groups, for example, fail to initiate innovation and environmental improvement.

With regard to the 'weak' form of the regulation-induced innovation hypothesis, ambitious environmental policies in developed nations can lead to the formation of 'lead markets' for environmental technologies (Jänicke and Jacob, 2005). However, the evidence suggests that "*the international diffusion of environmental innovations must be accompanied by international policy diffusion, or the adoption by other countries of the induced innovation must be economically reasonable*" (Beise *et al.,* 2003; p. 1). Both of these factors make it difficult to predict with any certainty whether an ambitious environmental policy is likely to create a lead market for the international diffusion of innovations (leading ecological modernization). The uncertainty surrounding the likely impacts to national industries of more stringent environmental [and health and safety] regulation is seen as one reason why governments hesitate to implement such policies (Blazejczak and Edler, 2004).

In a five-country study of the effectiveness of various government interventions collectively known as "industrial policy", MIT research found, paradoxically, that the only government policy that affected innovation was in fact health, safety, and environmental regulation, not strategies devised by government as a part of its industrial policy [Allen *et al.,* 1978].

Moreover, the effects of regulation on innovation turned out to be positive, not negative as expected by the conventional wisdom at that time.

Stringent regulation can stimulate *entirely new products and processes* into the market by new entrants with the displacement of dominant technologies rather than the transformation of technologies by existing firms. One of several vivid examples is the displacement of Monsanto's PCBs in transformers and capacitors by an entirely different dielectric fluid pioneered by Dow Silicone. Regulation can thus encourage disrupting innovations by giving more influence to new 'value networks' or 'customer bases' in which demands for improvements in both environmental quality and social cohesion are more sharply defined and articulated. Of course, industries that would fear being displaced by new entrants would not be expected to welcome this regulation. This explains in part their resistance to regulation and

their propensity to try to capture regulatory regimes, surreptitiously or through direct negotiation (Caldart and Ashford, 1999).

In principle, regulation can be an effective and proper instrument for government to guide the innovation process. Well-designed, regulation that sets new rules changes the institutional framework of the market and can be an important element in creating favorable conditions for innovation which could enhance environmental sustainability and create incentives for the development of powerful lead-markets which pull innovation towards that sustainability (Jaenicke and Jacob, 2004). With regard to regulation, what seems to matter is not only the stringency, mode (specification versus performance), timing, uncertainty, focus (inputs versus product versus process) of the regulation, and the existence of complementary economic incentives – but also the inherent innovativeness (usually in new entrants) or lack of it (usually the regulated firms) (Ashford and Heaton, 1983; Ashford *et al.,* 1985). The importance of new entrants is missing in the analysis offered by Porter.

In order for innovation to occur, the firm (or government itself) must have the *willingness*, *opportunity/motivation*, and *capability or capacity* to innovate (Ashford, 2000). These three factors affect each other, of course, but each is determined by more fundamental factors.

Willingness is determined by (1) attitudes towards changes in production in general, (2) an understanding of the problem, (3) knowledge of possible options and solutions, and (4) the ability to evaluate alternatives. Improving (3) involves aspects of capacity building through the diffusion of information, through trade associations, government-sponsored education programs, inter-firm contacts, and the like. Changing attitudes towards changes in production (1) often depends on attitudes of managers and on the larger culture and structure of the organization, which may either stifle or encourage innovation and risk taking. Factors (2) and (4) depend on internal intellectual capacities. In the context of disrupting innovation by firms representing the dominant technology, willingness is also shaped by the [rare] commitment of management to nurture new approaches that are at odds with its traditional value network or customer base.

Opportunity and motivation involve both supply-side and demand-side factors. On the supply side, technological gaps can exist between the technology currently used in a particular firm and the already-available technology that could be adopted or adapted (known as diffusion or incremental innovation, respectively), or alternatively the technology that could be developed (i.e., significant sustaining or disrupting innovation). Consciousness of these gaps could prompt firms to change their technology, as could the opportunity for cost savings. Regulatory requirements could also define the changes that would be necessary to remain in the market. On the demand side, three factors could push firms towards technological change - whether diffusion, incremental innovation, or major innovation. These are (1) opportunities for cost savings or expansion of sales, (2) public demand for more environmentally-sound, eco-efficient, and safer industry, products, and services, and (3) worker demands and pressures arising from industrial relations concerns. The first factor could result from changes in the customer value networks. All these factors, however, may stimulate

change too late in the dominant technology firms, if new entrants have already seized the opportunity to engage in developing disrupting innovations.

Capability or capacity may actually be the most important and limiting factor and can be enhanced by (1) an understanding of the problem, (2) knowledge of possible options and solutions, (3) the ability to evaluate alternatives, (4) resident/available skills and capabilities to innovate, and (5) access to, and interaction with, outsiders. Knowledge enhancement/learning (2) could be facilitated through deliberate or serendipitous transfer of knowledge from suppliers, customers, trade associations, unions, workers, and other firms, as well from the available literature. The skill base of the firm (4) could be enhanced through educating and training operators, workers, and managers, on both a formal and informal basis, and by deliberate creation of networks and strategic alliances not necessarily confined to a geographical area, nation, or technological regime.

Interaction with outsiders could stimulate more radical and disrupting changes. This last method of enhancing the capacity of firms to undertake technological change involves new 'outsider' firms and stakeholders with which the firm has not traditionally been involved. Capacity to change may also be influenced by the innovativeness (or lack thereof) of the firm as determined by the maturity and technological rigidity of particular product or production lines (Ashford, 2000; Ashford *et al.,* 1985). Some firms find it easier to innovate than others. The heavy, basic industries, which are also sometimes the most polluting, unsafe, and resource-intensive industries, change with great difficulty, especially when it comes to core processes. New industries, such as computer manufacturing, can also be polluting, unsafe (for workers), and resource and energy intensive, although they may find it easier to meet environmental demands.

If we were not living and trading in an increasingly globalized world, integrating national industrial, environmental, and employment policies might suffice for a major focus to achieving more sustainable development. However, trade does influence the outcomes of national domestic policy goals, such as improving the environment and creating an economy with meaningful, rewarding jobs with sufficient purchasing power as the next section discusses.

4. TRADE CAN BENEFIT OR HARM THE ENVIRONMENT AND EMPLOYMENT DEPENDING ON THE STRATEGY CHOSEN

Whether trade itself improves or harms a particular nation's environment has been debated for almost two decades and continues to be an intensely controversial issue (Bhagwati, 1993; Daly, 1993). On the one hand, the world-wide proliferation of toxic chemicals, pesticides and other technologies facilitated by global markets raises serious concerns. On the other hand, to the extent that nations improve their economic position, there may be more demand and revenues to implement environmental protection measures. There is evidence of both. But beyond trade in harmful technologies per se, there are more far-reaching effects of trade on the environment and employment, depending on the strategy chosen.

Technological innovation and trade can drive national economies in different ways, depending on whether trade is based on

innovation or cost-cutting (Charles and Lehner, 1998). Charles and Lehner (1998) argue that "the type of innovation which is the key to new employment is one which develops markets in new directions and creates new markets and thus enhances a strong leading-edge economy." One area n which markets might be developed is the environment. As Schumpeter has described, companies in the leading-edge economy can exploit a temporary monopoly resulting from their superior products and services (Schumpeter, 1939, 1962). Advanced-industry economies in their innovative sectors have already shifted in the last ten to fifteen years from technocentric to anthropocentric production systems - those that capitalize on human intelligence and are designed for continuous improvement and learning. Instead of a cost-driven strategy that calls for reduced labor costs, Charles and Lehner recommend that industrial economies aim for an innovation-driven strategy, which depend on a large number of human interfaces in the company that are likely to produce organizational learning, creativity, new ideas – and well-paying jobs. An innovation-driven strategy also affords an opportunity to modernize and improve products, processes, and services.

Technological innovation exploits a nation's innovative potential, while cost-cutting is often associated with a trade strategy driven by the desire to exploit a nation's excess production capacity. Innovation-based performance is enhanced by technological innovation and changing product markets, characterized by fluid, competitive production. Cost-reduction strategies are enhanced by increased scales of production and/or automation, usually characterized by rigid, mature monopolistic production. Economies seeking to exploit new international markets may enjoy short-term benefits from revenues gained as a result of production using existing excess capacity, but they may ultimately find themselves behind the technological curve. Performance-driven markets may be slower to gain profits. Nonetheless, they may outlast markets driven by cost-reduction strategies. The consequences for the environment and for workers may differ as well.

Innovation-based performance competitiveness presents opportunities for environmental improvements and for skill enhancement and building optimal human-technology interfaces, while cost-reduction strategies focus on lean production (with worker displacement and usually designed without health, safety, or environmental performance in mind), flexible labor markets, and knowledge increasingly embodied in hardware and software rather than in human capital. The consequences for the environment and for workers are different for these two strategies. The former strategy can lead to more environmentally-sustainable technologies of production and also reward and encourage skill acquisition for many, with appropriate financial benefits for those workers. The latter may seek to minimize environmental improvement costs and create a division between workers, some of whom are necessarily unskilled and many for whom the demand for higher-level skill is reduced. Different national strategies might be pursued, reflecting different domestic preferences and culture, but there are further implications, depending on the extent to which trade drives the economy.

The changing global economy presents challenges for all nations as concerns for the number of jobs, job security, wages, and occupational health and safety increase and compete for attention with environmental and

energy concerns. Since trade does influence the outcomes of other national domestic policy goals, there is a need for integrating trade policies with those initiatives focused on industrial development, energy, employment, environment, and worker and public health which are discussed after the next section (Diwan and Walton, 1997; Ekins *et al.,* 1994).

5. OPTIONS FOR GOVERNMENT INTERVENTION

Government has a significant role to play, but the government cannot simply serve as a referee or arbiter of existing competing interests, because neither future generations of persons nor future technologies are adequately represented by the existing stakeholders. Government should work with stakeholders to define far-future targets – but without allowing the agenda to be captured by the incumbents. Government should then use its position as trustee to represent the future generations *and* the future technologies to 'backcast' what specific policies are necessary to produce the required technical, organizational, and social transformations. Acting as a trustee takes the government beyond being a referee of those competing interests that might be at the table; trusteeship means factoring interests of those future technologies and persons not yet parties to the political process, as well as those who are here today but are under-represented. The needed backcasting will have to be of a next-generation variety of backcasting. It has to go beyond its historical focus on coordinating public and private sector policies. It must be multidimensional and directly address the present fragmentation of governmental functions addressing the various important societal needs – not only at the national level, but also at the regional level in closely-allied nations such as those in the European Union, and at the international level through multilateral environmental and labor agreements and within revised trade regimes such as the WTO and NAFTA.

The different determinants of willingness, opportunity, and capacity discussed in section 3 above offer a variety of different starting points for government policies for stimulating technological and organizational innovation to achieve a more sustainable industrial system. This represents an opportunity as well as a challenge. The opportunity is that government need not depend on a few specific instruments, but may have command of a whole variety of measures. These include direct performance of R&D; financial support of R&D in academia and industry through grants, subsidies, and tax incentives; removing regulatory barriers to innovation; stimulating innovation by getting the prices right for natural resources including energy; using government regulation to stimulate more environmentally-sound, inherently-safer, and employment-creating innovation; procurement and investment to develop *new* markets; advancing knowledge-transfer from universities to small and medium enterprises; implementing pro-active programs for the education and training of labor for a knowledge-based economy; and encouraging management and labor to bargain before technological changes are planned and implemented; and last but not least, cultural activities to enhance openness and willingness to engage in change (Ashford, 2000).

Tax policy can be particularly important. Others have called for taxing the "bads" (like pollution) and not the "goods" (like employment). But even within the present

system, less bold but important changes in incentives can be fashioned. For example, if more employment is desirable, financing unemployment and workers compensation from charges on employers on a per capita (worker) basis creates disincentives to hire new workers; these could be replaced by a tax on sales or profits. Similarly, providing accelerated tax depreciation for safer and less-polluting industrial processes, rather than for end-of-pipe pollution control or injury minimizing technology, would incentivize cleaner and inherently safer technology. But both require changes in law and regulation to implement. In order for law and regulation to have their necessary stimulatory effect, they have to be certain enough to change medium to long-term strategic decisions for both industry and (state and local) governmental entities. Thus, the adoption of a temporary or short-term suspension of "payroll taxes" may not lead to changes in employment.

As difficult as it may be to transform industrial economies into more *environmentally* sustainable systems, the challenges facing the creation of more satisfying, rewarding, and safer jobs with improvements in purchasing power is even more daunting. Simply 'priming the pump' to encourage economic growth is a blunt instrument when it comes to creating more employment —especially since replacing old facilities with new facilities usually results in shedding jobs— and greening the economy (without attention to the redesign of jobs as well) may return only a small 'double dividend.' Therefore, many call for a reduction in hours in the standard workweek as a means for spreading out available work, or even increasing the demand for work, but because workers are unlikely to be able to secure the same wages for less work, and because of the payroll tax on wages reflecting the funding of social benefits, employers, as well as current workers, are much more inclined to promote overtime, rather than hire new workers. Workers, on the other hand are likely to demand higher hourly wages for a shorter work week to maintain wage parity or seek a second job, leading to higher job turnover and net unemployment for some groups. For this reason, the French adoption of a 35-hour workweek was not very successful, leaving the overall level of employment unaffected (Estevão and Sá, 2008). Longer term policy, cultural and societal changes may be needed.

Developed countries (and pundits within them) are deeply divided as to whether Keynesian spending to stimulate the economy in order to create jobs and lead to greater consumer purchasing is what is needed to address low economic growth and high employment, or alternatively creating more flexible work rules, allowing for wage concessions or relaxing hiring/firing practices, is needed. Germany instituted more liberal labor policies but also the 'Kurzarbeit' (short work) policy by which employers were encouraged to keep workers, although on furlough or a shorter work schedule with the wage shortfalls made up for by a government fund to which employers had contributed in better times (Kulish, 2010). A kind of 'German miracle' lead to an annualized growth rate of 9 percent based on the 2010 second quarter growth. This reinforces the view that direct protection of jobs rather than indirect monetary and fiscal policies may be a better policy direction.

Decreasing demand for the consumption of material and energy-intensive products and services may not alleviate unemployment or underemployment, but

utilizing more human, rather than physical, capital may. For years, capital has replaced labor in the production of goods and the provision of services. Whenever industry restructures its production systems or routinizes its provision of services through the use of menus, it seizes the opportunity to shed labor and requires less thinking (knowledge-based work) on the part of its employees. Of course, the provision of welfare for the unemployed or underemployed ultimately has to be paid from the public treasury (or build the deficit), which eventually must be supported by taxes on business, consumers, and/or workers. Reversing decades-old trends of designing labor out of production and services by redesigning the utilization of labor may actually be cost-effective. It will certainly utilize unutilized human capital and have social benefits as well.

Moreover, instead of a household spending its disposable income on material and energy-intensive goods and services beyond the basic necessities, it could engage persons to deliver services that employ mostly human capital, such as tutors, language teachers, music and art teachers, financial advisors, and persons engaged in providing others social services. Also, increasing the teacher-to-student ratio in schools would be an important start. (While a discussion of comprehensive educational reform is beyond the scope of this work, we regard it as essential. Basing the financing of schools on property taxes which are constrained by 'proposition two and one half' limitations should be eliminated in favor of federal financing of education.)

The multiplier effect of employing human, rather than physical or natural capital, could be significant. To increase the demand for human capital in this context, would, of course, require significant cultural changes of a medium to long-term nature, and large corporations that have organized the current means of production driven by economies of scale and that use advertising to create artificial demand would be less likely to be interested in 'selling' these services.

Investing in better education and lifelong learning is of course central to cultural change and shifting demand towards the use of more human capital. Training professionals in a more trans-disciplinary way would also yield benefits. These professionals would then be able to simultaneously address problems of the economy, environment, public health, and employment in a more systematic way.

While many instruments are available to the government, it may be unreasonable to expect that government can play too definitive a 'futures making' role. There is a great deal of serendipity, and uncertainty in industrial transformation processes, and the long-term prospects may be not be sufficiently definable to suggest obvious pathways or trajectories for the needed transformations. Rather than attempting tight management of the pathways for the transformations that are sustainable, the government role might be better conceived as one of 'enabling' or 'facilitating' change, while at the same time *lending visionary leadership for co-optimizing economic development, environment, and employment*. This means that the various policies must be mutually reinforcing.

This newly-conceptualized leadership role —focused on 'opening up the problem space of the engineer/designer' (Allen *et al.,* 1978) so that multiple goals are addressed and solutions fashioned— is likely to require participation of more than one ministry and

more than division of the industrial firm, with the assistance of professionals trained in a more trans-disciplinary way (see Ashford, 2004). Multi-purpose design is exactly what is required to bring about system changes. While presenting more constraints, pursuing multiple goals also requires more flexibility in changing components or characteristics of a product or process and thus presents different opportunities for optimization of each of the goals pursued in isolation. It is also likely to require considerable public participation and societal support for aggressive, transformative initiatives. Factor-ten or more improvements depend on flexibility in design rather than changing a small number of components while leaving others unchanged. An example is found in making design changes that simultaneously take both engine configuration into account to improve collision safety and improvements in fuel efficiency that result in the automobile engine being mounted differently and subsequently allowing more room for piston movement leading to greater compression ratios.

6. INTEGRATING INDUSTRIAL, ENVIRONMENTAL, AND TRADE POLICIES

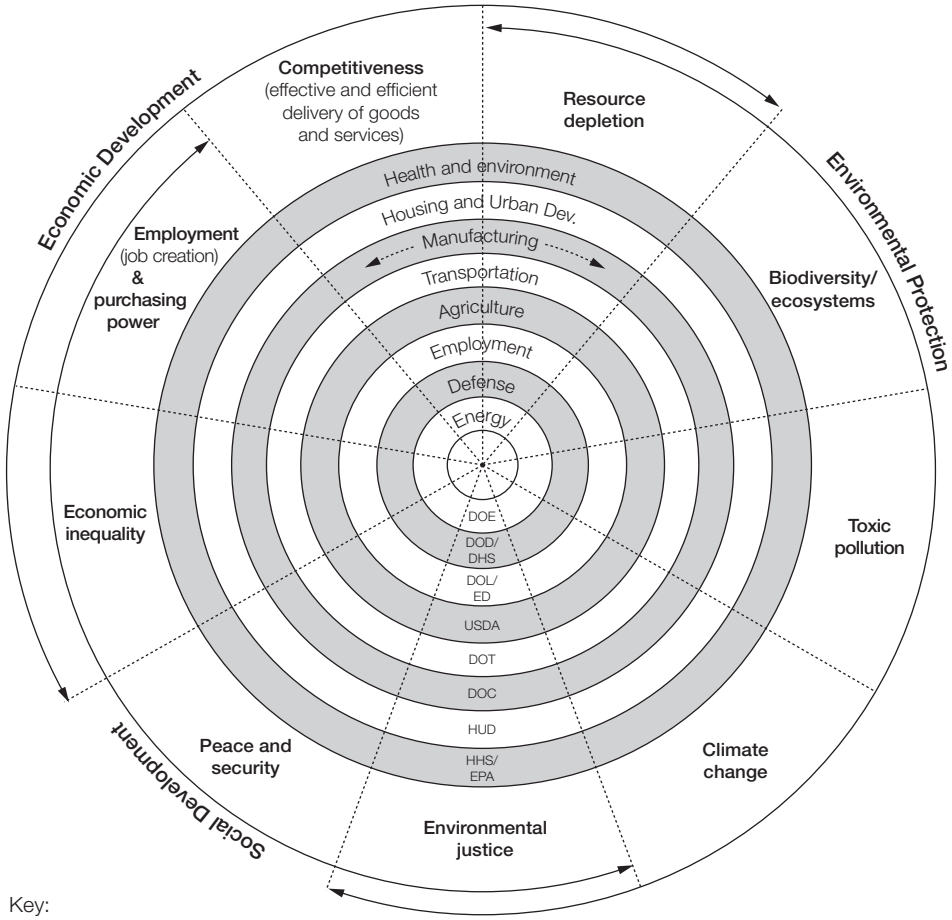
At best, national governments *coordinate* but rarely *integrate* their policy planning and implementing processes, although integration is precisely what is needed for success. Integration is more than coordination. Government initiatives, policies, and instruments must be integrated in a systematic way or they will create various contradictory and conflicting effects leading to 'compromise' rather than 'co-optimization' of multiple goals – as is often the case with uncoordinated public policy. The effective co-ordination of a variety of different policy instruments is a complex task which often exceeds government's capacities. The real challenge, however, is to move beyond coordination and to find effective approaches and methods to *integrate* a complex variety of instruments with complex impacts in a systematic way. The areas of government programs and initiatives in the United States are depicted in Figure 3. The 'wedges' in the figure relate to the different areas of sustainability concern, while the concentric circles identify areas of government authority and responsibility in the U.S. context. The figure is easily adapted to other national systems as well. There could be three different 'dartboard' diagrams for national, regional/state, and local governmental activity.

Integration requires (1) addressing multiple goals (e.g., economic development, employment, environment, and public health) in the same piece of legislation, or at least passing a group of complementary laws in parallel fashion, (2) planning regulatory and programmatic initiatives with participants from different governmental authorities, and (3) deliberate simultaneous or staged implementation and monitoring involving different governmental authorities. Ideally, integration also involves the merging of ministries, or at least increasing the porosity of departmental walls, but the former is likely to be more of a hope for the future than something that can be achieved in the short run.

Integration found its first serious expression as *environmental* policy integration (EPI) as a consequence of the Brundtland Report [WCED, 1987] placing environmental consideration as a priority to be balanced along with economic and social concerns. Agenda 21, emerging from the 1992 UN

Figure 3

Schematic of Areas of Government Programs and Initiatives Requiring Policy Integration



Source: Own elaboration.

Conference on Environment and Development in Rio, endorsed the integration of economic, social and environmental issues in the pursuit of development (UNCED, 1992; Chapter 8.4).

As a principle, EPI has had mixed success, with the most impressive advances found in some countries of the European Union (EU) (Jordan and Lenschow, 2010). The

EU placed environment at the center of its recent treaties advancing the union, but it was pushed back somewhat in the adoption of the Lisbon Strategy of the European Union to promote sustainable economic growth (via competitiveness) and employment, while respecting the environment (http://ec.europa.eu/growthandjobs/index_en.htm). Economic concerns slowly re-emerged in importance and have now found greater favor in the fragile balance among issues, especially after the 2008 financial crisis. Jordon and Lenschow comment that "generally speaking, new centre-left governments have tended to push the hardest for EPI, whereas centre-right governments have held back or even dismantled EPI frameworks and instruments" (Jordan and Lenschow, 2010; p. 151). These authors observe that "unless there is a high-level commitment to deliver greater EPI or a strong inducement, for example in the form of career enhancements, integration simply does not happen." They add that "'learning' or a 'change of awareness' seems to take place in response to political crises (for example, accelerating climate change) rather than the combined impact of different EPI instruments (Jordan and Lenschow, 2010, p. 154).

The challenge of integrating programs occurs among the different *issues*, the different *kinds of authority*, and the agencies/authorities at *different levels of government*. In the traditional fragmentation of governmental missions, there are plenty of opportunities for philosophical, goal, and turf conflicts. That is why strong leadership from the top, supported by people well-trained in a trans-disciplinary way is essential to optimize policy congruence and mutual reinforcement. Co-optimization rather than 'balance' distinguishes this approach from compromise (Ashford and Hall, 2011).

Integration of goals in government (as well as private sector) actions is indispensible for achieving major advances in sustainable development, and is consistent with the view that the journey to sustainability is a *process*, rather than a particular end state. Ideally and ultimately, government needs to be radically restructured to reflect the realities of the new millennium. Rather than departments and ministries separated according to traditional areas such as environment, health, commerce, trade, energy, transportation etc., governmental structures should focus on problem areas representing overlapping concerns, but possibly overseen by larger super-ministries such as one for economic and social welfare, and one for trade and international relations. Enabling legislation for the traditional agencies needs to revised to reflect mission broadening and changes. Given that the present infrastructure of government is not likely to be changed in the near to medium term, how else in useful integration to be accomplished?

Integration must take into account the major theses advanced in this article thus far:

1. Major technological, organizational, institutional, and social changes beyond incremental advances are necessary to achieve factor 10 improvements in material and energy use; adequate reductions in exposure to toxic substances; significant opportunities for stable, rewarding, and meaningful employment with adequate purchasing power; and an adequate level and distribution of economic welfare. Such improvements require more systemic, multidimensional, and disruptive changes.

2. These changes require system changes that "open up the problem

space" of the policy designer by co-optimizing advances, i.e., achieving mutual gains simultaneously, in the relevant economic, environmental , and employment realms.

3. Achieving transformations to a more sustainable economic system requires stringent banking, environmental, labor protection and labor market regulation, as well as the regulation of commerce, advertising, and financial transactions. Laissez faire market approaches are inadequate.

   To these, should be added observations related to policy integration initiatives *per se*.

4. While incremental advances are inadequate as articulated in (1) above, as a practical matter, major, non-incremental advances can be achieved through integration pursued deliberatively, even if piecemeal, by connecting key interventions, policies, and agency missions relevant to a specific policy domain.

   For example, advancing both energy technologies and green jobs requires co-visioning and implementation of industrial innovation, energy demand-side interventions, and labor market policy integration. Examples of policy integration in government do exist. The integration of fuel economy and emission concerns is evident in the joint efforts of the EPA and DOT. Unfortunately, a third element of motor vehicle concern —safety— has not been optimally integrated in those efforts. In the Netherlands, there is one agency for environment and spatial planning; in Greece, there is a single ministry for environment and land planning, although that ministry has been criticized for allowing land-use expansions that exacerbated the incidence of forest fires. Integration in mission titles in and of itself does not guarantee integration of all the areas in need of mutual gains.

5. Policy integration must account for the fact that developed nations especially now operate in a globalized market and integrating domestic-focused policies must extend to trade policies.

   For example, the U.S. promotion of hormone treatment of livestock to increase milk production and accelerate growth has run afoul of European Union trade sanctions. This has direct impacts on not only competitiveness in agricultural markets, but also on trade deficits.

6. Policy integration must occur at the international level as well.

The World Trade Organization (and other trading regimes) and the International Labour Organization address commerce and employment concerns, respectively. The multilateral environmental accords themselves are largely neither integrated not coordinated. For example in the use of the precautionary principle differs significantly in the Sanitary and Phytosanitary agreements and the Biosafety Protocol. It has been suggested that a World Environment Organization be created to present a more uniformed and coordinated environmental and public health face internationally. But note that this will not contribute much to integrating commerce, employment, and environmental concerns. Trade in commercial products is governed by the World Trade Organization which depends on principles of allowable protection for environmental or

public health concerns that are sometimes at variance with those in many multilateral environmental accords. Creating a World Sustainability Organization has been suggested in lieu of having three separate international organizations. Whatever, the eventual outcome of these proposals, national policies will need to account for the globalized nature of the major concerns.

Even in the absence of major restructuring of national and international governmental institutions, there are several pathways to more integrated decision-making and execution of government programs (Ashford and Hall, 2011):

1. The level of government at which integration is best accomplished (i.e., federal/national, regional, state, urban, or local government) may depend on the specific socio-technical goal. For example, integration of land-use planning, transportation, and housing is acknowledged to be best accomplished at the urban or local level, while integration of environmental pollution, workplace exposures, and product safety might best be accomplished at the federal/national level. Integration of planning for new industry and job creation initiatives might best be carried out at the regional level and involve state or provincial departments of commerce and labor.

2. Leadership for integration has to be emphasized at the top levels of the appropriate governmental units, and the performance of government employees has to be rewarded on the basis of multiple criteria, not only those relevant to a particular mission-agency's traditional goals.

3. The top-level and mid-level managers of mission agencies, whether at the federal/national, regional, or state level should be frequently rotated amongst those agencies so that fresh multi-faceted expertise and interest is continually evolving. For example, the head of the federal or state departments of commerce might move to departments of labor. Slowly, this will hopefully engender multi-dimensional thinking and planning, as well as tolerance for different missions and agencies.

4. Trans-disciplinary working groups, made up of different relevant mission-agency personnel should be constituted to work on different socio-technical problems, and housed together for periods of 6 months to 2 years to work together on problems requiring different concerns – such as environment, public health, and transportation.

5. Continuing education, reinforcing the related concepts relevant to inter-agency activities, needs to be provided to employees of different agencies in jointly-held sessions and workshops.

Experiments at inter-agency joint action should be encouraged and failures tolerated and learned from. Other initiatives should supplement the above, and a process of discovery should lead to the optimal levels and structures likely to spawn success. For all of these efforts, willingness to depart from narrowly-defined goals should be a starting point.

Articulating policy approaches to sustainability requires more than an understanding of the *challenges* to sustainability viewed from a narrow national context. Integrated sustainability policies

must utilize, alter, or supplant existing policies (and the institutions which administer them) in the areas of economy, employment, environment, *and* trade. Not only do national governments need to include trade policies in integration efforts, but international efforts need to integrate, for example, activities which are the traditional province of the United Nations Environment Program and United Nations Development Program, the multilateral environmental secretariats, the International Labour Organisation, and the World Trade Organization. No wonder that there have been calls for the creation of a World Sustainable Development Organization to integrate these concerns at the supra-national level.

The more disparate the governmental functions, e.g., economic growth, employment, and trade, the more challenging and important it is to pursue integration or suffer the consequences of unnecessary compromise.

7. **CONCLUSION**

This article makes the following contributions to the literature on sustainable development in arguing that:

1. Major technological, organizational, institutional, and social changes beyond incremental advances are necessary to achieve factor 10 improvements in material and energy use; adequate reductions in exposure to toxic substances; significant opportunities for stable, rewarding, and meaningful employment with adequate purchasing power; and an adequate level and distribution of economic welfare. Such improvements require more systemic, multidimensional, and disruptive changes. The capacity of the incumbent producers and providers of products and services to change can be the key limiting factor, and is often a crucial missing factor in optimistic planning scenarios.

2. These changes require system changes that "open up the problem space" of the policy designer by co-optimizing advances, i.e., achieving mutual gains simultaneously, in the relevant economic, environmental , and employment realms.

   Successful management of disruptive product innovation requires initiatives and input from outsiders to produce the expansion of the design space that limits the dominant technology firms (Van de Poel, 2000). Especially in sectors with an important public or collective involvement like transportation, construction, and agriculture, this means that intelligent government policies are required to bring about necessary change.

3. Achieving transformations to a more sustainable economic system requires stringent banking, environmental, labor protection and labor market regulation, as well as the regulation of commerce, advertising, and financial transactions. Laissez faire market approaches are inadequate.

   The current debate between imposing a significant carbon tax that will force the exit of old, inefficient power plants from the energy market and a cap-and-trade scheme which allows old power plants to stay in business by purchasing pollution credits exemplifies the differences between advancing the modernization of energy technologies

and achieving cost-efficient solutions from a static perspective (see Ashford and Caldart, 2008).

Rigid industries whose processes have remained stagnant also face considerable difficulties in becoming significantly more sustainable. Shifts from products to 'product services' rely on changes in the use, location, and ownership of products in which mature product manufacturers may participate, but this requires significant changes involving both managerial and social (customer) innovations. Changes in socio-technical 'systems', such as transportation or agriculture are even more difficult. This suggests that the creative use of government intervention is a more promising strategic approach for achieving sustainable industrial transformations, than the reliance of the more neo-liberal policies, such as reducing the corporate income tax or providing tax credits for adopting green technology which leverage firms' more short-term economic self-interest without leading to deeper organizational or societal changes.

This is not to say that enhanced analytic and technical capabilities on the part of firms; cooperative efforts and improved communication with suppliers, customers, workers, other industries, and environmental/consumer/community groups are not valuable adjuncts in the transformation process. But in most cases these means and strategies are unlikely to be sufficient by themselves for significant transformations, and they will not work without clear mandated targets to enhance the triple goals of economic development, improvement of environmental quality, and enhancement of employment/labor concerns.

4. Integration of often unconnected areas of policy and legal intervention at the national level —such as environment and employment— needs to be promoted. While incremental advances are inadequate as articulated in (1) above, as a practical matter, major, non-incremental advances can be achieved deliberatively, even if piecemeal, by connecting key interventions, policies, and agency missions relevant to a specific policy domain. For example, advancing both energy technologies and green jobs requires co-visioning and implementation of industrial innovation, energy demand-side interventions, and labor market policy integration. The current approach of working on energy technology alone will (co-) optimize neither consumption patterns nor energy-related employment. Wishful thinking that energy technology advances will lead to positive changes in demand and employment correct might be characterized as "trickle-down thinking."

5. Policy integration must account for the fact that developed nations especially now operate in a globalized market and integrating domestic-focused policies must extend to trade policies.

6. Policy integration must occur at the international level as well.

In the author's view, these policy prescriptions constitute the necessary and sufficient approaches to transforming the industrial state into a more sustainable one. The reader is referred to a larger work in press for more specific analysis and proposals (Ashford and Hall, 2011).

REFERENCES

ABERNATHY, W.J. and K.B. CLARK (1985), «Innovation: mapping the winds of creative destruction», *Research Policy* 14(1): 3-22.

ASHFORD, N.A. (ed.) (1976), *National Support for Science and Technology: An Examination of the Foreign Experience*, MIT Center for Policy Alternatives, CPA-75-12/Volumes I & II, may 15, 1976.

——, G.R. HEATON *et al.* (1979), «Environmental, Health and Safety Regulations and Technological Innovation», in *Technological Innovation for a Dynamic Economy*. C.T. Hill and J.M. Utterback. New York, Pergamon Press, Inc: 161-221.

—— and — (1983), «Regulation and Technological Innovation in the Chemical Industry», *Law and Contemporary Problems* 46(3), 109-157.

——, C. AYERS *et al.* (1985), «Using Regulation to Change the Market for Innovation.» *Harvard Environmental Law Review* 9(2), 419-466.

—— (1999), «Porter Debate Stuck in 1970s». *The Environmental Forum,* 3.

—— (2000), «An Innovation-Based Strategy for a Sustainable Environment,» in *Innovation-Oriented Environmental Regulation: Theoretical Approach and Empirical Analysis*, J. Hemmelskamp, K. Rennings, F. Leone (eds.). *ZEW Economic Studies.* Springer Verlag, Heidelberg, New York, pp. 67-107.

——, WIM HAFKAMP (EUR), Frits PRAKKE and Philip VERGRAGT (2002), *Pathways to Sustainable Industrial Transformations: Optimizing Competitiveness, Employment, and Environment* Cambridge, Ashford Associates.

—— (2004), «Major Challenges to Engineering Education for Sustainable Development: What has to Change to Make it Creative, Effective, and Acceptable to the Established Disciplines», *International Journal of Sustainability in Higher Education* 5(3), 239-250.

—— and C.C. CALDART (2008), *Environmental Law, Policy, and Economics: Reclaiming the Environmental Agenda*. Cambridge: MIT Press.

—— and R.P. HALL (2011), *Technology, Globalization and Sustainability*, Yale University Press.

BEISE, M.; BLAZEJCZAK, J.; EDLER, D.; JACOB, K.; JANICKE, M.; LOEW, T.; PETSCHOW, U.; RENNINGS, K. (2003), «The Emergence of Lead Markets for Environmental Innovations», *Forschungsstelle fur Umweltpolitik* (FFU): Berlin.

BHAGWATI, J. (1993), «The Case for Free Trade», *Scientific American*, 269(5):42-49.

—— (1997). «The Global Age: From a Skeptical South to a Fearful North.» *The World Economy* 20(3), 259-283.

BLAZEJCZAK, J.; EDLER, D. (2004), «Could Too Little and Too Much Turn Out to be Just Right? On the Relevance of Pioneering Environmental Policy». In *Governance for Industrial Transformation. Proceedings of the 2003 Berlin Conference on the Human Dimensions of Global Environmental Change,* Jacob, K., Binder, M., Wieczorek, A. Environmental Policy Research Centre: Berlin.

CALDART, C.C. and N.A. ASHFORD (1999), «Negotiation as a Means of Developing and Implementing Environmental and Occupational Health and Safety Policy», *Harvard Environmental Law Review* 23(1), 141-202.

CHARLES, T. and F. LEHNER (1998), «Competitiveness and Employment: A Strategic Dilemma for Economic Policy.» *Competition and Change* 3(1/2), 207-236.

CHRISTENSEN, C., J.M. UTTERBACK and F.F. SUAREZ (1998), «Strategies for Survival in Fast-Changing Industries.» *Management Science* 44(12), S207-S220.

CHRISTENSEN, C.M. (1997), *The Innovator's Dilemma*. Cambridge, Harvard Business School Press.

CLEFF, T. and K. RENNINGS (1999), «Determinants of Environmental Product and Process Innovation», *European Environment* 9: 191-201.

DALY, H.E. (1993), «The perils of free trade,» *Scientific American*, 269(5): 50-54.

DIWAN, I. and M. WALTON (1997), «How International Exchange, Technology and Institutions Affect Workers: An Introduction.» *World Bank Economic Review* 11(1), 1-15.

EKINS, P., C. FOLKE and R. COSTANZA (1994), «Trade, environment and development: the issues in perspective», *Ecological Economics* 9(1), 1-12.

ESTEVÃO, Marcello and Filipo SÁ (2008), «The 35-hour week», *Economic Policy* 23(55):417-463.

FREEMAN, C. (1982). *The Economics of Industrial Innovation*. London, Frances Pinter.

GUNNINGHAM, N.; SINCLAIR, D. (1999), «Integrative Regulation: A Principle-Based Approach to Environmental Policy.» *Law and Social Inquiry,* 24**:** 853-897.

HEMMELSKAMP, J., K. RENNINGS and F. LEONE (eds.) (2000), *Innovation-Oriented Environmental Regulation: Theoretical Approach and Empirical*

Analysis, ZEW Economic Studies. Springer Verlag, Heidelberg, New York

JAFFE, Adam B., STEVEN, R. Peterson, Paul R. PORTNEY and Robert N. STAVINS (1995), «Environmental Regulation and the Competitiveness of U.S. Manufacturing: What Does the Evidence Tell Us?», *Journal of Economic Literature* 33 (1), 132-163.

JAENICKE, Martin and JACOB, Klaus (2004), «Lead Markets for Environmental Innovations: A New Role for the Nation State», *Global Environmental Politics* 4(1), 29-46.

JORDAN, A. and A. LENSCHOW (2010), «Environmental Policy Integration: A State of Art Review». *Environmental Policy and Governance,* (20)3: 147-158.

KEMP, R. (1994), «Technology and Environmental Sustainability: The Problem of Technological Regime Shift.» *Futures* 26(10), 1023-1046.

—— (1997), *Environmental Policy and Technical Change: A Comparison of the Technological Impact of Policy Instruments* Cheltenham, UK: Edward Elgar.

KULISH, N. (2010), «Defying Others, Germany Finds Economic Success,» *New York Times*, August 13, 2010.

LUITEN, E.E.M. (2001), *Beyond energy efficiency: actors, networks and government intervention in the development of industrial process technologies* Utrecht, Utrecht University.

MONT, O. and LINDHQVIST, T., «The Role of Public Policy in Advancement of Product Service Systems», *Journal of Cleaner Production* 11 (2003) 905-914 (10 pages).

MOORS, E.H.M. (2000), *Metal Making in Motion: Technology Choices for Sustainable Metals Production Delft*, Delft University of Technology.

NELSON, R.R. and S.G. WINTER (1977), «In Search of Useful Theory of Innovation.» *Research Policy* 6, 36-76.

PARTIDARIO, P.J. (2003), *«What-if»: From path dependency to path creation in a coatings chain: a methodology for strategies towards sustainable innovation* Delft, Delft University of Technology.

PORTER, Michael (1990), *The Competitive Advantage of Nations* New York: Free Press.

PORTER, Michael E. and Claas VAN DEN LINDE (1995a), «Green and Competitive: Ending the Stalemate», *Harvard Business Review* September/October 1995:120-134.

––– and — (1995b), «Towards a New Conceptualization of the Environment-Competitiveness Relationship», *J. Economic Perspectives* 9(4), 97-118.

RENNINGS, K.; KEMP, R.; BARTOLOMEO, M.; HEMMELSKAMP, J.; HITCHENS, D. (2003), *Blueprints for an Integration of Science, Technology and Environmental Policy* (BLUEPRINT). Zentrum für Europäische Wirtschaftsforschung (ZEW): Mannheim.

SCHUMPETER, Joseph (1939), *Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process* New York, McGraw-Hill.

SCHUMPETER, Joseph A. (1962), *Capitalism, Socialism and Democracy*. New York, Harper torchbooks.

UTTERBACK, J.M. (1987). «Innovation and Industrial Evolution in Manufacturing Industries». *Technology and Global Industry: Companies & Nations in the World Economy*. B.R. Guile and H. Brooks. Washington, D.C., National Academy Press**:** 16-48.

—— (1996). *Mastering the Dynamics of Innovation*. Cambridge, Harvard Business School Press.

—— and H.F. ACEE (2005), «Disruptive Technologies: An Expanded View.» *International Journal of Innovation Management* **9**(1): 1-17.

VAN DE POEL, I. (2000), «On the Role of Outsiders in Technical Development». *Technology Analysis & Strategic Management*, 12(3): 383-397.

VOGEL, David (1995), «Chapter 1: National Regulation in the Global Economy», in *Trading Up: Consumer and Environmental Protection in a Global Economy* Cambridge, MA: Harvard University Press, 1995, pp. 1-23.

WALLEY, N.; WHITEHEAD, B. (1994), «It's Not Easy Being Green.» *Harvard Business Review,* 46-52.

WCED = WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT (1087), *Our Common Future*. Oxford Unversity Press: Oxford.

WORLD ECONOMIC FORUM (2002), «Yale Center for Environmental Law and Policy, Yale University, Center for International Earth Science Information Network and Columbia University». *Environmental Sustainability Index: An Initiative of the Global Leaders of Tomorrow*. Environment Task Force, World Economic Forum: Geneva.