Communications of the Association for Information Systems

Volume 27 Article 11

8-2010

Green IS: Concepts and Issues for Information Systems Research

Jason Dedrick
School of Information Studies, Syracuse University, jdedrick@syr.edu

Communications of the Association for Information Systems

CAIS

Green IS: Concepts and Issues for Information Systems Research

Jason Dedrick

School of Information Studies, Syracuse University

jdedrick@syr.edu

Abstract:

While public awareness of environmental sustainability is growing, there is concern about the economic costs of shifting to a greener economy. In the case of climate change, a critical issue is the relationship of economic output to greenhouse gas emissions, which has been labeled *carbon productivity.* Increasing carbon productivity means that economic growth can be sustained while emissions are reduced. Information technology has great potential to enhance carbon productivity, as IT is used to increase the energy efficiency of buildings, transportation systems, supply chains and electrical grids. On the other hand, the production and use of computers is a fast-growing component of global energy consumption and greenhouse gas emissions, a fact that must be balanced against the benefits of IT use. Green IS refers to the use of information systems to achieve environmental objectives, while Green IT emphasizes reducing the environmental impacts of IT production and use. This article focuses primarily on Green IS. It reviews existing Green IS research, presents a model of IT investment and carbon productivity, and lays out suggestions for future research.

Keywords: carbon productivity, sustainability, green IT, environment, greenhouse gas, climate change, ICTs

Volume 27, Article 11, pp. 173-184, August 2010

Editor's note: The article is based on a tutorial presented at the Americas Conference on Information Systems, August 2009, San Francisco, California.

I. INTRODUCTION

Interest in the environmental impacts of information technology has grown in recent years in response to increased public concern about the environment, growing eco-consciousness in business strategies, and introduction of new policy initiatives. Public consciousness of environmental issues has risen in response to scientific research and widespread media reporting on global warming and other environmental threats. For businesses, environmental sustainability is an important part of the movement toward corporate social responsibility. On the policy side, new environmental laws, regulations, and targets have been introduced at all levels of government, from transnational bodies such as the European Community down to local governments.

The environment is now high on the agenda for firms, governments, non-government organizations, and consumers. The likelihood of stronger national and international commitments to reduce greenhouse gas (GHG) emissions and achieve other environmental goals will create further pressure to find ways to achieve greater efficiency in the use of energy and other resources while sustaining economic growth. The threat of global warming is closely linked to issues of energy security and rising energy costs, as GHG emissions are highly correlated with energy use; thus there is increasing convergence of environmental, security and economic interests.

In the information systems community, sustainability has started to become a significant issue in the narrow sense of reducing the direct environmental impacts of IT use. Energy efficiency in hardware and data centers continues to receive a great deal of attention, given the potential to reduce emissions and lower energy costs. Recycling of electronic waste is another priority for many companies. In the IT industry, major hardware companies tout environmentally-friendly designs emphasizing reusability and elimination of toxic chemicals, while IT service companies offer green IT consultation to clients. So far, less attention has been paid to the potential of IT to enable environmental gains in the broader economy.

In this tutorial, I present a broad overview of the issues surrounding Green IS. As I will clarify, there is an important distinction between Green IT and Green IS [Watson et al., 2008]. My focus is primarily on Green IS, so I use that terminology unless specifically referring to the narrower topic of Green IT. My approach is to (1) frame and define the issue, (2) analyze existing academic research as well as other data and reports, (3) present a new model of the impacts of IT on “carbon productivity” in the economy, and (4) propose a set of issues and questions that might serve as an initial agenda for academic research on Green IS.

II. FRAMING THE ISSUE: GREEN IT AND GREEN IS

Green IT has been conceptualized in a number of ways, with wider or narrower scope, and with a variety of terminologies and concepts. Green IT has been defined as:

> … the study and practice of designing, manufacturing, using and disposing of computer, servers and associated subsystems … efficiently and effectively with minimal or no impact on the environment.
>
> Murugesan, 2008.

This view focuses on improving energy efficiency and equipment utilization through steps such as designing energy efficient chips, virtualization, reducing data center energy consumption, using renewable energy to power data centers, and reducing electronic waste [Watson et al., 2008, p. 2].

A broader scope, defined as Green IS by Watson et al. [2008], includes the use of information systems to enhance sustainability across the economy. This view includes improving efficiency in industries that are major sources of GHG emissions, such as the transportation, manufacturing, and energy sectors.

The Green IT view sees IT primarily as a problem to be mitigated; for example, data centers are a rapidly growing source of carbon emissions and need to be made more energy efficient to reduce their impact on the environment. The Green IS view sees information systems as a possible solution to many environmental problems. For example, electricity generation is a major source of GHG emissions; “smart grid” technology can employ information systems to increase efficiency in the production, transmission, and use of electricity. Ultimately, IT should be viewed both as part of the problem and part of the solution [Fuchs, 2008].

To better understand the impacts of IT on the environment, be aware that the use of information and communications technologies (ICTs) is credited for creating 2 percent of the total CO_2 emissions in the U.S., similar to the emissions created by the airline industry [Gartner, Inc., 2007]. From this perspective, Green IT seems to address a very small part of the overall climate change problem, although the environmental impacts of ICTs could grow very rapidly as hundreds of millions of people in the developing world go online for the first time, and data intensive applications such as video streaming demand more computing power. By contrast, the use of Green IS throughout the economy potentially addresses much of “the other 98 percent” of emissions. As such, even relatively small proportional gains in energy efficiency or emission reduction from Green IS would potentially dwarf the benefits of greener IT.

Taking a longer term, more dynamic view, researchers have framed the impacts of IT on the environment as first, second, and third-order effects [Hilty et al., 2006; Kohler and Erdmann, 2004].

- First-order effects are direct impacts from IT hardware during the product lifecycle, including production, use and disposal of computer equipment. These effects are similar to the scope of Green IT.
- Second-order effects are the effects of ICTs on other processes such as transportation or industrial production, influencing their environmental impacts. This is similar to Green IS.
- Third-order effects are longer term and more dynamic. They occur when widespread use of ICTs leads to changes in lifestyles and economic structures. Third-order effects may be seen in specific cases, such as telecommuting or the growth of home-based businesses built on e-commerce platforms such as eBay or Amazon. So far, these transformative effects are limited, but widespread adoption of the Internet is only a decade or less old in many countries. By comparison, widespread use of automobiles led to suburbanization, motels, fast food chains, and other changes in lifestyle and economic systems, but these changes were not evident until decades after the introduction of the Model T.

III. PERCEPTIONS OF GREEN IS

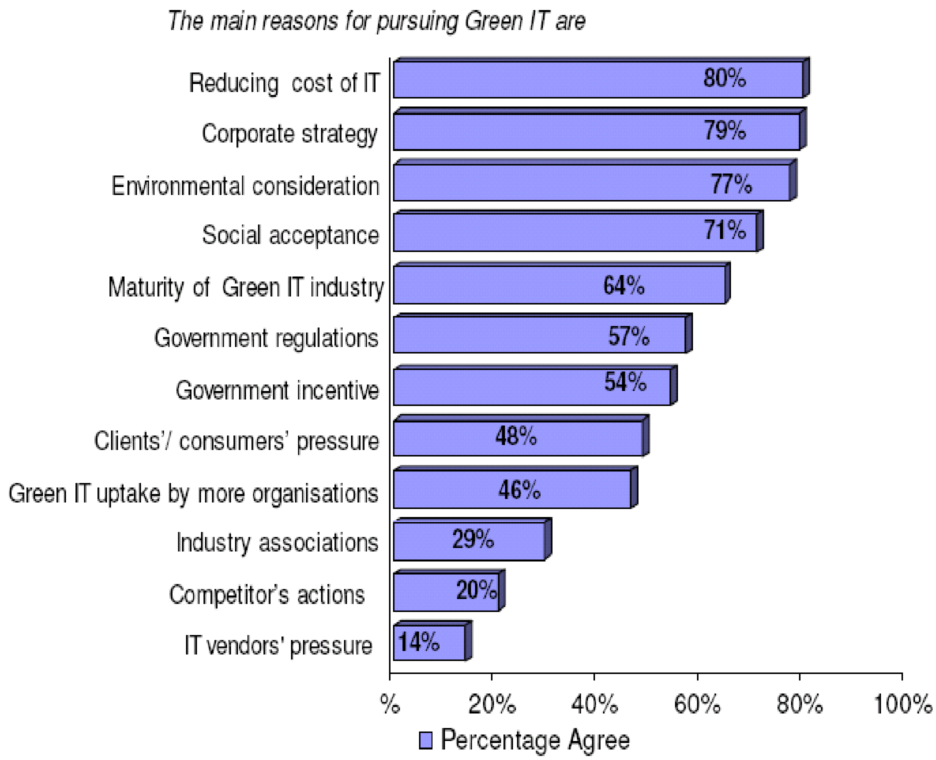
Concerns about the environment rose and fell in past decades, at times driven by notable environmental events such as Three Mile Island in 1979, or by the appearance of warnings such as Rachel Carson’s *Silent Spring* [1962], or Al Gore’s *An Inconvenient Truth* [2006] The reaction is usually some government action such as banning the use of DDT or passage of the Clean Air Act, often accompanied by individual and corporate efforts to adopt greener practices such as recycling. Often there is a backlash by economic interests who would be hurt by stronger environmental measures and by interest groups who either disbelieve the evidence of a real threat or believe that the costs of mitigating the threat would be too expensive and hurt the economy.

In the case of global warming, we see all of these forces in action, leading to very different perceptions of the scope of the environmental threat, the role of humans in causing the problem, and of the cost and benefits of trying to reduce that threat. Some, such as the Intergovernmental Panel on Climate Change [2007] warn of grave threats, while others downplay or deny the risks [e.g., Will, 2009] Among those who acknowledge the risk, some see a grim set of options: either accept lower standards of living in order to reverse or slow down climate change or pay the price of adjusting to its effects, such as relocating millions of people from low-lying coastal areas. Others are more optimistic, and see opportunities to create a cleaner and more energy efficient economy and develop innovative new industries. In the words of President Obama, just prior to his inauguration,

> We will put Americans to work in new jobs that pay well and can’t be outsourced—jobs building solar panels and wind turbines; constructing fuel-efficient cars and buildings; and developing the new energy technologies that will lead to even more jobs, more savings, and a cleaner, safer planet in the bargain.
>
> President-elect Obama, January 8, 2009.

The information systems community has begun to look seriously at the role that IT can play in both creating and reducing global warming. So far, much of the discussion and activity in the IS practitioner community is focused on reducing the direct (i.e., the first order) environmental impacts of IT by making data centers and personal computing equipment more energy efficient. These efforts can directly reduce IT costs, so there is a strong incentive for organizations to adopt them. Evidence from surveys confirms that IS organizations are responding to these incentives by adopting green practices.

In two different surveys of IS professionals [Molla et al., 2009; Forrester Consulting, 2009], the number-one motivation for adopting Green IT practices was to reduce costs. This finding confirms the "bottom line" view of most businesses. However, as shown in Figure 1, the next three choices in the Molla et al. survey of U.S., Australian, and New Zealand firms were corporate strategy, environmental consideration, and social acceptance. In the Forrester survey, the second choice was "do the right thing for the environment," and fourth was "improve the company's brand image with customers and the public." These answers suggest that many organizations do have a sense of corporate responsibility, and also that they feel the need to respond to public concerns about the environment. Both surveys show government regulation and incentives playing a secondary role, perhaps because there are currently few regulations or incentives that directly promote Green IT or raise the cost of emitting GHG.

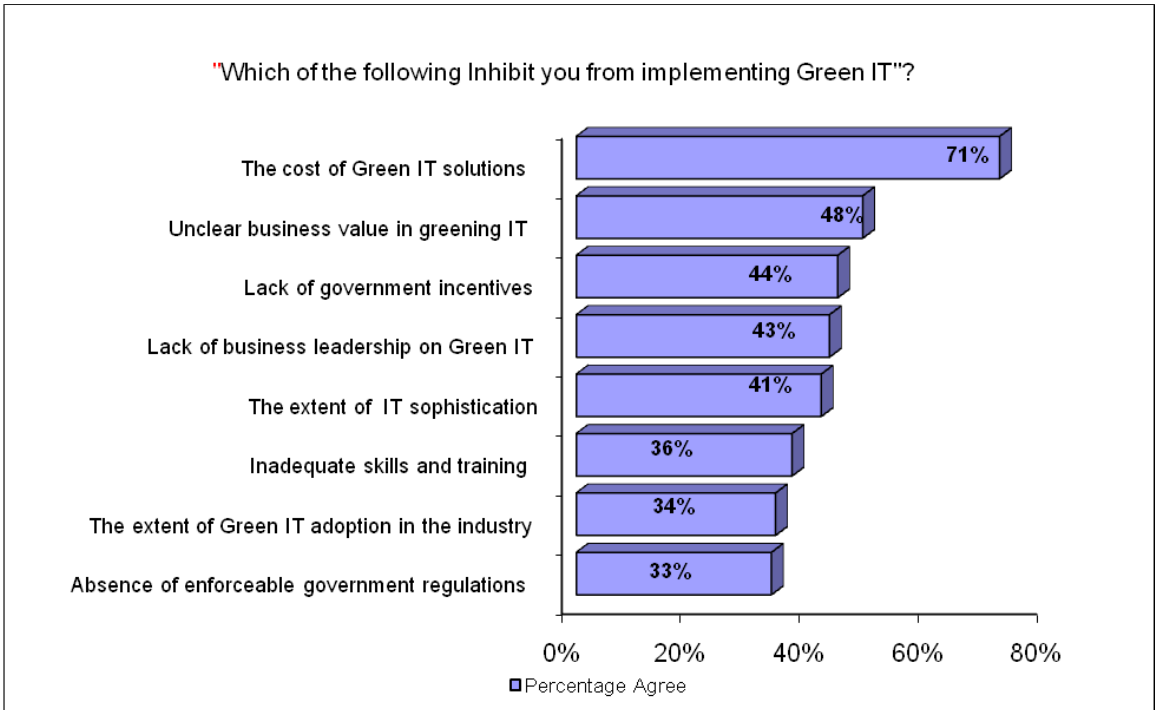


Source: Molla, A., et al. (2009) "An International Comparison of Green IT Diffusion," *International Journal of e-business Management* (3)2, pp. 3–23. Used with permission.

Figure 1. Reasons for Pursuing Green IT

The survey by Molla et al. also found that the biggest disincentive to adopting Green IT was cost, followed by unclear business value (Figure 2).

One thing that these surveys make clear is that companies generally will adopt greener IT practices only when it makes economic sense to do so. This finding raises issues for both managers and policymakers. For managers, it is important to be able to assess accurately the costs and potential savings from different "green" practices. The calculations become more complex as the solutions move from simple energy saving practices and technologies (e.g., turning off equipment at night, using energy saving software on PCs) to major enterprise-level practices such as virtualization or even location of data centers to tap renewable energy sources (e.g., Google's location of a major data center near a source of hydropower on the Columbia River). CIOs are a cautious lot, so they are less likely to make investments with uncertain costs and payoffs.



Source: Molla, A., et al. (2009) "An International Comparison of Green IT Diffusion," *International Journal of e-business Management* (3)2, pp. 3–23. Used with permission.

Figure 2. Barriers to Implementing Green IT

Even when green IT practices have a clear economic payoff, they may not be adopted. This is because some major variables often are beyond the scope of the IS department. For instance, the cost of energy for a data center is not always charged to the IS budget. When space is rented, utility bills may be paid by the company, but decisions about building design and utilities were already made by the building's original owner or the architect. Without direct control and responsibility, it is difficult for the CIO to achieve the greatest energy reductions, even when growing energy costs create the incentive to do so.

More significantly, most CIOs are not directly involved in the firm's efforts to reduce energy consumption and hence GHG emissions in the broader operations of the organization. The potential for achieving indirect or second-order benefits from IS is not part of the scope of the IS department's responsibilities. Human resources or functional departments make decisions about telecommuting; operations and logistics managers are concerned with transportation, production, and supply chain issues; product development is responsible for reducing the environmental footprint of a company's products or services. The Corporate Social Responsibility group, if there is one, may be an advocate for sustainability, but rarely has direct operational authority. The IS department focuses on IT costs and impacts, but may not be responsible for looking at how IT can be used strategically to reduce environmental impacts across the whole organization.

Consistent with this reality, most studies produced by IS researchers or consultancies have concentrated on direct, first-order impacts of IT. There are exceptions [e.g., Watson et al., 2008; McKinsey Global Institute, 2008], and more IS researchers are starting to deal with the second-order effects of IT. That work needs to connect with practitioners to learn from their experience and inform both IT practitioners and business executives about the broader potential and true costs of Green IS.

Beyond the corporate IS department and the mainstream world of information systems research, there is growing interest in different ways that IS can impact the "other 98 percent" through innovative uses of IS in transportation, energy, manufacturing, buildings, and elsewhere [Atkinson and Castro, 2008]. For example:

- IT is being built into advanced wind turbines in the form of sensors and controllers that allow turbines to operate efficiently and safely in a wider range of wind speeds and conditions.

- Smart grid technology is being developed to distribute electricity more efficiently and to match supply and demand in the grid.
- Smart buildings use sensors and controls to adjust automatically to changes in the environment,
- Smart meters allow users to adjust energy use away from peak demand periods.
- In transportation, smart cars and smart highways can improve traffic flows and reduce wasted time and energy from traffic jams.
- In operations management, major strides already have been taken to reduce energy consumption in manufacturing supply chains. In terms of academic research, operations management is years ahead of information systems in addressing environmental issues [Melville, 2010].

While the potential of these technologies is exciting, there are only the barest beginnings of a research effort to quantify the real costs and potential benefits of adopting them. McKinsey Global Institute [2008] looks at a number of green technologies and practices, estimating both their cost and potential to reduce GHG emissions. They find that many technologies and practices actually have a negative cost, i.e., they more than pay for themselves with direct cost savings. The private sector has incentives to make the necessary investments in such technologies and practices, as they have a positive return on investment.

If there are social benefits to IT investments that go beyond the private returns to businesses, it is up to society (individuals, governments, and institutions), to make those investments or create incentives for businesses to do so. However, even if there were a strong public consensus for government to act aggressively on climate change, the problem remains that we have poor information to guide policymakers as to the most effective and affordable combination of measures to take.

How does a dollar spent on a smart grid project compare to a dollar spent planting trees in the rainforest? Questions such as this need to be answered, as there are limited dollars to spend, and various regulations, incentives, taxes, and cap-and-trade schemes do have costs. One role of academics is to provide a scientific basis for others to make better decisions. The need for good academic research to guide policymakers and other decision makers with regard to the environment and climate change is enormous. Information systems scholars have a major role to play here, given their broad and deep expertise in areas from economics, technology diffusion, and social impacts to systems integration, data analysis, networking, and dozens of other specialties that are needed to assess the cost and potential benefits of all kinds of green initiatives. Working alone and with colleagues in other fields, we can develop and implement the new technologies and practices that will be required.

In the next section, I take a modest step to frame one important research topic in the economics of IS. I discuss a newly defined measure of productivity that relates economic output to the level of greenhouse gas emissions--"carbon productivity" [McKinsey Global Institute, 2008]. Then I develop a conceptual model for analyzing the impacts of IT on carbon productivity, in the tradition of the IT productivity literature.

IV. GREEN IS AND CARBON PRODUCTIVITY

Productivity is the relationship of output from any productive activity to the various inputs that go into it. A factory may employ labor, capital, energy, and raw materials to produce finished goods. The ratio of the value of those goods to the value of the factors that went into them is the measure of the productivity of the factory. Output can be increased by adding more inputs without raising overall productivity. The total productivity of the whole system (called total factor productivity), however, may be improved by applying knowledge of how to better organize production, e.g., by using energy or materials more efficiently, or by giving workers incentives to improve performance.

Information technology can be seen as an input into this production function, i.e., it is a form of capital that can be used by workers to increase output. There is well-documented evidence of a strong relationship between IT investment and productivity at the firm, industry, and national level [e.g., Lichtenberg, 1995; Brynjolfsson and Hitt, 1996; Devaraj and Kohli, 2000; Dewan and Kraemer, 2000; Oliner and Sichel, 2000].[1] The production function approach can also be used to estimate the relationship of IT to carbon productivity.

To do so, the first issue that needs to be addressed is how to account for the costs or negative impacts of greenhouse gas emissions when measuring the productivity of a production system, whether it is a single factory or the global economy. In the economics literature, pollution is usually treated as a negative externality, whose cost may be subtracted from output to obtain a truer adjusted measure of economic output. Another view is to treat

[1] See Dedrick et al. [2003] for a critical review of the IT and productivity literature.

emissions as a type of input into the production function and look at output per unit of emissions. The best possible model would account directly for GHG emissions, but such data is difficult to capture directly at the firm, industry or country level. For empirical studies, the best measure available may be energy consumption adjusted for type of energy source (e.g., coal, nuclear, hydropower).

Carbon productivity for the world economy in 2008 was estimated at $740 of GDP per ton of $C0_2$ equivalent emissions, or $C0_2e$.[2] To sustain historical rates of economic growth while reducing $C0_2e$ emissions below 500 parts per million (a target identified by the IPCC as limiting temperature increases to 2.5 degrees Celsius), carbon productivity must increase nearly tenfold by 2050 [McKinsey Global Institute, 2008].

For IS researchers, a key issue is what role IT can play in increasing carbon productivity. The potential impacts of IT on carbon productivity can be understood with a simple conceptual framework (Figure 3).

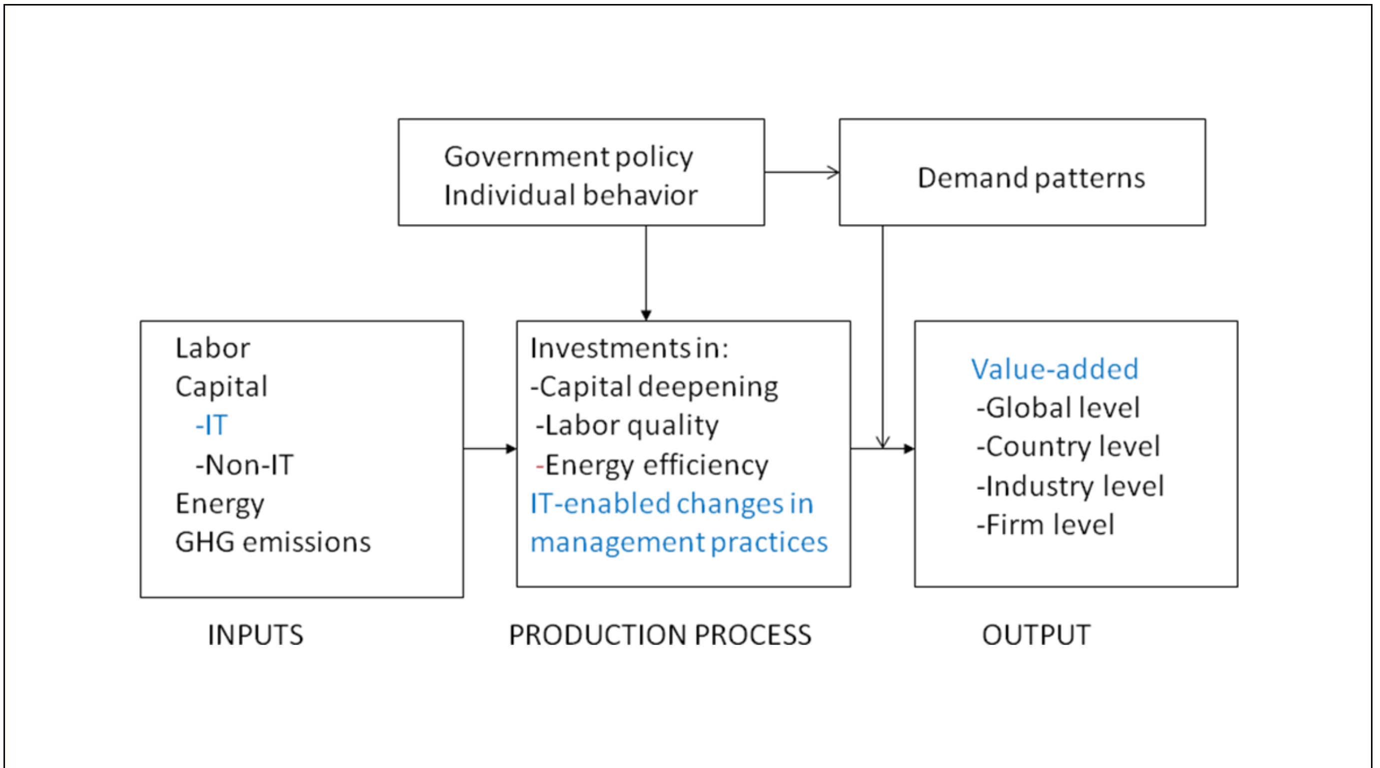


Figure 3. IT and Carbon Productivity

In this model, IT capital is an element in a production function through which inputs are transformed to outputs via a production process. The other inputs in this model are labor, non-IT capital, energy, and GHG emissions.[3] Energy use includes the energy consumed in the use of IT, primarily electricity to run computers and other devices. Output can be increased through capital deepening, improvements in labor quality, and energy efficiency. Much of the impact of IT is through capital deepening, i.e., giving workers more IT to carry out their work. However, IT can have another impact, by enabling changes in management practices that increase the overall productivity of the production process for different combinations of inputs.

Such an increase in total factor productivity is perhaps the most important way that IT can affect carbon productivity. An example is the use of IT and operations research to optimize transportation routes in a transportation company [Partyka and Hall, 2010; Sbihi and Eglese, 2010; Groer et al., 2009]. In this case, the same amount of goods could be shipped using less capital (trucks), labor (driver hours) and energy, with lower GHG emissions. Such changes would not necessarily require an increase in IT capital, just better use of existing processing capacity. The only trade-off would be an increase in energy used to process the necessary calculations and communicating this information to dispatchers or drivers, but this should lead to much bigger savings in energy used to fuel the trucks.

[2] C02e is a standardized measure of greenhouse gas emissions that accounts for the different warming potential of other GHGs such as methane [McKinsey Global Institute, 2008].
[3] The model can be expanded to include other inputs such as land or water.

Also, the electricity used to drive the IT could potentially come from non-carbon sources, while the potential for transforming trucking fleets to non-carbon fuels is probably further in the future.

The two other boxes in Figure 3 are not directly related to IT, but can influence the investments that firms make to improve carbon productivity. The first is government policy, which can change the relative prices of capital, labor, and energy, or directly put a price on GHG emissions, e.g., through cap-and-trade. Government policy also can influence demand, through government procurement, incentives, or taxes to encourage or discourage consumption of different types of products (e.g., rebates for buying energy efficient appliances, or taxes on gas-guzzling cars), or through direct regulation of emissions.

Individual behavior is the other variable that directly affects demand, as consumers may make buying decisions that take into account environmental consequences, such as buying a hybrid car or buying locally-grown produce. Individuals also are part of organizations, and their own attitudes can have impacts on how those organizations behave. In any organization, a host of decisions are made by individuals who are influenced by factors beyond pure profit maximization or other organizational goals. IS-related decisions, such as whether to allow an employee to telecommute or to set up a videoconference rather than flying to a meeting, may involve several trade-offs (e.g., employee satisfaction versus ability to monitor performance, time savings versus quality of communication), and the outcome may be ambiguous. In such cases, a manager who is conscious of the environmental implications of his or her choice might come to a different decision than one who does not care.

To summarize, information systems can influence carbon productivity and, hence, the ability to sustain economic growth while reducing GHG emissions. IT capital is an input into a production process, as is the energy required to use IT. IT capital can improve energy efficiency directly by substituting IT for energy in production. It also can improve the total factor productivity in an organization or a whole economy through IT-enabled management practices. However, these gains can be negated if the energy consumed by IT use is as great as the savings achieved through its use. Returning to the definitions presented in Watson et al. [2008], the impacts of both Green IT and Green IS must be taken into account in a conceptual framework such as that presented in Figure 3.

V. TOWARD A GREEN IS RESEARCH AGENDA

Researchers from across the entire information systems field have opportunities to contribute to a topic that is just emerging as a major area of interest. While the potential scope of Green IS research is broad, I focus on the economic, organizational, and policy issues that are raised by the foregoing discussion of IT and carbon productivity. Even carbon productivity is a broad subject area. The following is a point of departure for discussing a research agenda. I suggest that there is a need for research on the following topics, which follow the elements of the model in Figure 3.

1. Green IT, or first-order effects of IT. Figuring out how to reduce energy consumption has great appeal to business because of its direct impacts on the bottom line and the associated benefit of reducing GHG emissions. These benefits increase if we move toward an economy in which there is a price and market for such emissions. IS researchers can contribute by taking a broader view of the entire system and understanding how organizations can optimize a whole set of decisions, such as hardware selection, system architecture, data center design and location, and insourcing versus outsourcing, to optimize a combination of performance, cost, and GHG emissions. From an economic and policy view, it would be valuable to provide better understanding of the implications of such choices on carbon productivity.

2. Better understanding of the interaction of IT and other factors within the production process. Previous research shows that IT can be a substitute for labor and for non-IT capital in a production function [Dewan and Min, 1997], but also can be a complement for non-IT capital in some situations [Chwelos, et al., 2009]. It would be valuable to know the relationship of IT to energy use, i.e., the extent to which IT can be substituted for energy in producing a certain output. Also, to what extent can IT-enabled management practices and organizational processes lead to gains in total factor productivity, with impacts on carbon productivity that go beyond simply substituting IT for energy? Such relationships can be defined in general terms in a model, but understanding the actual mechanics requires deep study at the process level, including interactions across the value chain within and across firm boundaries. This takes field work, which can then lead to identifying measurable variables and developing hypotheses that can be tested in quantitative studies. Translating the conceptual framework in Figure 3 into a model with testable hypotheses and designing empirical studies to test and refine the model is a challenge for researchers in the economics of IS tradition.

3. Policy studies. The impact of government policy on IT investment and the consequences for carbon productivity is an area of vital importance. Much qualitative and quantitative research focuses on government IT policy and its impacts on IT production and use [e.g., Dedrick and Kraemer, 1998; Kraemer et al., 2006].

Models have been developed and tested to estimate these relationships for IT in general and e-commerce in particular [e.g., Shih et al., 2008]. Similar research focusing on government policies that either directly or indirectly influence specific carbon-reducing IT investments, and the impacts of those investments, would be of great value to scholars and policy makers.

4. Impacts of individual attitudes on adoption of carbon-reducing technologies. A body of IS research examines individual adoption of information technologies, using theories such as the technology adoption model [e.g., Davis et al., 1989]. A body of empirical research that studies the factors influencing adoption of green technologies is needed. A step in this direction is Molla et al. [2009]. Likewise, it would be valuable to understand how individuals' choices within organizations are influenced by attitudes regarding the environment. IS researchers can make an important contribution by applying the rich combination of theories and methodologies that the field has employed in other studies to the issue of Green IS.

VI. CONCLUSIONS

In many important areas, IS researchers can find fertile ground for Green IS research and contribute both to advancing scholarly knowledge and informing the public, policy makers, and business decision makers. I expect others to expand on the list of projects, and am aware that important research is already underway, as evidenced by presentations at the 2009 AMCIS [e.g., Hassan et al., 2009; Sayeed and Gill, 2009; Dwyer and Gomez, 2009; Erek et al., 2009; Mann et al., 2009] and ICIS [Babin and Nicholson, 2009; DesAutels and Berthon, 2009; Chen et al., 2009; Molla, Cooper and Pittayachawan, 2009; and Hedwig et al., 2009]. I expect that the fruits of these efforts will show up in peer reviewed journals in the near future, and look forward to the time when the IS field is deeply involved in informing the global community on the issues and potential of Green IS.

Still, it is possible that Green IS will turn out to be another fad that will fade when the next "critical" issue comes along. Gartner Group located Green IT at the "Peak of Inflated Expectations" in its 2008 Hype Cycle for Emerging Technologies [Mosher, 2008]. As energy prices have fallen from their mid-2008 peak levels, the economic incentives for going green have weakened. However, the underlying environmental issues have not changed, and it is important that the IS community continue to pursue research in the emerging field of Green IS regardless of short-term shifts in public opinion and attention

REFERENCES

Editor's Note: The following reference list contains hyperlinks to World Wide Web pages. Readers who have the ability to access the Web directly from their word processor or are reading the paper on the Web, can gain direct access to these linked references. Readers are warned, however, that:

1. These links existed as of the date of publication but are not guaranteed to be working thereafter.
2. The contents of Web pages may change over time. Where version information is provided in the References, different versions may not contain the information or the conclusions referenced.
3. The author(s) of the Web pages, not AIS, is (are) responsible for the accuracy of their content.
4. The author(s) of this article, not AIS, is (are) responsible for the accuracy of the URL and version information.

Atkinson, R.D. and D.D. Castro (2008) *Digital Quality of Life: Understanding the Personal and Social Benefits of the Information Technology Revolution*, Washington, DC: Information Technology and Innovation Foundation.

Babin, R. and B. Nicholson (2009). "How Green Is My Outsourcer—Environmental Responsibility in Global IT Outsourcing", *ICIS 2009 Proceedings,* Paper 83, http://aisel.aisnet.org/icis2009/83 (current April 16, 2010).

Brynjolfsson, E. and L.M. Hitt (1996) "Paradox Lost? Firm-Level Evidence on the Returns to Information Systems Spending", *Management Science* (42), pp. 541–558.

Carson, Rachel (1962) *Silent Spring*, Boston: Houghton Mifflin.

Chen, A.J., et al. (2009) "Organizational Adoption of Green IS & IT: An Institutional Perspective", *ICIS 2009 Proceedings,* Paper 142, http://aisel.aisnet.org/icis2009/142 (current April 16, 2010).

Chwelos, P., et al. (2009) "Research Note—Does Technological Progress Alter the Nature of Information Technology as a Production Input? New Evidence and New Results", *Information Systems Research*, published online before print August 31, 2009.

Davis, F.D., R.P. Bagozzi, P.R. Warshaw (1989) "User Acceptance of Computer Technology: A Comparison of Two Theoretical Models", *Management Science* (35)8, pp. 982–1003.

Dedrick, J., V. Gurbaxani, K.L. Kraemer (2003) "Information Technology and Economic Performance: A Critical Review of the Empirical Evidence", *ACM Computing Surveys* (35)1, pp. 1–28.

Dedrick, J. and K.L. Kraemer (1998) *Asia's Computer Challenge: Threat or Opportunity for the United States and the World?* New York: Oxford University Press.

DesAutels, P. and P. Berthon (2009) "Sustainable Notebooks: Who Carries the Cost?" *ICIS 2009 Proceedings,* Paper 110, http://aisel.aisnet.org/icis2009/110 (current April 16, 2010).

Devaraj, S. and R. Kohli (2002) "Information Technology Payoff in the Health Care Industry: A Longitudinal Study", *Journal of Management Information Systems* (16)4, pp. 41–68.

Dewan, S. and K.L. Kraemer (2000) "Information Technology and Productivity: Preliminary Evidence from Country-Level Data", *Management Science* (46)4, pp. 548–562.

Dewan, S. and C. Min (1997) "The Substitution of Information Technology for Other Factors of Production: A Firm-Level Analysis", *Management Science* (43)12, pp. 1660–1675.

Dwyer, C. and E.A. Gomez (2009) "Sustainability Course Modules for Information Systems and Interdisciplinary Courses", *AMCIS 2009 Proceedings,* Paper 79, http://aisel.aisnet.org/amcis2009/79 (current April 16, 2010).

Erek, K., et al. (2009) "Sustainability in Information Systems: Assortment of Current Practices in IS Organizations", *AMCIS 2009 Proceedings,* Paper 123, http://aisel.aisnet.org/amcis2009/123 (current April 16, 2010).

Forrester Consulting (2009) "IT's Role in Reducing Corporate Environmental Impact: A Commissioned Study Conducted on Behalf of Cisco Systems Inc.", http://www.cisco.com/en/US/prod/collateral/switches/ps5718/ps10195/Cisco_TLP__Final.pdf (current March 25, 2010).

Fuchs, C. (2008) "The Implications of New Information and Communication Technologies for Sustainability", *Environmental Development and Sustainability* (10)3, pp. 291–309.

Gartner, Inc. (2007) "Gartner Estimates ICT Industry Accounts for 2 Percent of Global CO2 Emission", Press release, http://www.gartner.com/it/page.jsp?id=503867 (current April 16, 2010).

Gore, A. (2006) *An Inconvenient Truth: The Planetary Emergency of Global Warming and What We Can Do About It*, New York: Rodale Press.

Groër, C., B. Golden, E. Wasil (2009) "The Consistent Vehicle Routing Problem", *Manufacturing & Service Operations Management* (11)4, pp. 630–643.

Hasan, H., A. Ghose, T. Spedding (2009) "IS Solution for the Global Environmental Challenge: An Australian Initiative", *AMCIS 2009 Proceedings,* Paper 122, http://aisel.aisnet.org/amcis2009/122 (current April 16, 2010.

Hedwig, M., S. Malkowski, D. Neumann (2009) "Taming Energy Costs of Large Enterprise Systems Through Adaptive Provisioning", *ICIS 2009 Proceedings,* Paper 140, http://aisel.aisnet.org/icis2009/140 (current April 16, 2010).

Hilty, L.M., et al. (2006) "The Relevance of Information and Communication Technologies for Environmental Sustainability—A Prospective Simulation Study", *Environmental Modelling & Software* (21)11, pp. 1618–1629.

Intergovernmental Panel on Climate Change (2007) *Climate Change 2007—Impacts, Adaptation and Vulnerability,* Cambridge, U.K.: Cambridge University Press.

Kohler, A. and L. Erdmann (2004) "Expected Environmental Impacts of Pervasive Computing", *Human and Ecological Risk Assessment* (10)5, pp. 831–852.

Kraemer, K.L., et al. (2006) *Global E-Commerce: Impacts of National Environment and Policy*, Cambridge, U.K.: Cambridge University Press.

Lichtenberg, F.R. (1995) "The Output Contributions of Computer Equipment and Personnel: A Firm Level Analysis", *Economic Innovations and New Technology* (3)3&4, pp. 201–217.

Mann, H., G. Grant, I.J. Singh Mann (2009) "Green IT: An Implementation Framework", *AMCIS 2009 Proceedings,* Paper 121, http://aisel.aisnet.org/amcis2009/121 (current May 18, 2010).

McKinsey Global Institute (2008) "The Carbon Productivity Challenge: Curbing Climate Change and Sustaining Economic Growth", McKinsey & Company.

Melville, N. (2010) "Information Systems Innovation for Environmental Sustainability", *MIS Quarterly* (34)1, pp. 1–21.

Molla, A., et al. (2009) "An International Comparison of Green IT Diffusion", *International Journal of e-Business Management* (3)2, pp. 3–23.

Molla, A., V.A. Cooper, S. Pittayachawan (2009) "IT and Eco-Sustainability: Developing and Validating a Green IT Readiness Model", *ICIS 2009 Proceedings,* Paper 141, http://aisel.aisnet.org/icis2009/141 (current April 16, 2010).

Mosher, B. (2008) "Get In on the Gartner Hype: Emerging Technologies 2008", http://www.cmswire.com/cms/enterprise-20/get-in-on-the-gartner-hype-emerging-technologies-2008-002998.php (current March 25, 2010).

Murugesan, S. (2008) "Harnessing Green IT: Principles and Practices", *IT Pro* (Jan/Feb.), pp. 24–33.

Oliner, S.D. and D.E. Sichel (2000) "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?" *Journal of Economic Perspectives* (14)4, pp. 3–22.

Partyka, J. and R. Hall (2010) "On the Road to Connectivity", *OR/MS Today* 37(1), pp. 42–49.

Sayeed, L. and S. Gill (2009) "Implementation of Green IT: Implications for a Dynamic Resource", *AMCIS 2009 Proceedings,* Paper 381, http://aisel.aisnet.org/amcis2009/381 (current March 25, 2010).

Sbihi, A. and R. Eglese (2010) "Combinatorial Optimization and Green Logistics", *Annals of Operations Research* (175)1, pp. 159–175.

Shih, E., K.L. Kraemer, J. Dedrick (2008) "IT Diffusion in Developing Countries: Policy Issues and Recommendations", *Communications of the ACM* (51)2, pp. 43–48.

Watson, R.T., et al. (2008) "Green IS: Building Sustainable Business Practices", *Information Systems,* Athens, GA: Global Text Project.

Will, G.F. (2009) "Everyone Out of the Water", *Newsweek* (November 7), http://www.newsweek.com/id/221608 (current April 16, 2010).

ABOUT THE AUTHOR

Jason Dedrick is Associate Professor at the Syracuse University School of Information Studies and is co-director of the Personal Computing Industry Center. His research is focused on the globalization of information technology production and use, on the creation and capture of value in global value chains, and on the organizational and economic impacts of information technology. Currently he is studying the globalization of innovation and knowledge work and its implications for firms, countries, and workers. He also is developing a new research program in green information systems. He is co-author of *Asia's Computer Challenge: Threat or Opportunity for the United States and the World?* (Oxford University Press, 1998) and co-editor of *Global E-Commerce: Impacts of National Environment and Policy* (Cambridge University Press, 2006). His research has appeared in leading journals such as *Management Science, Information Systems Research, the Journal of Management Information Systems, Communications of the ACM, California Management Review,* and *IEEE Computer.*

Communications of the Association for Information Systems

ISSN: 1529-3181