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Industrial Ecology as a Source of Competitive Advantage
Andrew J. Hoffman, Charles Corbett, Nitin Joglekar, and Peter Wells

[pull-quote: “We see this special feature as a call to arms; the first spark in igniting work at the interface of business management and IE. Its contribution may lie, not just in the specific set of papers in this special feature, but also in starting a discussion about the root cause of this as yet underdeveloped field, and hopefully sparking the interest of scholars to fill the void.”]

The goal of this special feature is to explore Industrial Ecology (IE) concepts and tools as the basis for competitive advantage for business. Past studies of the relationship between business and IE exist (e.g., Lifset and Boons 2011, Esty and Porter 1998, Reinhardt 1999, Hoffman 2003) but there is little sustained attention to this important issue. Without an understanding of the ways in which IE can be the basis for profitable business endeavors, the concept risks either remaining largely a technical exercise or being limited in its application to the public sector. But an appreciation for the strategic and economic motivations for companies to adopt IE principles, and the associated tools and models, can further the environmental benefits that this systems approach can provide. The competitive advantage obtained through IE could accrue through several alternative mechanisms, ranging from cost savings or enhanced profits to improved brand positioning, product differentiation, gains in market share, organizational know-how, ability to attract and retain talent, or gaining an advantageous position in an industry’s evolving structure. Hart (1995) provides an early discussion of various ways in which a firm’s approach to environmental matters in general can contribute to competitive advantage, and a substantial literature has evolved since then. The more focused question of how IE specifically can contribute to competitive advantage has yet to be addressed, hence this special feature. We are pleased with the final set of papers that resulted, but we were surprised with the low number of submissions. Below, we first summarize the contents of this special feature, and then provide our thoughts on why the number of submissions was lower than expected. We conclude with the directions we see for this emerging and important research domain.

<heading level 1> Contents of This Special Feature

In this feature, we offer five papers and three firm profiles that draw upon several world class brands – including PepsiCo, Dow Chemical, and Interface Carpet – and highlight issues such as skepticism documented among green consumers, changing business model and industry structure, and the typology of strategic benefits that both recognizes path dependence in capabilities and leverages the blind spots when the competition lacks a clear awareness of risks and benefits.

For example, three of our papers deal directly with the economic benefits of IE. In “A financial and environmental analysis of constructed wetlands for industrial wastewater treatment,”

Johnathan DiMuro, France Guertin, Rich Helling, Jessica Perkins and Scanlon Romer investigate the use of replacement cost methodology (RCM) for financial analysis and life cycle assessment (LCA) of constructing a wetland for water treatment at the Union Carbide Corporation (a subsidiary of The Dow Chemical Co.) plant in Seadrift, Texas, instead of installing a sequencing batch reactor (DiMuro et al. 2014). Their results quantify a total net present value savings for implementing the constructed wetland as US\$282 million over the project's lifetime. Further, they found that LCA demonstrates that the lower energy and material inputs to the constructed wetland resulted in lower potential impacts for fossil fuel use, acidification, smog formation, and ozone depletion and likely lead to lower potential impacts for global warming and marine eutrophication. In "Combining life cycle assessment with data science to inform portfolio-level value chain engineering," Christoph Meinrenken, Beth Sauerhaft, Anthony Garvan, and Klaus Lackner present a pilot system of key performance indicators (KPIs) that evaluates 3337 products across 211 brands and 5 countries of PepsiCo, Inc. (Meinrenken et al. 2014) In particular, the study analyzes PepsiCo's consideration of substituting one ingredient currently used in 7 brands with an alternative ingredient. Meinrenken and colleagues' portfolio-level analysis revealed that the substitution would lead to an 8% increase in greenhouse gas emissions and a 7-10% increase in procurement costs. Instead, their alternative approach saved PepsiCo an estimated ~200 years full time equivalent employee time (or alternatively ~USD 30 million in LCA consultant fees) relative to conducting an item-by-item LCA. And in "Benefits organizations pursue when seeking competitive advantage by improving environmental performance," Mark Finster and Michael Hernke develop a typology of strategic benefits related to competitive advantage that are enabled by IE concepts and methods, drawing on examples from Grohe, Interface, Maersk, Nestlé, Procter & Gamble, Unilever, and others (Finster and Hernke 2014).

The fourth paper explores the evolution of business models for applying IE principles. In "From refining sugar to growing tomatoes," Samuel Short, Nancy Bocken, Claire Barlow, and Marian Chertow explore the relationship between IE and business model innovation through the case study of British Sugar, the UK's largest sugar producer (Short et al. 2014). Based on a series of interviews, this research explores the temporal dimension of dynamic business model innovation, framing it in the context of a continuous evolutionary process rather than a discrete design activity, and illustrating how British Sugar used internal industrial symbiosis to do so.

Finally, the fifth paper focuses on consumers of products that employ IE principles. In "Exploring green consumers' mind-set towards green product design and life cycle assessment," Fred Lemke and João Pedro Pereira Luzio interview Brazilian and Portuguese green consumers to explore how they perceive relevant product design and LCA dimensions of IE (Lemke and Luzio 2014). Their conclusions reveal important gaps between what green consumers want and what businesses in Brazil and Portugal currently supply, and highlight the importance of establishing credibility through information transparency to bridge this gap.

These five papers are accompanied by three firm profiles that explore the application of industrial principles in practice. In "Shrinking footprint: A result of design influenced by life cycle assessment," Connie Hensler tracks the 20 year evolution of Interface's use of LCA as one

of the tools guiding the company towards more sustainable practices in carpet manufacturing (Hensler 2014). Her case study illustrates how a shrinking environmental footprint created by the use of carpet tiles, instead of broadloom carpets, has changed one aspect of competition in the carpet industry and created a new industry structure, with firms that leverage carpet tile technology steadily increasing their market share. In “Integration of industrial ecology approaches into business practices,” Mona ManYu Yang, Yilin Wei, and Li-Wei Lin present a case study of how AU Optronics Corp., a global leader in thin-film-transistor liquid-crystal display (TFT LCD), differentiated itself from its peers and competitors by implementing IE approaches, most notably carbon footprint management and de-materialization, both of which aim to increase resource efficiency and competitiveness (Yang et al. 2014). And finally, in “Securing a competitive advantage through industrial symbiosis development,” Joo Young Park and Hung-Suck Park present a case study of a two-phase industrial symbiosis development project involving a municipal waste-to-energy incinerator and Hyosung chemical company in Ulsan, South Korea (Park and Park). The case analyzes the direct economic and environmental benefits of the project as well as an assessment of how industrial symbiosis development led to competitive advantages for the Ulsan City and Hyosung chemical company.

<heading level 1> A Forward Looking View of Business and Industrial Ecology Research

While we are pleased with the final papers that make up this special feature, we are surprised and disappointed at the number and type of submissions we received despite having publicized this call widely in both IE and business management networks. Many of the submissions that we did receive and rejected offered little or no analysis of competitive benefits to the firm. We see five possible explanations for this type of response. First, it could be due to a lack of attention to business issues in the IE field in general. Second, it could be due to a lack of attention to IE issues in the business management field in general. Third, it could be a perception by management scholars that the *Journal of Industrial Ecology* speaks mostly to engineers. As Ehrenfeld (2007:74) argues, IE is subject to a debate between practitioners in academia “...as to whether industrial ecology is a positive (i.e., descriptive) scientific endeavor or is a quest for solutions to a set of societal problems that demand attention as something that must or should be done.” Is it simply a scientific endeavor that entails the dispassionate and disinterested measurement of variables? Certainly the perspective offered by Ehrenfeld would seem to suggest that the concept of competition within market societies was and is a part of the ‘modernist’ perspective and is, at a philosophical level, at variance with the sustainability paradigm to which the metaphor of IE appears to speak. Fourth, some businesses are not ready to disclose competitive data in the IE realm. We experienced this first-hand when an article was withdrawn, after having been submitted, revised and accepted, because the firm which the authors were reporting about changed its mind about allowing data disclosure. But this also highlights the contribution of the paper by DiMuro and colleagues that provides competitive data on both financial and environmental outcomes. Fifth, it could be a perception (and reality) reflected in the relatively low status accorded by business and management schools to journals in the realms of environment and sustainability. The fact is that business schools have very specific requirements regarding which journals count toward promotion and tenure. Regardless of these challenges, our goal in this special feature was, at its core, an attempt to bridge two

research domains and it could simply be that those bridges are further from completion than we thought. For that reason, we hope that this special feature may serve as a catalyst to help this type of cross-disciplinary work develop.

We see a number of questions that future work on IE and competitive advantage will have to come to terms with:

- When seeking to link IE/LCA to competitive advantage, what is the appropriate unit of analysis: the product, the business unit, the firm, its value chain, the system, or some other unit?
- Terms and concepts as “industrial ecology” and “competitive advantage” may not be as clearly defined as they need to be in order to be able to measure their presence. Each will have to be defined for the “other” community. We define competitive advantage broadly. It could be accrued and sustained based on several alternative types of organizational aspirations, as mentioned earlier, ranging from either cost savings or enhanced profits to brand positioning, product differentiation, gains in market share, know-how, talent or advantageous position in an industry’s evolving structure.
- We need to recognize that, in linking IE and competitive advantage, we should progress one step at a time, and not expect to provide a definitive conclusive answer in one fell swoop.
- In any assessment of the link between IE and competitive advantage, a key challenge will be dealing with the fact that both variables are endogenous: firms that are well-managed may be more likely to adopt IE tools and more likely to obtain competitive advantage, which could lead researchers to find correlations between IE and competitive advantage that do not have a causal basis.
- As research in this area matures, the measures and metrics of various dimensions of economic, environmental (and social) performance will need to be better defined, including coming to terms with the multidimensional nature of these concepts.
- The effects of IE on competitive advantage hinge in part on how individuals and consumers respond to changes made as a result of IE, which necessitates inclusion of a behavioral perspective.
- Clearly public policy has a role to play in fostering adoption of IE in a way that can help firms gain competitive advantage.
- There is already a rapidly growing literature on many aspects of how sustainability connects with competitive advantage, upon which studies focusing on IE and competitive advantage should draw.
- Many of the questions just listed are not unique to IE, so exploring how research on other phenomena has dealt with these can prevent a lot of unnecessary work.

Below, we discuss each of these issues in some more depth. Our aim is to cover both (a) unique challenges to IE scholarship based on a competitiveness driven research agenda and (b) a discussion of challenges to firms adopting IE. Indeed, we see the linkages between IE scholarship and real world application to be so close as to allow direct application of IE models and concepts to business practice.

<heading level 2> Unit of analysis. The tools and concepts of IE operate at different levels of analysis. Industrial symbiosis concerns the plant level, while LCA is typically a product-level endeavor. Competitive advantage, in contrast, is a firm-level issue. As a result, how can we link for instance product-level applications of LCA to firm-level competitive advantage? If we broaden the possibility of accruing the advantage through firm-wide use of IE, we find ourselves returning to the question “does sustainability pay,” on which enough has been written (e.g., King and Lenox 2001). What would it mean to apply IE at the firm level? Does that mean that the firm-level carbon footprint, and other environmental impact metrics, have been measured? For a good example, using input-output analysis and structural decomposition analysis, see the article by Wiedmann and colleagues (2009). Does it mean that “enough” product-level LCAs have been done? Does it mean that key decisions are informed by IE? To answer these kinds of questions, we see an opportunity for scholarly research, as well as an opportunity in practice for a firm to employ IE approaches selectively -- and thus bypass difficult endeavors like firm-level carbon footprinting -- and still be thought to have a firm-level strategy about the use of IE. For example, the paper by Short and colleagues (this issue) illustrates a bridge between the product level and the firm level analysis which reveals a process or journey from single-product to portfolio in which IE (and specifically industrial symbiosis) allows some evaluation of the environmental and resource benefits of this diversification in parallel with the strategic and competitive benefits to the business. Similarly, the paper by Meinrenken and colleagues (this issue) illustrates how a portfolio-level approach to LCA can be both practical and informative.

<heading level 2> Definitions and concepts. In bridging research domains, there is always the challenge of normalizing concepts and terms. For example, for business scholars, we need a consistent definition of IE: does it include not only industrial symbiosis, LCA, material flow analysis, but also design for environment, environmental labeling and partial equilibrium analysis, etc.? Similarly, we need to define competitive advantage for the IE scholars. The business imperative must include any of a number of business considerations, including: detailed financial metrics; specific models for organizational choices that allow for the integration of the IE practices into business processes; detailed quantitative analysis of how IE improved profitability through operational efficiency, market share increases, marketing and PR benefits, improved supply chain logistics, lower cost of capital, improved organizational performance, reduced government regulatory costs, lower feedstock or waste removal costs, and so on. These analyses should include both ways to motivate implementation of IE in business communities, and the actual implementation mechanics. For example, for both research and practice, IE will require new forms of cooperation and partnerships, new forms of contractual relationships, and perhaps new forms of government incentives and regulations. These steps must be balanced against the existing models, norms and rules that are based on competition and market protection, and, of course, the dangers of green-washing through IE rhetoric.

<heading level 2> Methodological foundations. At this point of the IE/business management interface, we call for some of the more "rudimentary" work to be done so that there is an

empirical foundation for the more sophisticated work in the future. Such foundational work includes determining the extent to which firms have adopted different aspects of IE, why they have done so, what results they report from doing so, what forms of competitive advantage those firms tend to have (if any), and related issues. Then we can begin to spell out a more robust research agenda, pointing to the exact questions, links, data, endogeneity issues, and so on, that would have to be addressed in order to find out whether and when there truly is a causal link between use of IE and competitive advantage. But as a start, we need to articulate and quantify the potential business benefits of IE approaches. Again, this has implications for both scholarship and practice.

<heading level 2> Endogeneity. Firms that adopt IE are presumably more sustainable in other ways too, and perhaps just better managed in every respect. So, if we observe improved competitive performance, can we truly attribute that to the use of IE or would that firm have gained competitive advantage no matter what, given that it's a well-managed enterprise? An ideal test-case would be a firm that is very "green" in many ways, but for some reason doesn't do IE, and then compare whether they gain more or less competitive advantage than another less green that did use IE.

<heading level 2> Measures and metrics. Not only do the focal firms in our submissions build their view of competitiveness on a single dimensional set of measures (e.g. cost saving from carbon dioxide equivalents avoided), but some of the policy-making bodies such as the US Advanced Research Project Agency-E (ARPA-E) also tend to promote 2X to 10X gain in performance along a single performance dimension in sectors ranging from building technologies to carbon sequestration (Erzurumlu et al. 2014). Such focus can bring competitive benefits using IE in terms of rapid buildup of capabilities, but it may also create a competitive vacuum (in terms of bundling features or making counter-cyclical choices) and take away from a "systemic" view of the underlying competitive opportunity. This creates an interesting paradox for both scholarship and practice. One of IE's characteristics is that it addresses a multiplicity of environmental endpoints (Ehrenfeld and Gertler, 1997). For instance, an LCA may address greenhouse gases, air and water pollution, resource use, human and ecosystem toxicity, ozone depletion, and so on, but many business endeavors of interest are uni-dimensional and measurement has a bias towards tangible metrics. While some of the papers in this special feature and elsewhere describe intangible benefits, they seemed to rely (or put larger weight) on tangible measures. This view might create organizational (and product/service innovation) bias towards competing on economic rather than behavior-driven opportunities. In a different vein, an integration of strategies around markets for ecosystem services with IE would bring a different sort of intangible into play. But the business benefits of some IE strategies are likely to fall in the realm of reputation benefits or minimization of regulatory pressure (i.e., things that are intangible and harder to quantify).

<heading level 2> Behavioral dimensions. One of the critical components of business model development is human behavior and the ways to change it through rewards, selection, socialization, and training. There is already work on behavioral dimensions of IE, primarily in terms of sustainable consumption (e.g., Hubacek et al. 2014). Its concrete manifestation is in

endeavors like collaborative consumption. Ironically, the weakness of this work in IE terms is precisely the failure to link it to actual environmental outcomes (as also noted in Lifset 2008). Recent research on corporate social responsibility (CSR) practices has moved into the realm of frontline employees identifying with the organization (i.e., organizational identification) and with customers (i.e., employee–customer identification) as a function of how much the employees perceive management and customers (respectively) to support the company's CSR activities (Korschun et al. 2014). However, these respective effects are stronger among employees for whom CSR is already tied to their sense of self (i.e., CSR importance to the employee). Arguably, such behavioral issues may also affect the way employees can leverage competitive IE practices.

<heading level 2> Public policy. Competitive alternatives in shaping and implementing public policy and standards are critical to fostering the kinds of information flow and collaborative partnering necessary to implement IE principles. This is an area where the field of public policy can have a strong role. For instance, the implementation of extended producer responsibility legislation has been examined (Gui et al. 2013). There also has been a recognition that such analysis ought to incorporate the perspectives of multiple stakeholders (Atasu et al. 2013). How can we understand industry association, network effects or free-riding in terms of public policy, standards (e.g. ISO14000), and competitive IE actions?

<heading level 2> Related research domains. While we explore multiple facets of the business/IE interface, there is a great deal of related literature that can be brought to bear. For example, as we study consumer perception of IE and LCA, there is more sophistication in the competitive market place about green-washing. For instance, it can be viewed in terms analogous to the “market for lemons,” where buyers are not able to distinguish between low and high product quality owing to the information asymmetry which occurs when a seller knows more about a product than the buyer. Buyers then resort to alternative mechanisms such as third party certification to separate the lemons (i.e. bad products that are mislabeled) from the good ones. Analysis of consumers in the hospitality sector supports a separation hypothesis (Zhang et al. 2014) where consumers provide a price premium to the hospitality sites who signal high quality based on eco-friendly practices over those who do not provide a certification and may be green-washing. Similarly, IE adoption can be placed within the context of innovation and learning, domains in which there is a vibrant body of research. Additionally, there is growing literature on business startup and growth in the entrepreneurship field (Hall et al. 2010), but our call for papers did not generate any work on startups, pivoting and growth issues, and the IE/competitive advantage interface.

<heading level 2> Related business models. Are there other tools that are comparable in scope and complexity to IE/LCA, that have (or have not) been linked to competitive advantage? For example, which of the following tools/frameworks/concepts would be reasonable analogies to IE/LCA: ISO 9000, ISO 14000, Six Sigma, Total Quality Management, Hazard Analysis & Critical Control Points, Computer Aided Design and Manufacturing and Failure Mode Effects Analysis? Are the rapid developments in sustainability reporting (e.g. Global Reporting Initiative (GRI), Carbon Disclosure Project (CDP), Sustainability Accounting Standards Board (SASB), integrated

reporting, etc.) going to change the way we think about IE/LCA and competitive advantage? Will IE/LCA be more widely used as GRI/SASB gain influence, or not? The development of Environmental Product Declarations (EPD) and Product Category Rules (PCR) are hugely important here because they have the potential to make some form of eco-labels more viable. While there is a community of practitioners active in this domain, this development is occurring largely under the radar screen. And finally, another potential area of interest might be in the area of corporate ecosystem services, an approach which has the merit of presenting a risk analysis framework that to some extent translates IE into the corporate domain.

<heading level 1> Conclusion

We see this special feature as a call to arms; the first spark in igniting work at the interface of business management and IE. Its contribution may lie, not just in the specific set of papers in this special feature, but also in starting a discussion about the root cause of this as yet underdeveloped field, and hopefully sparking the interest of scholars to fill the void. Further, we see tremendous opportunity for improvement in corporate environmental practice, applying IE principles to improve competitive advantage and environmental protection in the field. To properly address the intersections necessary to bring these changes to fruition, we need to see more collaboration among engineering, environmental, and management scholars. Industrial Ecology can provide that collaborative locale.

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