The paradox of sustainable innovation: The ‘Eroom’ effect (Moore’s law backwards)

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Article history:
Received 4 November 2016
Received in revised form 17 July 2017
Accepted 20 July 2017
Available online xxx

Abstract
Innovation has been widely acknowledged as a key mechanism for addressing sustainable development concerns. However, less attention has focused on downstream commercialization challenges such as achieving increasingly complex and stringent regulatory approval. Such challenges may hinder the development of more sustainable technologies, especially those coming from smaller or publicly funded institutes. As well, they may obstruct the development of applications that could provide societal benefits, but may only have limited commercial viability due to small market niches or applicability to customers with limited financial means. We explore this apparent paradox using the concept of the Eroom effect (Moore’s Law backwards), i.e. where improved price performance due to technological advances are outweighed by increasing costs of regulatory approval and other commercialization costs. We illustrate this phenomenon with two cases of publicly funded institutes, one developing transgenic cotton, and the other lignin transformation technology that can replace petroleum-based feedstocks in a number of industrial applications. We discuss the unintended consequences of the Eroom effect and conclude with implications for industry, policy and NGOs.

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1. Introduction
Innovation has been widely acknowledged as a key mechanism for addressing sustainable development concerns (Boons et al., 2013; Hall and Clark, 2003; Hall and Vredenburg, 2003; Hart and Milstein, 1999; Huisingsh et al., 2013; Matos and Silvestre, 2013; Silvestre, 2015a). Modern scientific advances, as well as our capabilities in technology management, provide enormous opportunities for improving the sustainability of products and services. For example, improved cost and performance have been recognized as facilitating the widespread diffusion of information technology, resulting in the information age. In 1965 Gordon Moore, a founder of Intel and Fairchild Semiconductor, noted: “With unit cost falling as the number of components per circuit rises, by 1975 economics may dictate squeezing as many as 65,000 components on a single silicon chip … The advantages of integration will bring about a proliferation of electronics, pushing this science into many new areas.” (Present, 2000, p 82). This improved price-performance phenomenon has since been called Moore’s Law, and in gene sequencing a similar phenomenon has been called Carlson’s Curve (Economist, 2006). It could thus be argued that the competencies and lab costs of developing many technologies should be decreasing with time, given that we have greater knowledge with which to build on, and a greater pool of trained scientists and engineers (Hall, 2016). Mobilizing such capabilities towards sustainability concerns can thus be a major driver of improved social and environmental impacts.

According to Montalvo and Koops (2011), there are a wide range of market and policy factors that drive more sustainable innovations, which in turn are shaped by for example ethical, environmental, health & safety and cost factors. By more sustainable, we mean innovations that have better environmental and social performance characteristics over incumbent products or services. Such innovations are typically developed through R&D labs in corporations, universities and government institutes (Hall et al., 2014a; Wagner et al., 2014). However, while the role of such market and policy factors have been well recognized within the literature, less attention has focused on some of the key challenges of
moving promising eco-innovations ‘off the shelf’ (Hall et al., 2014b), and specifically the barriers of meeting highly complex and increasingly stringent regulatory approval processes. For example, public concerns over emerging technologies, such as transgenic technology in agriculture, heightened by for example non-governmental organizations (NGO) and other public pressures, have resulted in major costs induced by regulation that now often outweigh the actual scientific lab costs. As a result, only a few large multinational corporations have adequate resources to bring new transgenic crop varieties to the market, and even then they are unlikely to be viable unless only one is competing in the segment. Furthermore, in addition to monopolistic tendencies, high regulatory barriers may also make it difficult for smaller organizations and public sector institutes to compete. These latter organizations often have a mandate to develop technologies that provide societal benefits, but may otherwise have limited commercial viability, due to small market niches or applicability to customers with limited financial means (Manjunatha et al., 2015).

In this paper we explore this apparent paradox, i.e. improved price-performance characteristics analogous to Moore’s Law, versus the actual costs of regulatory approval and other commercialization costs, and how this may hinder sustainable innovation. Drawing on data from the pharmaceutical industry, Scanell et al. (2012, p 191) have framed this paradox as “Eroom’s Effect”, i.e. Moore’s Law spelled backwards, noting that “R&D efficiency, measured simply in terms of the number of new drugs brought to market by the global biotechnology and pharmaceutical industries per billion US dollars of R&D spending, has declined fairly steadily.” Among other issues specific to the pharmaceutical industry, they note that regulators have become increasingly cautious, gradually reducing their risk tolerances to avoid safety disasters such as the drug Thalidomide, the anti-morning sickness treatment for pregnant women that resulted in birth defects. They further note that some corporations have increased their R&D resources to gain first mover advantage and create high barriers to entry.

We specifically explore the implications of the Eroom effect on public institutions such as university and government labs attempting to develop more sustainable technologies. To do so we investigate two cases. The first is a Brazilian public research institute, the Brazilian Agricultural Research Corporation (EMBRAPA) attempting to develop transgenic cotton to deal with a devastating pest infestation that avoids pesticide use. The developers believe the technology is thus likely to be more sustainable because it uses less inputs such as insecticides and herbicides, and the fuel consumption is substantially reduced because less spraying operations are needed. Although technologically feasible, the institute recognizes that gaining regulatory approval for this product may be beyond their resources or may take too long for reasonable impact. As a result there are concerns about commercial viability, and whether the potential societal benefits will be undermined by regulatory barriers, which in turn have been shaped by anti-GMO activism.

The second case draws on a Canadian university’s attempts to develop renewable lignin-based products based on new biodegradation technology that can be used to replace non-renewable petroleum feed stocks in various industrial settings, such as food flavoring (e.g. vanilla), and carbon fibers that can be used for automotive, electronics, energy and defense applications. For food additives, a key attribute is whether the technology can be framed as a natural ingredient, otherwise it cannot compete against the synthetic, low-cost guaiacol-based vanilla. Carbon fiber applications are highly dependent on the industry application, where for example regulatory approval in defense and aerospace applications are substantially higher than for example in consumer electronics.

We contribute by providing a greater understanding of the challenges associated with technology development that improves ecological and societal sustainability, specifically regarding the downstream costs that are often overlooked by those developing the technology. We argue that technological innovations are increasingly being hindered by complex and often prohibitive downstream costs such as regulatory approvals, labelling and trade policies. We discuss the unintended consequences of the Eroom effect and how social and environmental benefits can be used to overcome some of these challenges. More specifically, we propose that advocacy groups, which have played an important role in increasing regulatory standards, could differentiate their opposition to new technologies, for example by providing support for institutions developing technologies primarily for environmental and societal benefit. We also provide recommendations for how regulations can be reformed to avoid discouraging sustainable technology development.

In the next section we discuss the literature on innovation as a panacea for sustainable development, and how Moore’s Law and related concepts have been used to illustrate major advancements in technology and the proliferation of new industrial structures. We then discuss how relatively new non-technological Eroom hurdles, such as increased regulatory constraints and heightened concerns from NGOs and civil society, have in some cases negated the promise of improved price-performance.

2. The innovation and entrepreneurship panacea for sustainable development

Seminal studies, particularly those published in practitioner business journals, have identified innovation, the introduction of new products, services, means of transportation, sources of raw materials or new organizational structures (Schumpeter, 1942), as a panacea for sustainable development concerns. For example, the much cited (Porter and Van der Linde, 1995, p 120) paper argues that companies “… are constantly finding innovative solutions to pressures of all sorts—from competitors, customers, and regulators. Properly designed environmental standards can trigger innovations that lower the total cost of a product or improve its value. Such innovations allow companies to use a range of inputs more productively—from raw materials to energy to labor—thus offsetting the costs of improving environmental impact and ending the stalemate.”

Whereas Porter and Van der Linde focus primarily on environmental impacts in modern industrial settings, Hart and Milstein (1999) broaden the panacea perspective by emphasizing that environmental issues are closely connected, and thus correlated to, economic and societal concerns, and that a global perspective is needed. Drawing on Schumpeter, they argue that sustainability concerns are creating a new round of creative destruction, where incumbent non-sustainable technologies will be obsolete, providing “unprecedented opportunities” for businesses developing new sustainable technologies and business models, and by exploiting untapped developing and emerging markets (London and Hart, 2004). New entrants often drive creative destruction at the expense of incumbent firms.

The allure of innovation has been encapsulated in the above discussed Moore’s Law and Carlson’s Curve, which essentially illustrates how new technologies can drive down prices and increase performance. This appears to have happened in for example much of the electronics industry (Eizenberg, 2014). According to Fichman et al. (2014, p 333), “The main implication of Moore’s Law is to rapidly increase the range of what is technically and economically feasible to accomplish with IT. It explains why IT has become the dominant enabling force for both product and process innovations today. In fact, Moore’s Law can be seen as a fundamental enabler of many instances of disruptive innovation (Christensen, 1997) and creative destruction.
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