



Technology-based design and sustainable economic growth

Jianxi Luo^{a,*}, Alison L. Olechowski^b, Christopher L. Magee^c

^a Department of Technology Management, Polytechnic Institute of New York University, Brooklyn, NY 11201, USA

^b Department of Mechanical Engineering, Massachusetts Institute of Technology Cambridge, MA, USA

^c Engineering Systems Division, Massachusetts Institute of Technology Cambridge, MA, USA

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ABSTRACT

This paper seeks to analyze how design creates economic value. The literature on knowledge-based economic development has primarily focused on innovation as the analytical lens, whereas design is the original action that leads to innovation. Despite the fundamental importance of design, existing design research has offered few insights and little guidance for national strategies due to the lack of focus on and analysis of design in an economic context. This paper addresses such gaps by linking design research and economic development theory. We first elaborate on the relationship among design, invention and innovation, describing the necessity of design activity for invention and innovation. Our analysis of the fundamental characteristics of design across contexts sheds light on the strategic importance of the accumulative nature of *technology-based design* for sustaining economic growth. Through the lens of technology-based design, we further quantitatively compare Singapore and three similarly-sized countries (South Korea, Finland and Taiwan). Based upon interview data, we also qualitatively examine Singapore's national strategy focusing on design. The quantitative and qualitative results align well with the Singaporean government's use of design as a strategic lever to pursue innovation-driven economic growth, and also reveal its achievements and shortfalls which indicate possible directions for strategic adjustment.

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1. Innovation, invention, and design

Innovation is the critical driver of economic growth (Schumpeter, 1934; Solow, 1956), especially in advanced economies which have approached the frontier of knowledge and thus face limited opportunities to adapt exogenous technologies for production (Porter, 1990). Because of its clear importance, there have been numerous studies of how regions and nations can foster innovation through managing such factors as R&D manpower and spending (Mowery and Rosenberg, 1998; Griliches, 1998), industrial environment and competitive dynamics (Rosenberg, 1963; Porter, 1990), government policy and institutional environment (Lundvall, 1992; Nelson, 1993; Freeman, 1995), etc. In particular, the growing body of research on design has added greatly to our knowledge of the innovation process (Baldwin and Clark, 2000; Dym et al., 2005; Weisberg, 2006).

However, despite their relevance and importance, the findings and theories from design research have been overlooked in innovation policy and economic development studies (Hobday et al., 2012). This paper supplements the preceding economic

development studies on innovation alone by addressing design as the specific activity which results in innovation. In doing so, we build upon prior work which treats design as the process through which innovations emerge (Aubert, 1985; Walsh, 1996), and focus on technology-based design for its specific advantage over other types of design in sustaining economic growth. To our best knowledge, we are the first to link design research and economic development theory. In so doing, the work leads to new insights for national strategies for an innovation-driven economy.

Innovation, as defined by Schumpeter (1934), is "new combinations", and also – in the language of economics – "the setting up of a new production function." Schumpeter's concept of innovation includes technical, marketing and organizational activities. According to Solow (1957), technology-based innovation accounts for more than 80% of long term economic growth and has been the emphasis of most studies on "innovation". Technology innovation refers to the introduction of a new product, improvement in quality, and a new method of production, etc. (Hagedoorn, 1996). Innovation comes after invention and is invention that has successfully diffused in use, achieving real economic and social impact.

Both invention and innovation emerge through a design process. Design is defined herein as a *human process that uses knowledge to produce novel objects that are appreciated by or are useful to other humans*. Inventions are creatively designed by humans with new mechanisms and/or new functions. The most

* Corresponding author.

E-mail addresses: jluo@nyu.edu (J. Luo), alisono@mit.edu (A.L. Olechowski), cmagee@mit.edu (C.L. Magee).

recognizable inventions historically, such as the steam turbine, the electric generator, the light bulb, the car and the computer, were all “designed” and are thus “design output”. However, not all design efforts will necessarily result in invention, as some efforts result in less novelty than judged necessary for the label of invention. In a similar sense, not all inventions (despite their useful novelty) have sufficient benefits or are communicated in a way to result in adequate efforts to achieve diffusion and thus become an innovation. The relationship between innovation, invention and design output is shown in Fig. 1. Design activities create the possibilities for invention and innovation, but do not guarantee them. The design output may be inventions or not, and in turn inventions may become innovations or not.

However, innovation scholars on occasion overlook the design process, largely because the design process is difficult-to-anticipate and even difficult to recognize objectively. In contrast, the term “design” is used more often than “innovation” and “invention” by technologically-based practitioners, simply because design is the specific action which humans pursuing innovation actually perform. Thus, when one thinks about enhancing innovation, promoting design activities is more actionable than the narrative focus of innovation. In turn, design capability enables continual delivery of new products, services, and solutions, so is important as a strategic asset for a firm, region or nation to build up in order to compete in a knowledge-based global economy. Mastering it will give firms or regions sustainable competitive advantage (more detailed explanations are in Section 2.3). Therefore, focusing on promoting design activities and building up national design capability as explicit national strategies allows one to be more specific about what can be done for innovation.

When considering “design”, many studies combine various kinds of design in questionable ways; for example combining engineering design with industrial or aesthetic design (Candi and Saemundsson, 2008) and sometimes combining what “CAD (Computer Aided Design) technicians” do with engineering design (Walsh, 1996). This ambiguity has limited the potential for effective actions to be taken. Following a survey and synthesis of the broader design research literature in Section 2, we link design to an economic context as is necessary for innovation, and doing so allows “technology-based design” to appear fundamentally most valuable for driving and sustaining economic growth. We use “technology-based design” instead of an equivalent term “engineering design” (Dym et al., 2005) in order to explicitly emphasize the intensive use of scientific and technological knowledge and techniques in such processes.

On that basis, we further use “technology-based design” as the analytical lens to examine national attempts to move towards an innovation-driven economy. We particularly examine Singapore, assisted with a comparison with Taiwan, Korea and Finland. All four of these countries have been heavily involved in moving into

higher value-added activities and thus improving their design capability. The emphasis on Singapore arises because it is the only country, to our best knowledge, whose national strategy has explicitly emphasized the promotion of “design”-related activities for sustaining the nation’s economic growth. We conducted on-site semi-structured interviews at a number of organizations that participate in design-related initiatives in Singapore, in spring 2011, and report the interview results in this paper.

Our analysis at the national level has important similarities to national innovation studies (Lundvall, 1992; Nelson, 1993; Freeman, 1995), which emphasize the active roles played by specific institutions (companies, universities, government agencies, intermediary organizations, etc.) and government policies, and their interaction in nurturing innovations in specific countries (see Dosi, 1988 and Nelson, 1993 for comprehensive reviews of the perspectives in the national innovation system literature). In this paper, we also examine the incentives and behaviors of different kinds of institutions and their interactions in a national system. In addition to that, we believe that emphasizing knowledge development in technology-based design in the examination supplements what national innovation system studies have been able to conclude.

The paper is organized as follows. Section 2 reviews design research broadly and then design in an economic context which narrows the emphasis to technology-based design. Section 3 discusses potential metrics to assess national design capability. Section 4 uses such metrics to compare Singapore and three other countries quantitatively, and Section 5 further examines Singapore’s national design strategy using interview data. The final section concludes and discusses directions for future research.

2. Fundamentals of design: Survey and synthesis

In much academic literature and common language, design is diversely defined. This can hinder the effective use of “design” as a lens to develop strategies and action plans for economic growth. There is a body of knowledge that is commonly referred to as “Design Research” or “Design Theory” (a branch of which can be labeled “*engineering design research*”) where some care in definitions has evolved (Simon, 1996; Dym, 1994; Walsh, 1996; Baldwin and Clark, 2006; Purao et al., 2008; Hatchuel and Weil, 2009; Hobday et al., 2012) and where extensive research has been done. This section attempts to review this literature in order to identify the strategic focus for design-based strategy for actions and policies relative to moving to the knowledge or innovation economy.

2.1. Design process

In the existing literature, the term “design” has been used as either a verb (i.e., activity/process) or noun. When used as a noun, the term “design” often means the output of a design process. Baldwin and Clark (2006) defined design as “the instructions based on knowledge that turn resources into things that people use and value”. Treating design as a noun has led to important understandings on product architecture (Eppinger and Ulrich, 1995; Baldwin and Clark, 2000), organizational structure (Ulrich, 1995; Sosa et al., 2004), industry structure (Abernathy and Utterback, 1978; Suárez and Utterback, 1995; Tushman and Murmann, 1998; Baldwin and Clark, 2000), and the functional performances of technologies as output of design (Moore, 2006; Martino, 1970; Nordhaus, 2007; Koh and Magee, 2006, 2008). While useful, such studies are naturally limited in explaining how

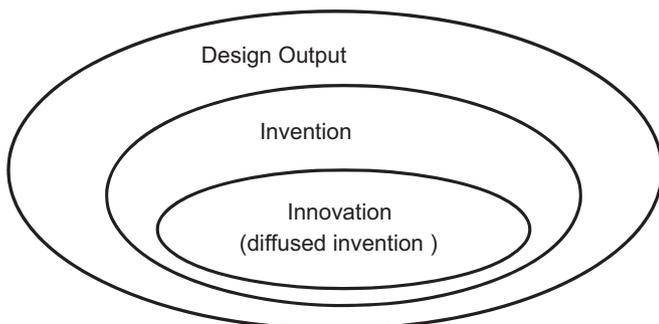


Fig. 1. Relationship between design output, invention, and innovation.

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