Standardization in Technology-Based Markets

Gregory Tassey

Senior Economist
National Institute of Standards and Technology
(gtassey@nist.gov)

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Gregory Tassey[1]

Senior Economist, National Institute of Standards and Technology

Abstract

The complexity of modern technology, especially its system character, has led to an increase the number and variety of standards that affect a single industry or market. Standards affect the R&D, production, and market penetration stages of economic activity and therefore have a significant collective effect on innovation, productivity, and market structure. Standards are classified into product-element and nonproduct categories because the two types arise from different technologies and require different formulation and implementation strategies. Because standards are a form of technical infrastructure, they have considerable public good content. Research policy must therefore include standardization in analyses of technology-based growth issues.

Keywords: standardization, innovation, R&D, economic growth, industry structure

Through R&D-performing industries and the effect of new technologies on other parts of the economy, technology accounts for one-third to more than one-half of U.S. GDP growth and at least two-thirds of productivity growth. However, the so-called "high-tech" sector only contributes approximately 7 percent of U.S. GDP.[2] This relatively small direct contribution implies substantial leverage by this sector on the overall economy, but also that extensive diffusion of new technology must take place if adequate productivity growth rates are to be achieved by the entire economy.

Standardization affects both innovation and technology diffusion. It also can influence industry structure and thereby help determine which firms benefit and which do not from technological change. Thus, a concern of R&D policy should be the evolutionary path by which a new technology

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[2] Tassey [1997]. The high-tech sector is defined here as consisting of four major categories: high-tech manufacturing (IT-related plus industrial electronics), communication services, software and computer-related services, and pharmaceuticals). For alternative definitions of IT-related high-tech industries, see American Electronics Association [1997, p. 128] and Department of Commerce [1998, Appendix p. A1–2]. The AEA definition results in a 6.1 GDP estimate for 1996 and the Commerce definition yields about 8 percent for 1998. To either of these definitions should be added pharmaceuticals, which brings the AEA-defined high-tech sector's GDP contribution to 7 percent.

or, more accurately, certain elements of a new technology become standardized. Over a technology's life cycle, standardization can affect economic efficiency. However, these effects can be both positive and negative. For example, standardization can increase efficiency within a technology life cycle, but it also can prolong existing life cycles to an excessive degree by inhibiting investment in the technological innovation that creates the next cycle.

Standardization can and does occur without formal promulgation as a "standard." This distinction between *de facto* and promulgated standards will be made apparent and discussed in the following sections. In one sense, standardization is a form rather than a type of infrastructure because it represents a codification of an element of an industry's technology or simply some information relevant to the conduct of economic activity. On the other hand, the selection of one of several available forms of a technology element as "the standard" has potentially important economic effects.

1. Economic Functions of Standards

A standard can be defined generally as a construct that results from reasoned, collective choice and enables agreement on solutions of recurrent problems. Looked upon in this way, a standard can be viewed as striking a balance between the requirements of users, the technological possibilities and associated costs of producers, and constraints imposed by government for the benefit of society in general (Germon [1986]).

More functionally, an *industry standard* is a set of specifications to which all elements of products, processes, formats, or procedures under its jurisdiction must conform. The process of *standardization* is the pursuit of this conformity, with the objective of increasing the efficiency of economic activity.

1.1. Nature and Scope of Impacts

Standards played an important role in the industrial revolution. They allowed factories to achieve economies of scale and enabled markets to execute transactions in an equitable and efficient manner. Standardization of parts made supplier specialization possible and increased efficiency over the entire product life cycle by facilitating part repair or replacement.

In a modern economy, standards constitute a pervasive infrastructure affecting the technology-based economy in a number of important and relatively complex ways. Some of these impacts even appear contradictory. For example, whereas the traditional economic function of standards in production can restrict product choice in exchange for the cost advantages of economies of scale, other types of standards common to advanced production and service systems can actually facilitate product variety and hence choice for the customer.

Fig. 1 depicts the multiple functions performed by standards. These functions transcend the three major stages of technology-based activity — R&D, production, and market penetration, and are difficult to construct and implement because many important technologies have both an intrinsic complexity and a "systems" character. Such characteristics demand more sophisticated technological foundations for standards and imply the need for technically competent standards setting processes.

The greater complexity of technologies and the associated networks of firms and supporting infrastructure that develop and disseminate these technologies mean that supply chains are becoming the most important level of policy analysis. Greater distribution of R&D among materials and equipment suppliers, manufacturers of products, and providers of services increasingly characterize high-tech supply chains. The consequent increase in market transactions involving technology also demands standards to reduce the associated transaction costs.

Technology consists of a number of discrete elements that tend to evolve in different institutional settings. These elements have distinctly different character and require different types and combinations of standards to effect efficient development and utilization (Tassey [1992, 1997]). Many variations exist but broadly defined they fall into the three major categories shown in Fig. 1:

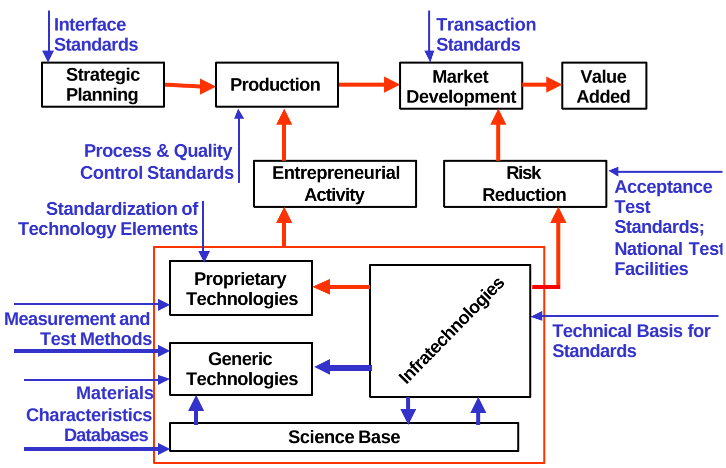

Fig. 1. Roles of Standards in a Technology-Based Industry

(1) The fundamental or ***generic technology*** base of the industry on which subsequent market applications (products and services) are based

(2) A set of ***infratechnologies*** that provide a varied and critical technical infrastructure to support for development of the generic technology and subsequent market applications

(3) The market applications (***proprietary technologies***)

Because the type of R&D required for each element differs significantly, so do private-sector investment incentives with the result that underinvestment varies across the different elements of an industrial technology. The greater the infrastructural character of a technology, the more underinvestment is likely to occur. Standards and thus their technical underpinnings have a strong infrastructure character, so that underinvestment is common.

1.2. Basic Functions of Standards

To analyze the economic functions of standards in a technology-based economy, a taxonomy is required that classifies standards by functions having unique economic characteristics. For the purpose of economic impact assessment, the functions of standards are classified into four categories.[3] The positive effects of each of the four functions are described below. However, as discussed in later sections, standards also can have negative economic consequences or simply fail to achieve their maximum potential economic benefit.

1.2.1. Quality/Reliability

Standards are developed to specify acceptable product or service performance along one or more dimensions such as functional levels, performance variation, service lifetime, efficiency, safety, and environmental impact. A standard that specifies a minimum level of performance often provides the point of departure for competition in an industry. For example, a case study by Putnam, Hayes and Bartlett [1982] points out that when an automobile manufacturer develops a new engine, the company specifies the minimum acceptable lubrication attributes. This specification then becomes the basis for competition among petroleum companies, who either compete on price at the minimum specified level of quality or by offering motor oil with a level of performance above the minimum.

1.2.2. Information Standards

Standards help provide evaluated scientific and engineering information in the form of publications, electronic data bases, terminology, and test and measurement methods for describing, quantifying, and evaluating product attributes. In technologically advanced manufacturing industries, a range of measurement and test method standards provide information, which, by virtue of being universally accepted, greatly reduce transaction costs between buyer and seller. In their absence, especially for complex, technology-based products, considerable disagreement will often ensue over verification of performance claims. These disputes raise the cost of consummating a marketplace transaction, which is reflected in higher prices charged. The economic impact is to slow market penetration.

Measurement methods are also essential to conduct state-of-the-art research. In today's semiconductor R&D, scientists and engineers must be able to measure the distances between individual atoms (dopants) that are added to silicon to achieve the desired millions of high-density electronic functions on a single chip. Standardization of some of these methods is essential for the efficiency of R&D itself. For example, being able to replicate and verify research results is often critical to obtaining follow-on research funding or commitment to commercialization. Standardized scientific and engineering data (in the sense of having been critically evaluated and verified for accuracy) and standardized equipment calibration techniques are also essential for efficient R&D.

Finally, the typical manufacturing process is increasingly measurement intensive because of growing demands for quality and real-time process control. Traditional manufacturing processes tested products after a production run. The inefficiency of this approach is large, not only because of the wasted material and labor when a production run must be scrapped, but also because of down

[3] This taxonomy follows Tassey [1982, 1992, 1997] and Link and Tassey [1987]. David [1987] proposes a similar taxonomy based on three kinds of standards (reference, minimum quality, and compatibility). Other taxonomies have been developed based on the process by which a standard comes into existence. For example, David and Greenstein [1990] provide a framework to classify standards as *de facto* ("unsponsored" or "sponsored") or promulgated (voluntary or *dejure*).

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