JOURNAL OF PUBLIC PROCUREMENT, VOLUME 9, ISSUE 1, 17-56 2009

PUBLIC PROCUREMENT AND INNOVATION: TOWARDS A TAXONOMY

Leif Hommen and Max Rolfstam*

ABSTRACT. The role of public procurement as an instrument to stimulate innovation has been increasingly emphasized by European policymakers. This perspective raises demand for the understanding of public procurement as an activity taking place in a variety of different procurement contexts and as an act of innovation. Accordingly, this paper proposes a taxonomy of public procurement and innovation, combining interactive learning and evolutionary perspectives on innovation processes to account for the broad range of different 'interaction environments' or 'resource interfaces' in which government or public sector organizations may act as lead users of innovations. On this basis, the taxonomy draws practical policy implications for the design of programmes and initiatives for the public procurement of innovations.

INTRODUCTION

Current policy and research literature on the public procurement of innovations lacks strategic perspective and attention to context. European Union (EU) policy-makers have increasingly encouraged "public procurement of innovative products and services" as a policy instrument appropriate to realizing the Lisbon and Barcelona goals for raising private sector R&D investment in member states (European Council, 2005; National IST Research Directors Forum, 2006). Several EC-funded projects, as well as individual national authorities, have specified principles, models, and examples of "best practice" (Edler et al., 2005; Georghiou & Cave, 2005; OGC, 2004). But such guidance has been based on generic models of the

---

* *Leif Hommen, Ph.D., and Max Rolfstam, M.Sc., are an Associate Professor, and a Ph. D. Student, respectively, Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE), Lund University, Sweden. Hommen's research interest is in innovation studies, Rolfstam's research interest is in public procurement of innovation.*

procurement process and a focus on particular projects, viewed as transactions and evaluated from the standpoint of public sector organizations as 'buyers'. This approach is unable to account for variety and change in the dynamics of user-producer interaction and longer-term processes of technological development and cannot inform broader strategies for the public procurement of innovations.

We propose a taxonomy that draws upon theory and research in innovation studies and related fields to map the variety of contexts and identify key features of context that should be addressed in planning and conducting public procurement of innovations. Theoretically, the taxonomy's main conceptual dimensions are drawn from interactive learning and evolutionary views of innovation, and for both of these main dimensions several sub-dimensions are elaborated. With respect to evolution, for example, the framework takes into account not only technological trajectories but also institutional aspects of market development and shifts in the balance of power and capability within established networks of innovation. The taxonomy also addresses key aspects of the design of programmes and initiatives for the public procurement of innovation. These aspects include the role of public *vis-à-vis* private demand, the goals for technology development, the character of innovation pursued, and the modalities employed.

A taxonomy is one of two kinds of typology. The methodological literature identifies typologies as theoretical constructs that are particularly useful for multiple case study research designs (de Vaus 2001). Dess et al. (1993) identify one of the chief virtues of typologies as "express[ing] complicated and interrelated relationships among many variables without resorting to artificial oversimplification". Some authors emphasize that typologies are conceptually derived classification schemes, resulting in complementary sets of "ideal types" (Bozarth & McDermott, 1998), constructed either deductively or inductively. The term 'typology' is sometimes applied to all such classification schemes. However, Turner (1992, p. 10) has differentiated "*naturalistic schemes*, which try to … capture the way in which invariant properties of the universe are ordered", from "*sensitising schemes*, … intended only to sensitise

and orient researchers and theorists to certain critical processes." Similarly, Sayer (1992) has distinguished between *causal groups*, and *taxonomic groups*. Hence, we reserve use of the term *typology* for what Turner (op. cit.) refers to as a "naturalistic" scheme, and apply the term *taxonomy* to its counterpart, the "sensitising" scheme. Below, we develop a taxonomy to guide exploratory case study research on public procurement and innovation.

There have been few attempts to classify the relations between public procurement and innovation. Edquist and Hommen (2000) developed a four-field matrix based on two dichotomies. The first was between "direct" and "catalytic" procurement (the latter being carried out on behalf of other eventual end-users) and the second was between "developmental" and "adaptive" technology procurement, (the former involving radical and the latter incremental product innovation). However, this matrix has never been fully tested, since it has not yet been applied to any cases of "catalytic" procurement (Edquist et al. 2000). It also fails to recognize instances where several public buyers act in concert (e.g., Kaiserfeld, 2000). Cave and Frinking (2003) have addressed the design and implementation of public procurement projects to promote innovation in terms of four key "dimensions" – relations between public and private demand, reasons for innovative procurement, the type of innovation involved, and the modalities available. However, they generate only a checklist, and not a typology. Our work incorporates key elements of Cave and Frinking's framework within a comprehensive classification scheme. We can also identify some relevant typologies developed for the study of the *private* procurement ('purchasing' or 'acquisition') of innovations, such as Håkansson and Johansson's (1993) early work on forms and contexts of user-producer interaction, and Stock and Tatikonda's (2000) more recent "inward technology transfer (ITT) typology". However, these sources have neglected the general case of public procurement and innovation, not to mention its variants (some of which may have no parallels in the private sector). We combine and integrate these perspectives with the aforementioned approaches to the study of public procurement to develop a specification of the relations between public procurement and innovation. The resulting taxonomy is based on the identification of two key dimensions: the interaction of users and producers and the evolution of technologies and markets.

The remainder of the article is organized as follows. The next section provides definitions in order to clarify the meaning of more specialized concepts. The distinction between product and process innovations is discussed, and related to a parallel distinction between procurement *of* innovations and innovations *in* procurement, drawn in order to clarify the empirical focus of this article. Then the theoretical foundations of the taxonomy that we develop are discussed. This is done by drawing upon the innovation studies literature to explain the main ideas underlying the taxonomy's two main dimensions: interaction and evolution. Subsequently, following that, we elaborate on the key sub-dimensions of each of these two main dimensions. The section titled 'Public procurement of innovation: a Taxonomy' presents the taxonomy and provides illustrative examples. The section thereafter discusses results from case study research related to the taxonomy, and, finally, the article discusses implications for theory, practice, and future research.

DEFINITION

Public procurement refers to the acquisition (through buying or purchasing) of goods and services by government or public sector organizations. In order to affect *innovation*, public procurement must influence either or both the direction and rate of technological change (Dalpé, 1994; Edquist & Hommen, 2000; Geroski, 1990). Influencing the rate of innovation may involve either raising investments in R&D (research and development) or increasing the application of R&D results. Influencing the direction of innovation involves selecting certain technological alternatives. In addition, public procurement can also influence innovation indirectly, by disseminating R&D results, reducing the costs and risks of innovation, and supplementing existing 'dedicated' R&D (Cave & Frinking, 2003). In all of these cases, public procurement affects innovation through transactions related to the development of new *technology,* a term that refers not only to artefacts but also to applied scientific and technical knowledge and operational skills or 'know how' (Layton, 1974).

Innovative public technology procurement occurs when a public agency acts to purchase, or place an order for, a product – service, good, or system – that does not yet exist, but which could probably be developed within a reasonable period of time, based on additional or new development work –e.g., R&D -- by the organization(s)

undertaking to produce, supply, and sell the product (Edquist & Hommen, 2000). In contrast, "regular public procurement" occurs when public-sector organizations buy ready made products for which no R&D is required and about which purchasing and supplier selection decisions can be made on the basis of readily available information about price, quantity, and performance, given the existence of standardized markets.

Innovation, according to Schumpeter (1939) "consists in carrying out New Combinations." Edquist et al. (2000, p. 19) translate this broad definition into a taxonomy of innovations that distinguishes between product and process innovations, as well as between product innovations in 'material goods' and 'intangible services' and between organizational and technological process innovations. For us, the distinction between product and process innovations is of central importance.

We follow Schumpeter (1911, p. 66) in defining product innovation as "the introduction of a new good … or a new quality of a good", and process innovation as "the introduction of a new method of production … [or] a new way of handling a commodity commercially." Essentially, this is a distinction between what is produced and how it is produced. *Product innovation* is fundamental to innovative public technology procurement as defined above, for the reason that any procurement entails the purchase of an economic good or commodity (Lundvall, 1985; 2003). In contrast, *process innovation* is only incidental, since it can occur without any transaction, and taking place entirely within the boundaries of a producer organization (Arrow, 1962).[1] As a special case of product innovation, then, innovative public technology procurement "involves buying things that go beyond where the market is at the moment" (Cave & Frinking, 2003, p. 17).

We will now make a final clarification concerning the difference between the procurement *of* innovations and innovations *in* procurement. As indicated, we are concerned with the procurement *of* innovations – that is, the purchase, by government or public sector organizations of products that are innovative, or 'new', in Schumpeter's sense, and whose development typically involves significant R&D expenditure. We do not propose to address innovations *in* procurement – i.e., changes or process innovations in the means by which procurement itself is carried out, as, e.g., in the

introduction of 'e-procurement' – except insofar as the acquisition of new systems for public procurement can be regarded as an instance of innovative public technology procurement.

THEORETICAL FOUNDATIONS

User-producer *interaction* is a fundamental aspect of product innovation, which typically involves interactive learning – i.e., inter-organizational learning processes based on such interaction (Lundvall 1985; 2003). Interactive learning can take place in a wide variety of contexts and involve exchanges of different kinds of knowledge (Lundvall, 1988; Lundvall & Johnsson, 1994). The innovation studies literature includes various typologies of learning (see, e.g., Malerba, 1992), but we focus here on networks as learning mechanisms (Lundvall & Archibugi, 2001). Von Hippel (1988) has shown that dyadic user-producer collaboration involving only two actors represents the most elementary kind of network relation. However, "development pairs" (Fridlund, 1993) are only one of several kinds of innovation networks (Powell & Grodal, 2004; Tidd, Bessant & Pavitt, 1997). Håkansson's (1989) distinction between 'vertical' and 'horizontal' network relationships provides an important basis for classifying extended networks. Horizontal relationships predominate in 'knowledge' networks based on co-operation, whereas vertical relationships are the main feature of 'trade' networks based on commodity exchange (Gelsing, 1992). Although user-producer interaction is always vertical, it may or may not also involve additional interactions or along the horizontal axis, and relationships along the vertical axis may be either simple or extended.

Another important aspect of user-producer interaction is the number of actors involved (Lundvall, 1985; 2003). Typically, it involves "small numbers," as well as "information impactedness" and "uncertainty and complexity" – problems of imperfect competition that are resolved by means of extensive exchanges of qualitative information in the context of stable cooperative relations mediated by a hierarchy rather than a market (Lundvall, 2003). In some instances, the hierarchical mechanisms involved might take the form of simple 'development pairs' – i.e., "long-term intimate collaboration on joint development between large manufacturers and large customers" (Fridlund, 1993, p. 4). However, the classification of markets into the categories of monopsony (single buyer), oliogopsony (several buyers),

and polypsony (many buyers) points to the need for alternative solutions (Edquist & Hommen, 2000; Rothwell & Zegveld, 1982). Close relationships between single buyers and single producers might be highly problematic in oligopsonistic and polypsonistic markets. In industrial markets where potential buyer networks lack central coordination, there is a strong possibility that demand for emerging capital goods may remain in a "low-level equilibrium trap" (Teubal, Zinnon & Zuscovitch, 1991, p. 382). In mass markets where many individual consumers may seek better products, and producers are aware of possibilities for improving products but not of the potential demand, the lack of a collective 'voice' for consumers can result in situations where "optima will not be sought, nor maintained, under normal market conditions" (Nilsson, 1994, p. 7n; Rothwell, 1994, p. 637).

A further key aspect of user-producer interaction is the kind of need that motivates such relationships. Public procurement of innovations naturally "takes societal problems and needs as its point of departure" (Edquist & Hommen, 2000, p. 23), but the concept of needs is "fuzzy," and requires clarification (Lundvall, 2003, p. 7). Understanding 'need' in the sense of "interdependence among economic agents" (Smith, 1997, p. 87) and building upon an earlier dichotomy between "direct" and "catalytic" public technology procurement (Edquist & Hommen, 2000), it is possible to identify three different categories: 1) needs that are *intrinsic* to the organization that acts as the 'buyer' in public procurement; 2) needs that are *congeneric* to, or jointly shared by, a number of organizations (possibly including private- as well as public-sector actors); and 3) needs that are *extrinsic* to the public agency or authority that acts as the 'buyer' – which, in this instance, acts to procure innovation on behalf of other actors. Needs of the first type can be illustrated by the "mission" requirements of a government authority or public sector agency – for instance, the military's need for new weapon systems (Bozeman & Dietz, 2001). Needs of the second kind can be exemplified by common or overlapping demands placed on the "knowledge infrastructure" by diverse groups actors – for instance, the multiple users who rely for innovation inputs on the stocks of knowledge maintained by libraries and other public in formation systems (Smith, 1997). Needs of the third variety can be elucidated by referring to cases where government or public sector bodies, to meet their own objectives, represent the needs of end-

users other than themselves. In efforts to reduce demands for energy provision by public utilities through public procurement of energy-efficient home appliances, the main end-users are private individuals and households motivated to reduce energy costs (Westling, 1996).

Evolution is a central theme in studies of innovation (Nelson & Winter, 1982), and work in this tradition has typically paid careful attention to stages of technology, industry and market development. Edquist and Hommen (2000) have differentiated between 'development' and 'adaptation' in innovative public technology procurement, following Schumpeter's (1939) distinction between 'creation' and 'diffusion' as successive stages of innovation. A technology's evolution, though, is tied to and influenced by its pattern of diffusion (Dosi, 1982; Grübler, 1989; Rosenberg, 1972; Sahal, 1981; Silverberg, 1987; Silverberg, 1990a; 1990b; Silverberg et al., 1988). The widely influential product-life-cycle (PLC) model (Abernathy & Utterback, 1978) therefore describes three consecutive phases, characterized by distinctive patterns of *both* creation *and* diffusion (Utterback, 1994). In this model, innovation and industrial evolution proceeds from an initial 'fluid' stage marked by extensive product innovation through a 'transitory' stage in which process innovation predominates towards a final 'specific' stage in which innovation is minimal. The PLC model does not, however, apply well to many long-established complex product systems (CoPS) (Prencipe, 2003).[2] Moreover, not all product technologies eventually lose innovative dynamism in the 'specific' stage (Hidjefäll 1997). Boisot (1995) and Nooteboom (2000) have therefore elaborated extended, cyclical models of innovation, which stress the potential for creative activity in later stages.[3] Nooteboom (2000, p. 184), for instance, describes a cycle of exploration and exploitation consisting of three main phases – consolidation of novel combinations, generalization, and differentiation and reciprocation – that "can be characterized succinctly as an alternation of variety of content and variety of context." In addition, Boisot's and Nooteboom's models recognize that the evolution of new technologies depends on the market contexts in which they first develop and to which they later spread. Particularly in their emphasis on the possibilities for launching new trajectories in later stages, they support Langlois's (2003) argument that innovation in mature technologies and industries can be boosted by re-aligning organizations, institutions and technologies.

Understanding market development is an essential aspect of the development of new technologies and requires moving beyond conventional notions of markets as largely pre-given contexts and addressing the 'construction' of markets (Coombs et al., 2001; Laestadius, 2003). Historical studies of industrial organization have focused primarily on producer strategies for creating or structuring markets (Berk 1994, de Grazia, 1998; Glimstedt; 1995; Herrigel, 1996; Sabel & Zeitlin, 1997; Scranton, 1997; Zeitlin & Herrigel, 2000). Economic sociologists have also emphasized the role of producers (Granovetter & McGuire, 1998). Fligstein (2001) has propounded a theory of market development as a process of institution-building, driven by ongoing struggles between 'incumbent' and 'challenger' firms and arbitrated by the state. The process entails the elaboration of "four types of rules": property rights, governance structures, rules of exchange, and conceptions of control (Granovetter & McGuire, 1998). This theoretical framework also develops propositions related to three main phases of market development: emergence, where there is open rivalry amongst firms with alternative strategies; stability, where status hierarchies are established among firms; and crisis, where incumbent firms begin to fail and are reorganized along the lines of successful invaders (Granovetter & McGuire, 1998). Contests between incumbents and challengers have often been discussed in innovation studies literature, but seldom in relation to institutions. Market development has been addressed by diffusion studies, which with only a few exceptions (e.g., Dutton, 1999; Mansell & Silverstone, 1996) have paid scant attention to institutional analysis.

The innovation studies literature has, however, not only focused on *producers*, but also recognized the importance of *users* – particularly, 'lead' industrial users, but more recently also 'professional' and sophisticated 'amateur' end-users (von Hippel, 1988; 2005). Work in this tradition has focused on the competitive advantages that producers can acquire by establishing ties with key users or user groups (e.g., Ceruzzi, 1998; Francke & Shaw, 2003). Institutional implications have remained largely unexplored -- except in Lundvall's (1985; 2003) seminal contributions on 'organized markets.' Lundvall first establishes that neither perfect competition nor vertical integration is conducive to complex product innovation; subsequently, he specifies the most appropriate institutional set-up as a "vertical division of labour between producers and users

belonging to different organisations" (Lundvall 2003, p. 16). Here, co-ordination depends upon "codes of conduct" expressing "mutual trust and responsibility" as well as "elements of hierarchy" (Lundvall, 2003, p. 17). Social structure in markets develops and is eventually institutionalized on the basis of recurrent cooperative relations.[4] Over time, though, constellations of social structure often emerge that spawn 'unsatisfactory' innovation trajectories, due to producers' domination of users and related factors (Lundvall, 2003). In stable market contexts, 'industrial complexes' of major users and producers can foster "convergence and agreement on technological trajectories …, excluding new and more promising avenues" (Lundvall & Borrás, 2004, p. 610). Hence, there is a need for a policy oriented towards enhancing user capabilities, including those of 'final users.' Innovative public technology procurement addressing neglected users and other 'outside' actors may be particularly effective for such policy, since it involves state or public sector bodies as powerful 'lead users' and can contribute directly to both technological innovation and the (re)organization of product markets (Edquist & Hommen, 2000, p. 5).

Far from being a simple progression towards a state of maturity marked by minimal uncertainty and clearly defined standard markets, technology development is a complex, non-linear process. To map it, we require a framework that "allows for intermediate cases" and captures "a spectrum of innovation and diffusion, of creation and realization" (Nooteboom, 2000, p. 66). By relating different constellations of the key actors in product innovation to broad stages of technological development, we can discern different interaction environments characterized by different kinds of collaborative relations and constituted by activities in which the key actors combine, develop, exchange or create resources (Håkansson & Johansson, 1993). Where the state – or the public sector -- enters as a 'lead user,' we can expect its priorities to vary with respect to the role of public *vis-à-vis* private demand, goals for technology development, the character of innovation pursued, and the means employed (Cave & Frinking, 2003).

TAXONOMY DEFINITIONS AND SUB-DIMENSIONS

In this section we elaborate key sub-dimensions of the two main concepts or dimensions discussed in the preceding section – i.e.,

'interaction' (especially of users and producers) and 'evolution' (of both technologies and markets). For each dimension, we relate sub-dimensions to concrete policy examples and discuss their main implications. We also address the design of policies and programmes for the public procurement of innovation.

Interaction

Our taxonomy's first dimension is interaction, particularly between users and producers, which is fundamental to product innovation (Lundvall 1985, 2003). Table 1 specifies three modes of interaction in public procurement of innovations: direct, co-operative, and catalytic. These categories are based on three important sub-dimensions of interaction. Namely, these are interactive learning, structure of demand, and the needs that innovative public technology procurement responds to. Below, each is discussed in turn.

Interaction and thus *interactive learning* can occur in different *contexts* and be based on different kinds of *networks* (Lundvall & Archibugi, 2001). Since it encompasses both horizontal 'knowledge' and vertical 'trade' networks (Gelsing, 1992), one particularly relevant context for public procurement of innovations is 'learning regions' (Asheim, 1996; 2001; Cooke & Morgan,. 1998; Florida, 1995; Lundvall & Maskell, 2000; Morgan, 1997). Here, flows of knowledge among actors are normally facilitated by common

TABLE 1
Modes of Interaction

Modes of Interaction	Aspects of User Producer Interaction		
	Interactive Learning Contexts (Networks)	Demand Structure	Needs Addressed
Direct	*Development Pairs* (simple networks or dyadic relationships)	*Monopsony* (markets with a single buyer)	*Intrinsic Needs* (pertaining solely to buyer organizations)
Co-operative	*Knowledge Networks* (horizontally extended)	*Oligopsony* (markets with several buyers)	*Congeneric Needs* (shared by buyer and other organizations)
Catalytic	*Trade Networks* (vertically extended)	*Polypsony* (markets with many buyers)	*Extrinsic Needs* (pertaining to other actors than buyer organizations)

channels, codes, and conventions of communication, fostered by "shared institutional environments" and accumulation of social capital (Asheim & Gertler, 2005, p. 293). Regional innovation studies point to numerous instances of the importance for economic advantage of markets and demand-side factors (Best, 2001; Kenney & von Burg, 1999; Langlois, 1992; 2002; Saxenian, 1994; 1999). One clear implication of such analyses is that, as suggested by Rothwell (1984), regions with 'traditional' industrial structure, where private sector demand may exert only weak influence on emerging technologies, might compensate by means of public procurement initiatives aimed at developing new market segments, to provide producers with stimuli and inputs for successful innovation.

Demand structure is important, since effective user-producer interaction usually involves only a few main actors with fairly stable inter-organizational relations (Lundvall, 2003), and in fragmented industrial and consumer markets, users and producers cannot communicate effectively. In such contexts, there may be compelling reasons for public procurement initiatives representing collective interests of individual users. Concern about potential 'information society' exclusion of disadvantaged groups (Haddon and Silverstone 1996) has prompted EC support for numerous RTD&D projects for inclusive product design in, e.g., telematics and overcoming barriers to the use of electronic services (Silverstone & Haddon, 1997). But problems of social exclusion cannot be resolved by 'technological fixes' alone; "they also require the evolution of institutions with mandates providing incentives for people to become prepared and motivated to seek ways of mitigating the issues of exclusion" (Mansell & Steinmueller, 2000, p. 42)

Three types of *need* may be addressed by public procurement of innovations: intrinsic, congeneric, and extrinsic. In certain areas, all three types of need may be present, requiring differentiated strategies. One example is technological innovation policy initiatives for environmental sustainability (Meyer-Krahmer, 2001a). Here, there remains considerable scope for conventional 'mission-oriented' projects, but there are also increasing requirements for "active participation of a wide range of [public sector organizations] and firms", and an imperative to lead not only firms but also consumers (Meyer-Krahmer, 2001a). When public procurement of innovations addresses this wide range of actors, needs, and interests, coordination becomes essential. It becomes necessary to maximize

complementarity of diverse initiatives through close interaction of firms, consumers and public authorities. For these reasons, "Regions can act as pioneers … because they are an ideal platform for such social innovation experiments" (Meyer-Krahmer, 2001a , p. 189).

Evolution

The second dimension of our taxonomy is the evolution of technologies, markets, and networks, which can affect direction of demand in public procurement of innovations, sources of innovation, and aspects of procurement mechanisms (Nelson & Winter, 1982; Nooteboom, 2000). The product life cycle (PLC) model (Utterback 1994) specifies three main phases: early, middle, and late. In Table 2, these phases are related to key sub-dimensions: technological trajectories, institutional aspects of market development, and the balance of power and capability in network relations. Below, we discuss each in turn.

With regard to *technological trajectories*, unilinear models have given way to multilinear models (Boisot, 1995; Nooteboom, 2000), where possibilities for innovation do not necessarily diminish with wider diffusion in the middle and late stages. Rather, diffusion presents opportunities for developing new trajectories. US innovation policy debates on 'dual use' technologies and 'conversion' of military technologies into civilian applications provide insight into these possibilities (Bozeman & Dietz, 2001; Mowery, 2001a). In the late 1980s and early 1990s, such concerns led to several major programmes complementing US Department of Defence (DOD) technology procurement with cooperative development of civilian applications in strategic high technology sectors. (Mowery, 2001a) Although US 'dual use' initiatives were largely abandoned by the late 1990s, along with 'cooperative' technology development policies, they still provide models for exploration and exploitation along multiple trajectories via public procurement and related measures. Moreover, that model could still be revived if commercialization of defence and other Federal Government 'mission' technologies regain high priority in US economic policy (Bozeman & Dietz, 2001).

Concerning *institutional aspects* of market development, conflict between 'incumbents' and 'challengers' drives elaboration of rules concerning property rights, governance structures, rules of exchange, and conceptions of control (Fligstein, 2001). Mansell and

Steinmueller (2000) distinguish between "incumbent" strategies" based on the control of unique fixed assets supporting dominant market positions and "insurgent" strategies that combine network externalities with economies of scale. They also point to both

TABLE 2
Phases of Evolution

Phases of Evolution	Aspects of Evolution		
	Technological Trajectories	Institutional Development of Markets	Balance of Power and Capability
Early ('Fluid phase' marked by extensive product innovation)	*Consolidation of Novel Combinations* Closing variety of content to establish efficient production and clear paradigms or platforms for development.	*Emergence* Open rivalry and shifting alliances among incumbent and challenger firms with varying ideas on con-trolling competition. Coalition building.	*User-led Innovation* Producers depend on key users for vital in-formation. Competent lead users are instrumental in selecting dominant designs and successful firms.
Middle ('Transitory phase', with a main focus on process innovation)	*Generalization* Opening variety of context, for insight into misfits, needs and opportunities for adaptation. Avoidance of 'distant' contexts.	*Stability* Identities and status hierarchies among producers are firmly established. Strong isomorphism in firm strategy and structure.	*Industrial Complexes* Convergence of vested user and producer interests; agreement on certain trajectories. Some promising avenues may be neglected.
Late ('Specific phase', featuring minimal innovation by major producers in either processes or products)	*Differentiation and Reciprocation* Opening variety of content for different versions and extensions; transfer of elements between practices and contexts; new combinations.	*Crisis* Failure of incumbent firms and re-organization to emulate successful invaders. Markets in crisis are highly susceptible to transformation.	*Producer Domination* Users are increasingly marginalized by established producers. New technological alternatives can arise out of new user-producer constellations

commercial and non-profit "virtual community" strategies. (Mansell & Steinmuelle, 2000) They argue that "the virtual community strategy offers a particularly attractive avenue for European information society development", not only due to potential employment creation, but also because insurgent strategies are advantageous to North American producers. But EC public policy actions have tended to "tilt the playing-field" against virtual communities – notably in decisions on copyright. Public procurement could contribute to building virtual communities through new infrastructure and public applications for information systems (Mansell & Steinmuelle, 2000). However, it could only level the playing-field for virtual communities if combined with institutional reforms in areas such as copyright, standards development, and governance.

With respect to changing *balances of power and capability* in network relations, longer-term trends towards producer domination have negative consequences for innovation (Lundvall, 2003). In telecommunications, innovation is demand-led (Garrard, 1998), particularly in software (Meyer-Krahmer 2001b). National or regional competitive advantage in this field depends on sophisticated markets and competent users. However, liberalization of telecommunications in the EU (and elsewhere) has transferred 'system competence' from operators to equipment manufacturers (Hommen & Manninen, 2003; Hommen, 2003). ETSI (European Telecommunications Standards Institute) and other regional standards development organizations (SDOs) have provided "important epistemic communities" (Humphreys & Simpson, 2005, p. 48) for "user-led" standards development (Hawkins, 1995, p. 29). Nevertheless, 'standards-led' EC competitive strategy faltered by the late 1990s (Glimstedt, 2001; Humphreys & Simpson, 2005) – as did EC procurement policies that advantaged European vendors by requiring reference to European standards developed by ETSI and other EC-recognized SDOs (Bekkers, 2001). Although the EC has more recently moved towards "technologically neutral" telecommunications public supply contracts, past policies and their effects on infrastructure investment have continued to induce strong bias in technological choices made in procurement (Bekkers, 2001, pp. 116 – 117). Further reform should arguably include measures assuring non-restrictive, unbiased competition of both formal and non-formal technical standards (Bekkers, 2001, p. 565). Of course, it should also address how to

improve competence among telecommunications operators and other 'lead users.'

Design of Innovative Public Technology Procurement

Cave and Frinking (2003) identify four key aspects of design of public procurement programmes promoting innovation: relations between public and private demand, reasons for intervention, kinds of innovation involved, and choice of modalities. These design aspects entail both 'interactive' and 'evolutionary' issues.

In the *relation between public and commercial demand*, interactive issues arise regarding strength and variability of public relative to commercial demand. A monopsonistic public agency pursuing its own priorities can behave quite differently from one that attempts instead to lead a group of buyer organizations with related but perhaps only partly overlapping agendas. Evolutionary issues concern direction of demand – i.e., whether public demand influences commercial demand, or *vice-versa*.

Regarding *reasons for public intervention*, some major issues concern interaction -- in particular, questions of need. As noted, public technology procurement initiatives in areas like environmental sustainability may be simultaneously motivated by several complementary types of need, requiring effective co-ordination. Evolutionary issues also arise – particularly, those concerning distribution of power and capability between users and producers. In later stages, intervention may be directed towards enhancing user capabilities or encouraging interaction with non-incumbents to foster new alternatives.

Concerning *kinds of innovation involved*, interactive issues concern forms of innovation – i.e., product vs. process innovation. Both needs and networks are important. Where public agencies sponsor design contests to establish effective communication between producers and other potential end-users, e.g. consumers, they will focus strongly on product design criteria, and require vertically extended learning networks. Evolutionary issues are reflected in whether innovation occurs only directly within transactions between 'buyer' and 'seller', or also indirectly – i.e., further along supply chains.

In *choice of modalities*, interactive issues are reflected in strategies to facilitate innovation, and organization of procurement projects. With high levels of risk and uncertainty, public-sector agencies may have to provide direct support for innovation through strong co-operative ties such as 'development pairs'. Evolutionary issues arise concerning selection of suppliers and how specifications are made. Use of multiple suppliers has long been recognized as an aspect of US military procurement policies beneficial to commercial 'spin-off'. Regarding specification, a functional approach maximizes competition among suppliers, encourages buyers to explore alternatives, and avoids technological lock-in, especially in mature industries -- a point illustrated by EC 'technological neutrality' in public supply contracts in telecommunications.

PUBLIC PROCUREMENT OF INNOVATION: A TAXONOMY

Tables 3, 4 and 5 below present a taxonomy of public procurement of innovation, emphasizing product innovation and development of relevant supplier industries and product markets. Key characteristics in focus are policy 'design' aspects discussed earlier by Cave and Frinking (2003). We identify nine separate kinds of procurement of innovation, specified by discussing three different modes of interaction at early, middle, and late stages.

We begin with *direct* procurement of innovations (Table 3). Classic *early-stage* examples include military procurement of radar and sonar technologies, and more recently, the Internet (Mowery, 2001b). In this cell, public demand is far in advance of public demand and procurement is oriented towards 'mission critical' issues. It exerts direct 'demand-pull' on suppliers, often through long-term contracting arrangements. The *middle stage* is exemplified by public utilities' procurement of established but still developing – and possibly also 'alternative' -- production technologies for their own commercial purposes, advancing general markets for these technologies and improving the technologies themselves. A specific instance is the Swedish power company, Vattenfall's recent procurement of wind power technology, in the form of 48 offshore wind power plants located in southern Sweden (Vattenfall, 2004). Here, 'own account' public demand typically establishes performance requirements superior to existing market requirements, and may thus

TABLE 3
Direct Procurement

DIRECT PROCUREMENT			
Modes of Interaction / Design Aspects	Phases of Technology and Market Evolution		
	Early (Fluid)	Middle (Transitory)	Late (Specific)
Relationship of Public to Private Demand	Path-finding (far in advance of private demand)	Pace-setting (higher requirements than private demand)	Differentiation but possible comple-mentarity
Reasons for Public Intervention	Mission critical (solving urgent problems)	Own account (improving standard solutions)	Mission critical (fostering new alternatives)
Type of Innovative Activity	Direct demand pull (on a 'new' product market)	Indirect demand pull (on commercial application)	Supply push (to new commercial markets)
Characteristic Modalities	Long-term contracting	Dual or multiple sourcing	Technological Neutrality

lead, via 'indirect demand pull' to new commercial applications. Dual or multiple sourcing is a preferred modality for developing competitive supplier industries.

In *late-stage* 'direct' procurement, new solutions to 'mission critical' needs may be sought. Public demand often becomes increasingly different from private demand, but may still complement it. One example is Sweden's ongoing "24/7" programme to make public services accessible to citizens at all times and interconnect government offices and public agencies, by integrating information and communication technologies such as Internet, telephony, and television (Statskontoret, 2000; 2002). Although "24/7"has been in progress since the late 1990s and several contracts have been awarded (Karlberg, 2004), inter-agency co-ordination and technological integration have continued to raise problems (Kleja, 2004). Achieving these goals will help facilitate full interoperability of government IT systems with commercial ones – as in electronic procurement systems (Single Face to Industry 2004). New solutions of this kind may also be made mandatory for the private sector, thus facilitating 'supply push' on the part of producers. More generally, governments can encourage the suppliers of directly innovative public services to find commercial applications, which could find a ready

market among 'neglected' users for whom standard solutions have become problematic (Cave & Frinking, 2003, p. 20). Since established producers tend to disregard many users' needs in late-stage technology and market development, direct public technology procurement requires increased market power vis-à-vis producers, to motivate product improvements and induce innovation. Several countries have therefore created centralized agencies, such as National Procurement Ltd in Denmark (SKI, 2005), OGC buying solutions in the UK (OGCbuying.solutions 2005), and the US Federal Energy Management Program, FEMP (Oak Ridge National Laboratory, 2004). Another, already-discussed strategy for boosting innovation at this stage is 'technological neutrality' (Bekkers, 2001).

In *co-operative* public technology procurement (Table 4), one of the main historical motivations has been to revitalize declining commercial 'spin-off' from mission-oriented direct procurement of innovation, especially in late-stage technology development (Brody, 1996; Fukasaku, 1999). Aggregation of public and private demand to stimulate private sector innovation is an important rationale for cooperative procurement. This is often primarily a public sector effort in *early stage*s, where public procurement typically leads an emerging market, and not only 'critical mass' but also infrastructure is important. U.S. Government procurement of alternative fuelled vehicles (AFVs) has responded to perceived threats to fossil fuel supplies through coordinating targeted acquisitions by several government departments of fleet vehicles with alternative power sources and cooperating with other levels of government to develop supporting infrastructures ("The Advanced Battery Consortium and the Partnership for a New Generation of Vehicles," cited in Cave & Frinking [2003, p. 37]). Eventually, private sector organizations and individuals, as well as public sector organizations other than the initial public procurers will become buyers and users of these vehicles. In *middle stage* technology and industry development, relations between public and private demand shift from creating initial markets to providing introductions to new market segments, via 'show-case' demonstrations and identification of 'best practice' models acquainting private sector buyers and producers with new criteria for purchasing and product design. Public sector procurement typically fosters producer innovation by rewarding high performance, and requires special forms of cooperation with both producer

TABLE 4
Cooperative Procurement

COOPERATIVE PROCUREMENT			
Modes of Interaction / Design Aspects	Phases of Technology and Market Evolution		
	Early (Fluid)	Middle (Transitory)	Late (Specific)
Relationship of Public to Private Demand	Leadership of an emerging market	Introduction to new market segments	Sponsorship/promotion across market segments
Reasons for Public Intervention	Demand aggregation via concentration (mainly) within public sector	Demand aggregation via 'show-case' models & 'best practice' criteria	Demand aggregation via large, mandated 'launching markets'
Type of Innovative Activity	Achieving initial critical mass in new/alternative technologies	Introducing new decision criteria to suppliers & buyers.	Influencing product standards to ensure wide user inclusion
Characteristic Modalities	Directed purchasing and development of essential supporting infrastructure	Co-operation with industry and financiers; performance rewards	Purchasing, labeling and endorsement based on functional criteria.

industries and capital markets. In Denmark, all public agencies are required to consider environmental issues and energy efficiency in all procurement activities. The Environmental Protection Agency (EPA) assists with documenting these considerations in public procurement plans. The objective is to boost and stimulate markets for environmentally friendly products, and to develop broader markets of both private- and public-sector buyers (Cave & Frinking, 2003).

In *late-stage* cooperative technology procurement, public demand progresses from 'demonstrating' new or alternative technologies and introducing them to new market segments to promoting them actively across a range of market segments. Here, public sector demand provides a large 'launching market'. Innovative activity typically entails developing and defining product standards. In this connection, 'producer domination' typical of technologies and industries in late

stages of development can be counteracted through standards development processes that insure wide user inclusion and lead to systematic articulation of functional requirements. These, in turn, provide a basis for approved purchasing lists, labeling, and endorsement of performance assessment. Such practices are exemplified in the listing of "best practice" products by the USA's Federal Procurement Challenge, which aims at private market development. Here, the public sector acts as a 'leading consumer,' and its market power is directed not towards short term price reduction but rather towards incentives for innovation and levels of demand that will eventually sustain lower prices (Cave & Frinking, 2003).

In *catalytic* public technology procurement (Table 5), public sector organizations that act as buyers are not intended end-users. Intervention is, therefore, 'on behalf of others', and public demand articulates, sponsors, and helps to shape private demand. *Early-stage* innovative activity focuses on investigating private demand to inform dialogue with producers. The main operational mode is to formulate functional requirements based on user contexts. Sweden's Commission on Environmental Technology stimulates and facilitates procurement of sustainable technologies in collaboration with users. It formulates functional specifications for environmental products to create new products, processes, and technologies. Here, the procurer does not obtain anything, but potentially contributes to creating new markets. (Cave & Frinking, 2003) One important offshoot in Sweden has been NUTEK's Design for Environment (DFE) programme to support specific product development projects in SME-based networks (NUTEK, 2006). In *middle-stage* catalytic technology procurement programmes like DFE, public demand promotes private market acceptance through pilot projects and evaluations. Innovative activity concentrates on matching user and producer 'searches' through collaborative experiments, and characteristic modes of intervention are 'design contests,' trials, demonstrations, and dissemination. Such measures are exemplified by activities of the OECD-sponsored International Energy Agency (IEA), which coordinates collaborative research, development, and demonstration of new environmentally friendly energy technologies. IEA conducts collaborative procurement actions to introduce innovative, energy-efficient, products that have not yet reached the marketplace. A

TABLE 5
Catalytic Public Procurement

CATALYTIC PUBLIC PROCUREMENT			
Modes of Interaction / Design Aspects	Phases of Technology and Market Evolution		
	Early (Fluid)	Middle (Transitory)	Late (Specific)
Relationship of Public to Private Demand	Defining and representing private demand	Promoting private market acceptance	Focusing expression of existing private demand
Reasons for Public Intervention	On behalf of others, by initiating and mediating dialogue between end-users and producers.	On behalf of others, by soliciting, piloting and evaluating new solutions addressing user needs	On behalf of others, by ensuring that products meet or surpass essential requirements
Type of Innovative Activity	Investigating and articulating private demand	Matching user and producer 'searches' via collaboration and trials.	Performance standards and testing for product approval
Characteristic Modalities	Formulation of essential functional requirements based on user contexts	Design contests and trials; demonstration and dissemination.	Labeling and official endorse-ment; subsidies to private consumers.

leading example of the kinds of measures discussed here would be IEA's "DSM Awards of Excellence," where companies were challenged to develop technology meeting environmentally friendly and/or energy saving criteria. (Westling, 2000)

In *late-stage* industry and technology development, catalytic technology procurement is less concerned with creating or stimulating private demand than with focusing it. This is usually accomplished by ensuring that products meet or surpass essential requirements and promoting those that do. Thus, innovative activity by procuring agencies typically takes the form of setting performance standards and testing for product approval, and key modes of intervention include labeling and official endorsement, as

well as subsidies to private consumers – or, possibly, regulatory requirements that only products meeting certain standards can be used. Labeling, whereby procuring organizations introduce standards into mature markets on behalf of end-users and also reflecting consumer preferences, is widespread internationally. The USA's Federal Procurement Challenge supports "best-practice" energy-efficient, renewable and water-conserving products by assigning the "Energy Star" to products that meet recommended performance levels (Cave & Frinking, 2003). In Sweden, there is a similar practice of labeling environmentally friendly products with the "Krav" label. Any product bearing this symbol must live up to certain standards concerning environment, animal husbandry, health, and social responsibility (KRAV, 2004). Where performance standards or criteria employed are functionally defined, they provide producers with considerable latitude for innovation in designing products and production processes.

RESULTS

In this section, we discuss results from exploratory case study research related to the taxonomy. Empirical research for the case studies presented here was conducted in 2004 and 2005 within the framework of two EU-funded research projects. One project, *Innovative Utilities*, included three in-depth case studies of 'innovation-friendly public procurement' in a key public utility sector, telecommunications, and a further three case studies of an important public service sector, healthcare. The other project, *Innovation and Public Procurement*, provided an additional eight case studies of the procurement of innovations by government and public sector organizations in a number of EU member states. Together, the two projects generated a total of 14 case studies covering eight EU member states, plus Norway. For analytical purposes, though, the number of cases was effectively reduced to 12 by treating the three healthcare cases from the *Innovative Utilities* project as a single complex case. The comparative analysis of these cases was based primarily on the six (or four) case studies conducted for the *Innovative Utilities* project, but case studies compiled for the *Innovation and Public Procurement* project were referred to verification. Case summaries and details of the analysis are documented in Section 4 of the *Innovative Utilities* project's 10th Deliverable report *Towards an*

Innovation-Friendly Public Procurement Framework in Europe (Hommen, 2005).

The case studies were exploratory investigations of successful public procurements of innovation. Data collection from interviews and documentary sources, including archival materials and secondary sources, was conducted according to the methodological procedures for descriptive case study research specified by Yin (1994). Analytically, the research followed the inductive or 'theory-building' strategy outlined by Eisenhardt (1989). Thus, we began by conducting a 'within-case' analysis for each case, focusing on the identification of the main problems encountered and the solutions that were applied to them. Subsequently, we conducted a 'cross-case' analysis that involved relating each of the cases to the composite set of problems and solutions that could be derived from all of the cases. The series of problems or issues elaborated by these procedures could be subdivided into three basic categories corresponding to different levels of analysis: Institutional and Regulatory issues (macro-level), inter-organizational issues (meso-level), and Organizational (or Intra-organizational) issues (micro-level). The analysis sought to identify alternative solutions to common problems, and also to indicate the conditions under which particular solutions might be most appropriate. In this connection, we employed the taxonomy presented above as a comparative framework that could be used, among other things, to assess the "generalizability" of both problems and solutions across different types of cases. The analysis therefore involved situating cases within the taxonomy, which provided a basis for what Eisenhardt (1989) refers to as "shaping hypotheses" about variation across cases.

In these respects, then, our analysis of case studies from the two research projects referred to above involved testing the taxonomy. It was not possible to determine how well the taxonomy accounted for variation along the horizontal axis of 'evolution', since without exception the various cases under investigation all corresponded to the middle-stage of technology and market development, involving the adaptation of existing technologies to new contexts of application. However, it was possible to examine variation along the vertical axis of 'interaction', since the cases provided examples of all three categories of direct, co-operative, and catalytic public technology procurement. Cross-case comparisons revealed that although some issues in innovative public technology procurement appeared to be

evenly distributed and thus "universal", others were not. Some issues appeared to be more strongly associated with certain types than they were with others. These issues were those of external governance at macro-level, technological risk management at meso-level, and demand articulation at micro-level.

At the macro-level, *external governance* problems occurred mainly in co-operative procurement, though not exclusively. However, there were stronger requirements for effective regulation of inter-organizational conflict in co-operative procurement. These cases were large-scale projects involving multiple government or public-sector organizations, and also had serious implications for wide ranges of stakeholder groups. The findings indicated that there may be a higher incidence of external governance problems in inter-governmental projects, since they require cooperation and coordination among organizations with possibly conflicting agendas. As shown in one case, powerful government departments that are not represented within inter-governmental projects can still demand to have input into governmental decision processes. In such instances, effective backing from and communication with higher-level decision-makers may be essential to securing positive outcomes. Another observation was that national regulatory frameworks can require projects to avoid resistance from key stakeholders – e.g., unions opposed to workforce reductions – by, e.g., adopting goals acceptable to them.

Technological risk management was a meso-level issue that had an especially high profile in cases of co-operative procurement. We observed that technological risk *per se* also posed a serious problem in other types of project, suggesting that the causes of technological risk may be related primarily to uncertainty arising out of a lack of technological competence or the complexity of a given technology, rather than the type of societal need addressed or the kind of demand structure involved. However, our findings indicated that there may be greater potential for mismanagement of technological risk, due to poorly defined managerial responsibilities and procedures, in co-operative procurement. Our set of 'verification' cases supported this proposition, indicating that failures to assess risks properly could be directly attributed to lack of effective coordination and an ambiguous division of labor among multiple buyer organizations. One case also showed that risk management problems could be overcome by, among other things, centralizing legal and administrative functions and expertise.

At the micro-level, *articulation of demand,* requiring both the competence to define appropriate specifications and the exercise of sufficient market power to influence suppliers and other key actors, constituted a serious problem in cases of both cooperative and catalytic procurement, but not in cases of direct procurement. One explanation concerns the involvement of multiple buyer organizations in both cooperative and catalytic procurement. This condition contributes to greater severity of scheduling and co-ordination requirements, since it requires more complex patterns of interaction and more complicated processes of interactive learning among buyers than in direct procurement. All of these cases demonstrated the importance of market power. The chief difficulty encountered was that of developing, mobilizing, and coordinating competence among multiple buyers. Key solutions included 'pooling' technical expertise, elaborating effective structures and routines for integrative knowledge management, and relying upon 'performance standards' to place the burden of innovation squarely on suppliers.

DISCUSSION

In this article we have proposed and elaborated a taxonomy of innovative public technology procurement, meant both to guide research in this area and to inform strategies for the public procurement of innovations, including the design of policies and programmes. In the foregoing section, we have presented the results of exploratory case studies carried out in conjunction with the development of the taxonomy. In this section, we briefly discuss implications of our findings for theory, practice, and future research.

As stated, the case studies provided only a partial test of the taxonomy, since the selection of cases only permitted the examination of variation along one of two dimensions – i.e., the taxonomy's vertical axis of 'modes of interaction'. Lacking parallel sets of cases providing the same coverage of the early and late stages as we have obtained for the middle or 'adaptation' stage of technology and market development, we remain unable to address the taxonomy's horizontal axis of 'phases of evolution'. Moreover, since case studies can generate only indicative findings, even those conclusions that can be drawn from our research are at best propositions that require further empirical testing.

Notwithstanding these limitations, the case study results reported above indicate that the taxonomy makes useful distinctions among 'direct', 'co-operative' and 'catalytic' modes of interaction in innovative public technology procurement. These categories are not only fruitful at several levels of institutional and organizational analysis, but also practically relevant for the planning and execution of innovative public technology procurement. In particular, our case studies indicate that co-operative technology procurement is especially problematic, compared to other types, in terms of external governance, the management of technological risk, and the articulation of demand. The last-mentioned issue may also be a serious obstacle to the success of catalytic technology procurement projects where multiple buyers are involved. Consequently, the design of multiple-buyer projects should, in selecting modalities (Cave & Frinking, 2003), pay special attention to stakeholder relations, the structure and operation of project teams in relation to risk and knowledge management, and the definition of product specifications. In addition, our case study findings have important implications beyond the project level. One strategic implication is that innovative public technology procurement programmes involving series of projects that include more than one mode of interaction should not assume that 'what works' in direct procurement projects will also work in co-operative and catalytic procurement projects – especially with regard to the issues addressed above.

We have noted that the taxonomy's distinctions among 'modes of interaction' did not account for variation with respect to some problems or issues, which might be 'universal' to innovative public technology procurement projects of all types. However, it may be premature to suggest that these problems are evenly distributed across all types, or that the taxonomy as a whole may be unable to account for the actual pattern of distribution. As mentioned, we have yet to explore the horizontal axis of 'phases of evolution.' Technological risk, for example, appears on the basis of the evidence discussed here to be a possibly 'universal' issue. However, we have investigated only cases corresponding to the middle or 'adaptation' stage of innovative public technology procurement, and the taxonomy suggests that much higher levels of risk could be encountered at both the early and late stages of market and technology development. As this example indicates, much more empirical research will be

required in order to provide an adequate basis for testing the entire taxonomy, despite positive initial results.

Of course, particular typologies and taxonomies are always useful for certain kinds of purposes and not others. We do not suggest that the taxonomy outlined here can potentially provide explanations and solutions for any and all problems that might be encountered in the design and implementation of innovative public technology procurement policies and programmes. Important factors or variables that are not taken into account by the taxonomy include project scale (or size), technological complexity, the pace of technological change within a given market context, and regulatory bottlenecks such as those recently addressed by the recent EC report on *Pre-commercial Procurement of Innovation* (National IST Research Directors Forum, 2006). We therefore recommend that the taxonomy presented in this article should not be used on an exclusive basis for designing and executing innovative public technology procurement policies and programmes. Rather, it should be used in combination with other relevant frameworks, such as Stock and Tatikonda's (2000) ITT typology, which is particularly well suited to matching technology and organization at the project level. Other useful frameworks and sources of guidance include both recent EC reports (e.g., Edler et al., 2005; Georghiou and Cave 2005) and guidelines published by national authorities (e.g., OGC, 2004).

ACKNOWLEDGEMENTS

The authors thank Olof Ejermo, Thomas Kaiserfeld, Annika Rickne, and Charles Edquist for comments on earlier drafts of this manuscript. The usual disclaimers apply.

NOTES

1. Theorized as s "learning-by-doing" carried out by firms within competitive markets, process innovation is essentially concerned with increasing efficiency and achieving optimal resource allocation of resources (Arrow, 1962). If this were the sole form taken by technical progress, Lundvall (2003, p. 3) has argued, "the end result would be stagnation, de-qualification of the labour force and technological unemployment."

2. The definition of CoPS refers to "multi-technology, multi-component products, often produced in multi-firm alliances, as a one-off or in small batches for specific customers" (Prencipe 2003: 114).

3. In this spirit, Boisot (1995, p. 211) has argued that "Design and development, contrary to the way they are usually depicted, can never be reduced to the mere application of an existing stock of knowledge which itself remains unmodified by the exercise." Similarly, Nooteboom (2000, 189) holds that "exploitation and exploration are complements rather than substitutes; one can continue exploitation in a way that contributes to exploration at least up to the point that a breakdown of architecture occurs to form novel combinations.

4. This analysis is mainly concerned with micro-economic organization and focuses primarily on 'informal' rather than 'formal' institutions. In terms of the classification of institutional analysis proposed by Hollingsworth Rogers (2000, Table 1), institutions are not addressed here at the level of "norms, rules, conventions, habits [and] values" but rather at that of "*institutional arrangements*: markets, states, corporate hierarchies, networks, associations [and] communities."

REFERENCES

Abernathy, W. J., & Utterback, J. M. (1978). "Patterns of Industrial Innovation." *Technology Review,* 81: 41-47.

Arrow, K. (1962). "The Economic Implications of Learning by Doing." *Review of Economic Studies,* 29 (3): 155-173.

Asheim, B.T. (1996). "Industrial Districts as 'Learning Regions': A Condition for Prosperity?" *European Planning Studies, 4* (4): 379-400.

Asheim, B.T. (2001). "Learning Regions as Development Coalitions: Partnership as Governance European Workfare States? Concepts and Transformation." *International Journal of Action Research and Organizational Renewal, 6* (1): 73-101.

Asheim, B.T. & Gertler, M.S. (2005). "The Geography of Innovation: Regional Innovation Systems." In J. Fagerberg, D. C. Mowery & R.

R. Nelson (Eds.), *The Oxford Handbook of Innovation* (pp. 291-317). Oxford, UK / New York: Oxford University Press.

Bekkers, R. (2001). *Mobile Telecommunications Standards: GSM. TETRA, and ERMES.* Boston, MA: Artech House.

Berk, G. (1994). *Alternative Tracks: The Constitution of American Industrial Order, 1865-1917.* Baltimore, MD: Johns Hopkins University Press

Best, M. (2001). *The New Competitive Advantage*. Oxford / New York: Oxford University Press.

Boisot, M. (1995). *Information Space: A Framework for Learning in Organizations, Institutions and Culture*. London, UK: Routledge.

Bozarth, C. & McDermott, C. (1998). "Configurations in Manufacturing Strategy: A Review and Directions for Further Research." *Journal of Operations Management, 16*: 427-439.

Bozeman, B., & Dietz, J.S. (2001). "Research policy Trends in the United States: Civilian Technology Programs, Defence Technology, and the Development of the National Laboratories." In P. Larédo & P. Mustar (Eds.), *Research and Innovation Policies in the New Global Economy: An International Comparative Analysis* (pp. 47-78). Cheltenham, UK / Northampton, MA: Edward Elgar Publishing, Inc.

Brody, R.J. (1996). *Effective Partnering: A Report to Congress on Federal Technology Partnerships.* Washington, DC: US Department of Commerce, Office of Technology Policy.

Cave, J. & Frinking, E. (2003). "Public Procurement and R&D: Short Analysis of the Potential and Practices." In J.P. Gavigan (Ed). *Public Procurement and R&D: A JRC/IPTS-ESTO Fast Track Working Paper* (pp. 11-44). Paris, France: European Commission Joint Research Centre-Institute for Prospective Technological Studies, European Science and Technology Observatory.

Ceruzzi, P. (1998). *A History of Modern Computing,* Cambridge, MA: MIT Press.

Cooke, P. & Morgan, K. (1998). *The Associational Economy: Firms, Regions and Innovation*. Oxford, UK / New York: Oxford University Press.

Dalpé, R. (1994). "Effects of Government Procurement on Industrial Innovation." *Technology in Society, 16* (1): 65-83.

Coombs, R., Green, K., Richards, A. & Walsh, V. (Eds.). (2001). *Technology and the Market: Demand, Users and Innovation*. Cheltenham, UK: Edward Elgar.

De Grazia, V. (1998). "Changing Consumption Regimes in Europe, 1930-1970." In S., Strasser, C. McGovern & M. Judt (Eds.), "*Getting and Spending: European and American Consumer Societies in the Twentieth Century* (pp. 59-83) Cambridge, UK: Cambridge University Press.

Dess, G.G., Newport, S. & Rasheed, A.M.A. (1993). "Configuration Research in Strategic Management: Key Issues and Suggestions". *Journal of Management, 19* (4): 775-795.

de Vaus, D. (2001). *Research Design in Social Science*. London, UK / Thousand Oaks, CA / New Delhi, India: Sage Publications.

Dosi, G. (1982). "Technological Paradigms and Technological Trajectories." *Research Policy, 11*: 147-163.

Dutton, W.H. (Ed.). (1999). *Society of the Line: Information Politics in the Digital Age*. Oxford, UK: Oxford University Press.

Edler, J., Edquist, C., Georghiou, L., Rigby, J., Hafner, S., Hommen, L., Papadakou, M., Rolfstam, M. & Tsipouri, L. (2005, December). *Innovation and Public Procurement: Review of Issues at Stake* (Study for the European Commission). Brussels, Denmark: European Commission.

Edquist, C. & Hommen, L., (2000). "Public Technology Procurement and Innovation Theory." In C., Edquist, L., Hommen and L., Tsipouri (Eds.), *Public Technology Procurement and Innovation* 5-70. Boston, MA / Dordrecht / London, UK: Kluwer Academic Publishers.

Edquist, C., Hommen, L., & McKelvey, M. (2000). *Innovation and Employment: Product versus Product Innovation*. Cheltenham, UK: Edward Elgar.

Edquist, C., Hommen, L., & Tsipouri, L. (2000). "Analysis, Findings and Conclusions." In C., Edquist, L. Hommen, & L. Tsipouri (Eds.), *Public Technology Procurement and Innovation* 281-299. Boston, MA / Dordrecht / London, UK: Kluwer Academic Publishers.

Eisenhardt, K. (1989). "Building Theories from Case Study Research." *Academy of Management Review, 14* (2): 532-550.

European Council (2005). *Council Recommendation of 12 July 2005 on the Broad Guidelines for the Economic Policies*. (2005/601/EC) [Online] Available at http://ec.europa.eu/employment_social/employment_analysis/earnings/bepg_2005_601_ec_en.pdf. [Retrieved November 28, 2006].

Fligstein, N. (2001). *The Architecture of Markets: An Economic Sociology of Twenty-first Century Capitalist Societies*. Princeton NJ: Princeton University Press.

Florida, R. (1995). "Toward the Learning Region." *Futures, 27*: 527-536.

Franke, N., & Shah, S.K. (2003, January). "How Communities Support Innovative Activities: An Exploration of Assistance and Sharing Among End-users." *Research Policy, 32*: 157-178.

Fridlund, M. (1993). *The 'Development Pair' as a Link Between Systems Growth and Industrial Innovation: Cooperation Between the Swedish State Power Board and the ASEA company*. (Trita HST working paper 93/9). Stockholm, Sweden: Royal Institute of Technology (KTH), Department of History of Science and Technology.

Fukasaku, Y. (1999). "Public-private Partnerships for Developing Environmental Technology." *OECD STI Review,* 23: 106-130.

Garrard, G.A. (1998). *Cellular Communications: Worldwide Market Development.* Boston, MA: Artech House.

Gelsing, L. (1992). Innovation and the Development of Industrial Networks. In. Lundvall, B.-Å. (Ed.), *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning* (pp. 116-128). London, UK: Pinter Publishers.

Georghiou, L. & Cave, J. (Eds.). (2005, December). *Procurement for Research and Innovation. (*Report of an Expert Group on measures and actions to assist in the development of procurement practices favorable to private investment in R&D and innovation). Brussels, Denmark: European Commission.

Geroski, P.A. (1990). "Procurement Policy as a Tool of Industrial Policy." *International Review of Applied Economics, 42* (2): 182 – 198.

Glimstedt, H. (1995). "Non-Fordist Routes to Modernization of Production: Innovation and Political Construction of Markets in the Swedish Automobile Industry before 1960." *Business and Economic History, 24*: 243-53.

Glimstedt, H. (2001). "Competitive Dynamics of Technological Standardization: The Case of Third Generation Cellular Communications'." *Industry and Innovation,* I 8: 49-78.

Granovetter, M. & McGuire, C. (1998). "The Making of an Industry: Electricity in the United States." In M. Callon, (Ed.), *The Laws of the Markets* (pp. 147-173). London, UK: Basil Blackwell Publishers.

Grübler, A. (1989). "Diffusion: Long-term Patterns and Discontinuities." Paper presented at the International Conference on Diffusion of Technologies and Social Behaviour, 14-16 June, Luxembourg.

Haddon, L., & Silverstone, R. (1996). "*The Young, Elderly and Their Information and Communication Technologies*." (CICT Report No. 13). Brighton, UK: SPRU, University of Sussex.

Hawkins, R.W. (1995). "Enhancing the User Role in The Development of Technical Standards for Telecommunications." *Technology Analysis and Strategic Management, 7* (1): 21-40.

Herrigel, G. (1996). *Industrial Constructions: The Sources of German Industrial Power*. Cambridge, UK: Cambridge University Press.

Hidjefäll, P. (1997). *The Pace of Innovation: Patterns of Innovation in The Cardiac Pacemaker Industry*. Linköping, Sweden: Linköping University.

Hommen, L. (2003). "Third Generation Mobile Telecommunications - UMTS." In C. Edquist (Ed.), *The Fixed Internet and Mobile Telecommunications Sectoral System Of Innovation: Equipment Production, Access Provision and Content Provision* (pp. 129-161). Cheltenham, Glos., UK / Northhampton, MA: Edward Elgar Publishing.

Hommen, L. (Ed.), (2005). *Towards an Innovation-friendly Public Procurement Framework in Europe.* (Innovative Utilities Project Deliverable 10). Heidelberg, Germany: EURESCOM.

Hommen, L. & Manninen, E. (2003). "Second Generation Mobile Telecommunications – GSM." In. C. Edquist (Ed.), *The Fixed Internet and Mobile Telecommunications Sectoral System of Innovation: Equipment Production, Access Provision and Content Provision* (pp. 71-128). Cheltenham, Glos., UK / Northampton, MA: Edward Elgar Publishing.

Humphreys, P. & Simpson, S. (2005). *Globalisation, Convergence and European Telecommunications Regulation*. Cheltenham, Glos., UK: Edward Elgar Publishing.

Håkansson, H. (1989). *Corporate Technological Behaviour: Co-operation and Network*s. London, UK: Routledge.

Håkansson, H. & Johanson, J. (1993). "The Network as a Governance Structure: Interfirm Cooperation Beyond Markets and Hierarchies." In F. Grabher (Ed.), *The Embedded Firm* (pp. 35-51). London, UK: Routledge.

Kaiserfeld, T. (2000). "A Case Study of The Swedish Public Technology Procurement Project, 'The Computer in The School' (COMPIS), 1981 – 1988." In C., Edquist, L., Hommen, and L., Tsipouri (Eds.), *Public Technology Procurement and Innovation* 121-141. Boston, MA / Dordrecht / London, UK: Kluwer Academic Publishers.

Karlberg, L. A. (2004). "Tre IT-Bolag Fick Ramavatal med ESV." *Ny Teknik* [Online]. Available at www.nyteknik.se/pub/ipsart.asp?art_id=35569. [Retrieved November 5, 2004].

Kenney, M. & von Burg, U. (1999). "Technology, Entrepreneurship and Path Dependence: Industrial Clustering in Silicon Valley and Route 128." *Industrial and Corporate Change, 8* (1): 67-103.

Kleja, M. (2004). "IT-ministrar i Bråk om 24-timmarsmyndigheten." *Ny Teknik* [Online]. Available at http://www.nyteknik.se/pub/ipsart.asp?art_id=36700 [Retrieved November 5, 2004].

KRAV (2004). *The KRAV Standards Version of July 2004*. *Krav Kontroll AB*. [Online]. Available at http://arkiv.krav.se/arkiv/regler/Standards2004EditionJuly.pdf, [Retrieved January 5, 2005].

Laestadius, S. (2003). "Technology and the Market – Demand Users and Innovation." *Technovation, 23*: 782-783.

Langlois, R.N. (1992, Spring). "External Economies and Economic Progress: The Case of the Microcomputer Industry." *Business History Review, 66*: 1-50.

Langlois, R.N. (2002). "Digital Technology and Economic Growth: The History of Semiconductors and Computers." In B. Steil, D. Victor & R.R. Nelson (Eds.), *Technological Innovation and Economic Performance* (pp. 265-284). Princeton, NJ: Princeton University Press.

Langlois, R.N. (2003). "The Vanishing Hand: The Changing Dynamics of Industrial Capitalism." *Industrial and Corporate Change, 12* (2): 351-385.

Layton E. (1974). "Technology as Knowledge." *Technology and Culture,* 15: 31-41.

Lundvall, B.-Å. (1985). *Product Innovation and User-producer Interaction*. Aalborg, Denmark: Aaalborg University Press.

Lundvall, B.-Å. (1988). "Innovation as an Interactive Process: From User-producer Interaction to the National System of Innovation." In G. Dosi, C. Freeman, G. Silverberg, and L., Soete (Eds.), *Technical Change and Economic Theory* (pp. 349-369). London, UK: Pinter.

Lundvall, B.-Å. (2003). Product Innovation and Economic Theory (Unpublished Mimeo). Aalborg, Denmark: Department of Business Studies, Aalborg University.

Lundvall, B-Å. & Archibugi, D. (2001). "Introduction: Europe and the Learning Economy." In D. Archibugi & B.-Å. Lundvall (Eds.), *The Globalizing Learning Economy* (pp. 1-17). Oxford, UK / New York: Oxford University Press.

Lundvall, B.-Å. & Johnson, B. (1994). "The Learning Economy." *Journal of Industry* Studies, 1: 23-42.

Lundvall, B.-Å & Maskell, P. (2000). "Nation States and Economic Development – From National Systems of Production to National Systems of Knowledge Creation and Learning." in G.L. Clark, M.P. Feldman & M.S. Gertler (Eds.), *The Oxford Handbook of*

Economic Geography (pp. 373-394). Oxford, UK / New York: Oxford University Press.

Lundvall, B.-Å. & Borrás, S. (2004). "Science, Technology and Innovation Policy." In J. Fagerberg, D.C. Mowery and R.R. Nelson (Eds.), *The Oxford Handbook of Innovation* (pp. 599-631). Oxford, UK / New York: Oxford University Press.

Malerba, F. (1992). "Learning by Firms and Incremental Economic Change." *Economic Journal, 102*: 845-859.

Mansell, R., & Silverstone, R., (Eds.). (1996). *Communication by Design: The Politics of Information and Communication Technologies*. Oxford, UK: Oxford University Press.

Mansell, R., & Steinmueller, W.E. (2000). *Mobilizing the Information Society: Strategies for Growth and Opportunity*. Oxford, UK / New York: Oxford University Press.

Meyer-Krahmer, F. (2001a). "Industrial Innovation and Sustainability – Conflicts and Coherence." In D. Archibugi & B.-Å. Lundvall (Eds.), *The Globalizing Learning Economy* (pp. 177 – 194). Oxford, UK / New York: Oxford University Press.

Meyer-Krahmer, F. (2001b). "The German Innovation System." In P. Larédo & P. Mustar (Eds.), *Research and Innovation Policies in the New Global Economy: An International Comparative Analysis* (pp. 205–252). Cheltenham, UK / Northampton, MA: Edward Elgar Publishing, Inc.

Morgan, K. (1997). "The Learning Region: Institutions, Innovation and Regional Renewal." *Regional Studies, 31*: 491-504

Mowery, D.C. (2001a). "The United States National Innovation System after the Cold War." In P. Larédo & P. Mustar (Eds.), *Research and Innovation Policies in the New Global Economy: An International Comparative Analysis* (pp. 15-46). Cheltenham, UK / Northampton, MA: Edward Elgar Publishing, Inc.

Mowery, D.C. (2001b). "Is the Internet a US Invention? An Economic and Technological History of Computer Networking." Paper presented at the DRUID Conference, 12-15 June, Aalborg, Denmark.

National IST Research Directors Forum (2006, March). *Pre-commercial Procurement of Innovation – A Missing Link in the*

European Innovation Cycle (Report of the Working Group on Public Procurement in Support of ICT Research and Innovation). Brussels, Denmark: European Commission.

Nelson, R. & Winter, S. (1982). *An Evolutionary Theory of Economic Change*. Boston, MA: The Bellknap Press of Harvard University Press.

Nilsson, H. (1994). "Technology Procurement for Market Transformation – A Customer Tool for Sustainable Design and Manufacturing" (Discussion paper). Stockholm, Sweden: NUTEK.

Nooteboom, B. (2000). *Learning and Innovation in Organizations and Economies*. Oxford, UK: Oxford University Press.

NUTEK. (2006). *Design for Environment*. [On-line] Available at www.nutek.se/sb/d/113. [Retrieved April 29, 2006].

Oak Ridge National Laboratory. (2004). Federal Energy Management Program. [On-line] Available at www.ornl.gov/sci/femp. [Retrieved January 13, 2005].

Office of Government Commerce (2004). *Capturing Innovation: Nurturing Suppliers' Ideas in the Public Sector*. London, UK: Author.

Ogcbuyingsolutions (2005). [On-line] Available at www.ogcbuying solutions.gov.uk. [Retrieved January 13, 2005]

Powell, W.W. & Grodal, S. (2004). "Networks of Innovators." In Fagerberg, J., Mowery D.C. & Nelson, R.R. (Eds.), *The Oxford handbook of innovation* (pp. 56-85). Oxford, UK / New York: Oxford University Press.

Prencipe, A. (2003). "Corporate Strategy and Systems Integration Capabilities: Managing Networks in Complex Systems Industries." In A. Prencipe, A. Davies & M. Hobday (Eds.), *The Business of Systems Integration* (pp. 114-132). Oxford, UK / New York: Oxford University Press.

Rogers Hollingsworth, J. (2000). "Doing Institutional Analysis: Implications for The Study of Innovations." *Review of International Political Economy, 7* (4): 595-644.

Rosenberg, N. (1972). "Factors Affecting the Diffusion of Technology." *Explorations in Economic History, 10* (1): 3-33

Rothwell, R. (1984, April). "Creating a Regional Innovation-oriented Infrastructure: The Role of Public Procurement." *Annals of Public and Cooperative Economics, 55* (2): 159-172.

Rothwell, R. (1994). "Issues in User-producer Relations in the Innovation Process: The Role of Government." *International Journal of Technology Management, 9* (5, 6 &7): 629-649.

Rothwell, R. & Zegveld, W. (1982). *Industrial Innovation and Economic Policy*. London, UK: Frances Pinter.

Sabel, C.S. & Zeitlin, J. (Eds.). (1997). *Flexibility and Mass Production in Western Industrialisation*. Cambridge, UK: Cambridge University Press

Sahal, D. (1981). *Patterns of Technological Innovation.* New York: Addison Wesley.

Saxenian, A.-L. (1994). *Regional Advantage: Culture and Competition in Silicon Valley and Route 128.* Cambridge, MA: Harvard University Press.

Saxenian, A.-L. (1999). "Comment on Kenney and von Burg: 'Technology, Entrepreneurship and Path Dependence: Industrial Clustering in Silicon Valley and Route 128'." *Industrial and Corporate Change, 8* (1): 105-110.

Sayer, A. (1992). *Method in Social Science: A Realist Approach* (2nd ed.). London, UK and New York: Routledge.

Schumpeter, J.A. (1911). *The Theory of Economic Development* (R. Opie, trans.) (1934 English ed.). Cambridge, MA: Harvard University Press.

Schumpeter, J.A. (1939). *Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process.* New York and London, UK: McGraw Hill.

Scranton, P. (1997). *Endless Novelty: Specialty Production and American Industrialization, 1865-1925*. Princeton, NJ: Princeton University Press

Silverberg, G. (1987). "Technical Progress, Capital Accumulation and Effective Demand: A Self-organization Model." In D. Batten, J. Casti & B. Johansson (Eds.), *Economic Evolution and Structural Adjustment* (pp. 116-144). New York: Springer Verlag.

Silverberg, G. (1990a). "Adoption and Diffusion as a Collective Evolutionary Process." In Freeman C. & Soete, L. (Eds.), *New Explorations in the Economics of Technological Change* (pp. 177-192). London, UK: Pinter Publishers.

Silverberg, G. (1990b). "Dynamic Vintage Models with Neo-Keynesian Features." In OECD (Ed.), *Technology and Productivity: The Challenge for Economic Productivity*. Paris, Paris: OECD.

Silverberg, G., Dosi, G. & Orsenigo, L. (1988). "Innovation, Diversity and Diffusion: A Self-organization Model." *Economic Journal, 98*: 1032-1054.

Silverstone, R. & Haddon, L. (1997). "The Role of AC Services in Preventing Social Exclusion in the Emerging Information Society" (FAIR Working Paper No. 28). Brighton, UK: Graduate Research Centre in Culture and Communication, University of Sussex.

"Single Face to Industry." (2004). [On-line] Available at http://www.eh.svekom.se/index.html. [Retrieved November 2, 2004]

SKI (2005). Statens & Kommunernas Indköbsservice A/S [On-line] Available at http://www.ski.dk/. [Retrieved January 13, 2005]

Smith, K. (1997). "Economic Infrastructures and Innovation Systems." In C. Edquist (Ed.), *Systems of innovation: Technologies, Institutions and Organizations* (pp. 86-106). London, UK: Pinter – Cassell.

Statskontoret (2000). *24-timmarsmyndighet Förslag till Kriterier för Statlig Elektronisk Förvaltning i Medborgarnas Tjänst..* Statskontoret 2000:21. [On-line] Available at www.statskontoret.se/upload/Publikationer/2000/200021.pdf. [Retrieved November 5, 2004].

Statskontoret (2002, May 23). *Interconnected Government. A Proposal for Strengthening Central Co-ordination of E-government Development Efforts*. [On-line]. Available at www.statskontoret.se/upload/Publikationer/2002/200207B.pdf. [Retrieved November 5, 2004].

Stock, G.N., & Tatikonda, M.V. (2000). "A Typology of Project-level Technology Transfer Processes." *Journal of Operations Management, 18*: 719-737.

Teubal, M., Yinnon, T., & Zuscovitch, E. (1991). "Networks and Market Creation." *Research Policy, 20:* 381-392.

Tidd, J., Bessant, J. & Pavitt, K. (1997). *Managing Innovation: Integrating Technological, Market and Organizational Change*. Chichester, UK: John Wiley & Sons.

Turner, J.H. (1992). *The Structure of Sociological Theory*. Belmont, CA: Wadsworth Publishing Company.

Utterback, J.M. (1994). *Mastering the Dynamics of Innovation: How Companies Can Seize Opportunities in the Face of Technological Change*. Boston, MA: MIT Press.

Vattenfall (2004, November 17). "Vattenfall to Invest in Wind Energy Technology in the Sound." *Press Release*. [On-line]. Available at www.vattenfall.com. [Retrieved November 19, 2004].

von Hippel, E. (1988). *The Sources of Innovation*. Oxford: Oxford University Press.

von Hippel, E. (2005). *Democratizing Innovation*. Cambridge, MA: MIT Press.

Westling, H. (1996). *Co-operative Procurement: Market Acceptance for Innovative Energy-efficient Technologies*. NUTEK B1996:3. Stockholm, Sweden: NUTEK.

Westling, H. (2000). *Implementing Aagreement on Demand-side Management Technologies and Programmes*: Final Management. Report. Annex III: Co-operative Procurement of Innovative Technologies for Demand-side Management (EI 6:2000). Stockholm, Sweden: Swedish National Energy Administration.

Zeitlin, J. & Herrigel, G. (2000). *Americanization and its Limits: Reworking US Technology and Management in Post-war Europe and Japan.* Oxford, UK: Oxford University Press.

Yin, R.K. (1994). *Case Study Research: Design and Methods*. Thousand Oaks, CA / London, UK / New Delhi, India: Sage Publications.