1. PUBLIC TECHNOLOGY PROCUREMENT AND INNOVATION THEORY

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1. INTRODUCTION

Public technology procurement (PTP) occurs when a public agency places an order for a product or system which does not exist at the time, but which could (probably) be developed within a reasonable period. Additional or new technological development work is required to fulfil the demands of the buyer. This is the 'ideal type' of public technology procurement.

In contrast to 'public technology procurement', regular 'public procurement' occurs when public agencies buy ready made 'simple' products such as pens and paper – where no R&D is involved. Only price and performance of the (existing) product is taken into consideration when the supplier is selected.

Public technology procurement can also be contrasted with private technology procurement. Both processes involve a buyer's purchase from a supplier of a not-yet-existing product or system whose design and production will require further, if not completely novel, technological development work. The main difference between the two kinds of technology procurement is that in private technology procurement, the buyer is a private business organisation, not a public agency.[1]

In capitalist economic systems, where markets are effective mechanisms for articulating and satisfying most economic needs or demands, the point of departure in the application of public technology procurement must be the satisfaction of *genuine* social needs – in other words, specific societal needs unlikely to be met by the market. The products and systems that are developed – and the technical change that enables their provision – as the result of public technology procurement must therefore be targeted to solve specific problems.

On the basis of the socio-economic needs identified, the procuring agency specifies the 'functional demands' of the product or system required to satisfy these needs.

[1] We will deal extensively with private technology procurement in part 3 of this chapter, below.

This demands a highly developed competence on the part of the procuring organisation. Close collaboration between procurers and suppliers is also a necessary element in effective technology procurement.

Public technology procurement has been used as an instrument of innovation policy in the defence material sector in many countries. It has also proven to be an extremely potent means of influencing the speed and direction of innovation on the civilian side in some countries – usually in traditional infrastructure development. In addition, it has served to enhance the competitiveness of those firms successfully meeting the demands and thereby winning the contracts. Such procurement was, for example, highly instrumental in the consolidation of some firms of a Swedish origin which are currently large and international. Examples are Ericsson and ABB.[2]

In spite of its great practical value as an innovation policy instrument, public technology procurement has not received a commensurate level of serious attention in the research and theoretical literature on innovation. In economic policy making, moreover, there now appears to be a corresponding disregard for public technology procurement. Recent policy developments in the European Union, in particular, indicate that this situation is not simply the consequence of oversight, but is to a large extent the product of systematic neglect.[3] For policy makers and public authorities in the European Union, the long-term result of such neglect could be a seriously diminished capability for initiating processes of economic growth based on innovation.

The project of economic integration, central to the policy agenda of the European Union for the past decade, has focused on the creation of a common framework for economic activity. Both the Single European Act and the Maastricht Treaty have sought to lay key foundations for a convergence in real incomes and living standards across the countries and regions of the Union. This was to be achieved through means such as completion of the internal market, common regulatory frameworks, and ultimately a common currency. In this policy context, stimulating innovation has figured less importantly than achieving economies of scale, and only 'regular public procurement', in the sense discussed above, has been the focus of debate and legislation. Public technology procurement has largely been 'exempted' from the policy arena.

In this discussion, we will present the case for a serious reconsideration of public technology procurement as an instrument of innovation policy, making special reference to the current situation in the European Union and its member states. We will begin, in this first part, by outlining the main elements of past and present debates about public technology procurement, the current EU policies regarding public procurememfi, and their underlying theoretical rationale. In subsequent parts of the discussion we will develop an alternative perspective, based on theory and research concerning the economics of technological innovation. We will proceed from developing a typology of different kinds of public technology procurement and their relation to other kinds of innovation policy to considering the nature of (non-public) technology procurement as

[2] Public technology procurement has been dealt with previously elsewhere (Edquist, 1994; Edquist, 1996).

[3] This situation may be changing. Very recently, DG XVII of the European Commission has begun to discuss the use of public technology procurement as a policy instrument.

an economic phenomenon. Returning to our main topic, we will elaborate a general theoretical perspective on public technology procurement – a perspective that can serve as the basis for its utilisation as an instrument of innovation policy.

1.1 Debating Public Technology Procurement

The 'exemption' of public technology procurement from policy making and policy debates in the European Union is clearly indicated by the absence, in the recent EU "Green Paper" (European Commission, 1997) on public procurement policy, of any reference to the role of governments and public agencies in stimulating innovation through public technology procurement.[4] Instead, the "Green Paper" deals mainly with regular public procurement from the standpoint of achieving savings in public expenditure and introducing competitive conditions into the award of public supply contracts. The regulatory framework already created by the EU for these purposes is simply re-affirmed.

The current system of EU procurement rules and their enforcement by the EU and member states were developed in the early 1990s, as a result of both the establishment of a single European market and the need to rationalise and enforce effectively previously existing EU procurement regulations. The objectives were to eliminate artificial barriers to trade and reduce unnecessary differences in regulations. The EU policy regarding public technology procurement has been contained within this broader initiative, which has been almost exclusively concerned with the *regulatory* aspect of policy – i.e., the rules governing public procurement, including public technology procurement. However it is possible to identify another policy dimension that has been largely ignored. It concerns the *strategic* aspect – i.e., the use of public technology procurement as an instrument of innovation policy by the EU or by national government agencies.

When it is carried out by public agencies, procurement is not simply an economic but also a political phenomenon.[5] It is not surprising, therefore, that the development of EU policy on public procurement has been ideologically charged to some extent. Generally speaking, two ideologies have been counterposed to one another: a 'free market' orientation, which "emphasises the need to exclusively apply commercial criteria when awarding the contract" and an 'interventionist' orientation, which "regards public procurement as an instrument to realise social and economic objectives wider than mere efficiency in the use of public money" (Martin 1996: 41).

Of these two approaches to procurement, the first, or 'free market', orientation has clearly been the dominant influence in the development of the EU rules regarding public procurement. It finds a theoretical basis in classical 'economic efficiency' principles

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[4] The only exception to this rule is a discussion of the potential role of public procurement as a vehicle for the achievement of environmental policy objectives. Even in this context, however, the main emphasis is on regulatory standards. Technological innovation, as such, is not mentioned. (European Commission, 1997: chap. 5 - VI)

[5] The political and institutional dimensions of procurement are clearly indicated by the existence of various national models of public technology procurement, as discussed below in section 1.2 of this chapter.

that regard the maximisation of competition as the chief means of reducing costs, increasing public savings, and guaranteeing the 'fair and equitable' use of taxpayers' money (Ponssard and Pouvourville 1982: 6 - 7). This position has been buttressed by a large body of economic research and analysis indicating that broader competition in tendering or bidding on public contracts in the European Union will not only result in public savings but also promote macro-economic growth through restructuring and adjustment (Baldwin, 1987; Finsinger, 1988; McLachlan, 1985; Parker, 1990; Tovias, 1990; Utterly & Harper, 1993).

The second, or 'interventionist', orientation in public procurement has been severely limited by the EU procurement rules, though some allowances are still made for it. Although alien to the spirit of the EU rules, it is highly consistent with the past practices of most national governments of EU member states. Many of them, especially under the influence of Keynesian doctrines during the postwar period (Roll, 1982), have made extensive use of public procurement, including PTP (Public Technology Procurement), as an instrument of socio-economic policy, including industrial policy (Geroski, 1990).

It is possible to distinguish at least five instrumental uses of this general approach to the use of public procurement as a tool of policy (Jeanrenaud, 1984). First, procurement (though not necessarily PTP) has been used as a means of increasing overall demand and stimulating economic activity, thereby creating employment (Keyzer, 1968). Second, it has been used to protect national industry against foreign competition (Goodman & Saunders, 1985; McLachlan, 1985). Third, procurement has been used to improve the competitiveness of certain industrial sectors, by linking secure access to public supply contracts to commitments on the part of national champions to invest in R&D (Jeanrenaud & Meyer, 1984). Fourth, it has been used to remedy regional disparities, so as to attain redistributory objectives (Jeanrenaud, 1984). A fifth use is that of using procurement to create jobs for marginal sections of the labour force (McCrudden, 1994).

Of these five instrumental uses of public procurement, nearly all have in effect been rejected in principle, if not entirely in practice, by the EU regime governing public procurement. From an integration policy perspective, "the Commission has followed a straightforward economic efficiency approach to the regulation of public procurement, thereby neglecting other perspectives applied at national level" (Martin 1996: 89). However, some recognition has been afforded to the third use, that of enhancing "competitiveness". This may be largely due to the fact that this use of procurement is most consistent with the general principles and aims of the economic efficiency approach, which ultimately seeks to promote economic growth through improving the competitiveness of firms and nations.

A concern with the competitiveness of European industry and firms based in EU member states can be said to be fundamental to the EU regime for public procurement. The Cecchini Report, which ushered in the current EU procurement regime, gave considerable attention to the importance of improving "the rate of innovation, investment and growth in the sectors enjoying the benefits of restructuring, with positive effects on their international competitiveness" (WS Atkins Management Consultants and Associates 1988: 7). The report stressed viewing competition policy on an EU-wide basis, permitting both national and transnational mergers so that world-league EU firms could be built (Business International Ltd. 1991: 6 - 7). In this respect, the EU can be said to remain committed to "competitiveness" as an instrumental use of procurement, particularly in sectors where "European champions" may now be required to replace national ones (Hartley, 1987).

In addition to its 'competitiveness' ethic and ultimate concern with fostering economic growth, the EU procurement regime has, in practice, been required to make some concessions to national-level public interest. In case law, it has had to achieve compromises between the forces of economic cohesion and those of market integration (Snyder, 1990). And, more generally, it has had to recognise that in certain contexts, "overwhelming importance granted to the pursuit of efficiency is regarded as detrimental to wider administrative and political aims" (Parsons, 1988).

Where the 'wider administrative aims' in question are those of enhancing competitiveness in the form of innovation, this may involve the limitation or even suspension of 'competition'. The EU procurement regime is therefore largely permissive, rather than restrictive, in such cases – providing that the argument for competitiveness can be made. Even though EU policy may have altered some of the basic 'rules of the game', public technology procurement remains an area in which national governments and public agencies continue to enjoy considerable autonomy. Thus, the continued existence of various national models of PTP should not be considered moribund or irrelevant in the context of European integration.

The EU has neglected the *strategic* dimension of public technology procurement, which has been dealt with only by relegating it to the national level. Even at this level, moreover, the EU has not directly addressed the 'interventionist' aspects of public technology procurement, except in a negative way. The EU procurement rules have, it is true, allowed for the continuation of public technology procurement in public supply contracts through certain special tendering procedures, permissible exemptions from the regular procurement rules, and a flexible regime of enforcement (Westling, 1996: Appendix 5).[6] However, this has been done without an explicit policy rationale – only the implicit understanding that these are necessary accommodations of national and sectoral interests.

Concerning the *regulatory* dimension, EU legislation has paid considerable attention to the establishment of competitive market conditions affecting the technology procurements of public agencies. Competition has been strengthened through the reduction of protectionism, the imposition of requirements for more transparent tendering procedures in formerly 'excluded' sectors (water, energy, transport and telecommunications), and complementary initiatives aimed at the liberalisation of publicly owned 'natural monopolies' (Business International Ltd., 1991). These measures have diminished the number of sectors in which public technology procurement can be readily used as an instrument of innovation policy, and it has discouraged this from being done as a matter of course, even in those sectors where it remains possible. The present EU legislation implicitly regards such intervention as an aberration – a deviation from the legalised norm of anonymous 'market' relationships.

[6] See the further discussion in section 1.4 of this chapter, below.

Given these circumstances, it is not immediately possible to open a dialogue with current EU policy on public technology procurement. Several preliminary steps are required. First, it is necessary to refer to practical and theoretical arguments concerning the interventionist uses of public technology procurement which have hitherto been excluded from debates concerning the development of the EU regime governing public procurement. Second, it is necessary to investigate the theoretical rationale which underlies the current EU policy and motivates its neglect of innovation. This rationale can then be counterposed to an alternative perspective.

Later parts of this discussion are devoted to an examination of the theoretical and research literature concerning technology procurement (including technology procurement in the private sector), and the arguments that are offered for and against the use of public technology procurement as an instrument of innovation policy. The last section (1.4) of this part of the chapter is largely concerned with the theoretical rationale underlying the present EU procurement regime. Before proceeding to take up that topic, it will be appropriate to refer, at least briefly, to arguments about the actual practice of public technology procurement in different national contexts. These arguments, reviewed in the next two sections (1.2 and 1.3) of this chapter, foreshadow the alternative perspective that will be developed in subsequent parts of the chapter.

1.2 Practices of Public Technology Procurement

Implicitly, at least, the EU regime governing public procurement regards public technology procurement as a practice at variance with sound economics, and for this reason merely tolerates its practice at the national level. Accordingly, it can be fairly stated that EU policy does not directly address public technology procurement. To understand the reasons for this conscious 'oversight' it is useful to consider some of the main features of the practice of public technology procurement in EU member states and in other countries from an historical and comparative perspective.

In many Western European countries, there has been a relative lack of reference to technological innovation in public procurement policies. Where this condition has been present – as, for example, in countries such as Sweden – much of the national effort with respect to public technology procurement has often been concentrated in defence and other strategically important public sector domains. However, there have been relatively weak attempts to encourage the commercialisation of results, by such means as requiring contractors to diffuse research results and promoting the development of spin-off companies capable of commercially exploiting the new technologies developed through PTP.

Instead, the main focus has been on developing close relationships between public agencies and large firms deemed capable of becoming 'national champions'. As we will illustrate below, this policy orientation has not always worked to the benefit of the national economies involved. It is not surprising, therefore, that current EU policies regarding public procurement express little interest or confidence in public technology procurement as a potential engine of economic growth.

With respect to the problematic economic behaviour of 'national champions', the experience of Sweden is typical of the more general pattern in Western European countries that are now EU member states. In Sweden, public technology procurement has been characterised by informed public purchasing and the exercise of a fairly high level of technological capacity (or 'user competence') on the part of clients during the strategic stages of technical specification and product development. These features of PTP have, for example, been credited with playing an important role in the successful development of the telecommunications industry in the Nordic countries (Granstrand & Sigurdson, 1985). The fairly high success rate of public technology procurement in promoting industrial development in Sweden has meant that PTP has been widely accepted by the general public, by a large segment of industry, by trade unions and by most political parties.

The Swedish practice of PTP has featured the common occurrence of close relationships between public agencies and major firms: "This has, to a large extent, taken the form of long-term intimate collaboration on joint development between large manufacturers and large customers – a type of industrial relationship for which the ... term 'development pair' has been coined" (Fridlund 1993: 4). This is perhaps an extreme case of a more "generally accepted" historical tendency in Europe for government selection, through the advantage conferred to innovators by the concentration of purchases by public agencies, "to favour the emergence of national champions" (Dalpé 1994: 73). However, national economies have not always been well served by national champions. This is also increasingly the case in Sweden – a country which has in the past excelled in 'growing' large, multi-national corporations but has not succeeded in developing a very large population of technology-based small and medium-sized enterprises. Trends towards internationalisation have made the multi-national corporations increasingly independent of Sweden, but Sweden remains as dependent as ever upon them (Edquist & Lundvall, 1993: 291 - 292). During the later half of the 1990s this problem has become more severe. Several large Swedish companies have merged with firms in other countries, with the consequence that the head offices have left Sweden. Examples are Pharmacia, Stora, Nordbanken and Astra.

However, the past and current problems that Sweden and other member states have experienced with capturing the benefits of PTP should not be regarded by EU policy makers simply as a justification for disregarding the developmental potential of public technology procurement. There are various 'national' policy traditions and approaches to public technology procurement from which it is possible to draw both positive and negative lessons that might contribute to a 'strategic' perspective on PTP for the European Union.[7] Of particular relevance to the present discussion is the US approach to public technology procurement, which emerged in the developmental context of the United States' postwar technology policy.

[7] For example, Japan minimises direct public purchasing (Freeman 1988: 331) but relies on public agencies to play an important role in the organisation of industrial 'clusters' (Carlsson and Stankiewicz 1995: 43). Japan's policy offers a 'network' model (Allen 1981; Vogel 1980) that may be of some interest to EU policy makers.

Certain features of the US experience are well known – in particular, the central role of the US defence program. The extent to which defence-related spending and defence-related procurement historically dominated the US innovation system has been widely recognised (Mowery & Rosenberg, 1993). Similarly, the degree to which defence contracting was responsible for the origin and subsequent development of several major commercial industries in the US – for example, aeronautics (Mowery & Rosenberg, 1982), semiconductors (Levin, 1982), and computers (Flamm, 1987) – has been documented in numerous studies. The protectionism of US procurement policies under the "Buy American Act" is also a widely known feature of the US model of PTP (Goodman & Saunders, 1985).

There are, however, other equally important though less frequently noted elements of the US model – including the influence of anti-trust policy and the commercial orientation of much US procurement for defence purposes. It has been observed, for example, that in public technology procurement supporting the development of computers and semi-conductors, "the US military and intelligence communities pursued a very different path from that followed by Western European governments" (Mowery 1995: 7). In particular, they awarded contracts not only to established firms but also to new ones, and supported projects undertaken by firms that were mainly interested in commercial markets (Flamm 1988: 134).

These agencies also sought to disseminate technical information on both computers and semi-conductors across a broad industrial community, rather than confining it to a 'military enclave' (Levin, 1982). And, they made sure of having more than one supplier for a given procurement through a policy of 'second sourcing', which "served both to diffuse knowledge of advanced technology amongst a range of firms, and to facilitate the entry of new firms to the market" (Geroski 1990: 188). These practices led to substantial "spillovers" from military procurement of defence technology into civilian applications. They also fostered the development of competition in procurement contracts. Such practices "appear to have been motivated by policymakers' belief that in order to create a viable military supplier community, a larger commercial industry was needed" (Mowery 1995: 7).

Of course, the various identifiable national models of PTP are not static. The US model has been in transition since the 1980s, and the Swedish model is also changing. Both have been affected by intensified international competition in sectors that were formerly national 'strongholds', the rise of liberal or neo-liberal orientations in economic policy and, more recently, the end of the cold war. In the US, in particular, this has led to an ambiguous "new direction" in technology policy (Ham & Mowery, 1995), motivated in part by extensive controversy on the effectiveness of defence procurement practices (Kanz, 1993).

In the EU, which now includes Sweden, there has been since 1985 a "revolution in ... public procurement policy", marked by the subsequent passage of legislation and other measures related to the consolidation in 1992 of a single European "Internal Market" (Martin 1996: 16). However, this revolution has occurred with little if any reference to public *technology* procurement and there has been no apparent attempt to learn from the experience of the US and other countries in the area of PTP. This is unfortunate, since in many other jurisdictions the debate on public procurement, including technology procurement, has focused attention on failures and successes in public technology procurement and thereby helped to clarify the justifications for its continued use as an instrument of public innovation policies.

1.3 Failures and Successes in Public Technology Procurement

In the US, at least, debate on public technology procurement has been fuelled by the publication of works documenting notable failures in PTP (Cohen & Noll, 1991). To name but one fairly recent US example, the attempt to develop civilian uses for an 'on the shelf' military technology for the generation of nuclear power was spectacularly unsuccessful. Due to premature commitment to a specific commercial application, the liquid metal fast breeder reactor (LMFBR) project at Clinch River, Tennessee, was terminated in 1983 in view of the complete lack of commercial consequences after the expenditure of more than five billion US dollars (Nelson, 1984).[8]

Much of the recent debate on public procurement, including but certainly not limited to the discussion of failures in PTP, has drawn attention to the distorting effects on rational economic decision making of what may be broadly termed 'political considerations' (Burton, 1983). Risk avoidance on the part of elected officials, their tendency to favour short-term projects with fairly immediate pay-offs, and their preference for decisions that have no clear distributional impact (and hence, no electoral consequences) are three such characteristics of public sector demand that have been alleged to have adverse consequences on procurement decisions in particular (Cohen & Noll, 1991). On these grounds, the case can be made that "elected officials tend to be reluctant to make procurement decisions, which, according to innovation theory, could favour innovation" (Dalpé 1994: 74).

These problematic aspects of behaviour on the part of public procurers can be exacerbated by the effects of public procurement contracts on the behaviour of potentially innovative firms. Public buyers tend to maintain the same suppliers over long periods of time, often on a sole-source basis, thus inducing them to specialise in public supply contracts (Ponssard & Pouvourville, 1982). Firms with guaranteed access to public supply contracts may tend to neglect acquiring new markets and commercial applications for their products (Cohendet & Lebeau, 1987; Zysman, 1977). Both the buyer and the supplier may tend to maintain the same technology, in order to avoid the risks of innovation and the costs of adjusting to new relationships (Williams & Smellie, 1985). And, as recent evidence from the US suggests, when suppliers limited to a single client do innovate, the potential for transfer to other applications may be minimal, even though this is an intended goal of a procurement programme (Barfield, 1994).

[8] Europe, too, has had its failures. In Sweden, an often cited procurement failure is the Marviken nuclear power reactor contracted by Statens Vattenfallsverk (Granstrand and Sigurdson 1985: 10). The British-French Concorde programme is widely acknowledged to have resulted in a kind of technological success — but not a commercial one (Eads & Nelson, 1971).

There are thus both occasional failures and enduring problems in public technology procurement. Governments and public agencies may fail, just like markets. However, there is also a strong case to be made for PTP from the standpoint of the economics of innovation. Arguments for public technology procurement can be derived from more general arguments for public intervention in technological development. Following Blume (1981: 9 - 10), these can be summarised as private sector problems of underinvestment, knowledge imperfections, underdevelopment, high risk, undercapacity in terms of necessary economies of scale, and disinterest in strategic issues such as national security (c.f. Granstrand and Sigurdson 1985: 7 - 8).

Since public technology procurement is a demand side policy instrument, the arguments in its favour are more specifically related to the nature of demand, rather than that of supply or investment. A general argument for specifically *public* technology procurement is that public agencies are better able to make demands for technological solutions to problems that private actors are either unable or insufficiently motivated to address. The case for PTP can thus be made on the grounds that strong social needs or demands often correspond to normally weak rates of short term private return on investments in innovation (Mansfield & Rapoport, 1977). However, the most frequently cited arguments in favour of PTP are those which refer primarily to certain special characteristics of demand: strategic importance, largeness of scale, high risks, and high costs (Rothwell & Zegveld, 1982). With respect to these problems, there is a fairly large body of empirical research demonstrating that public demand can be a positive, though not exclusive, factor in the promotion of technological development.[9] Further, it has been demonstrated convincingly that under certain market conditions, in sectors of significant technological content, the high concentration of public demand early in the product cycle acts as a potential catalyst for innovative activity (Faucher & Fitzgibbons, 1993).

To illustrate arguments in favour of public technology procurement under certain conditions, Rothwell (1994) cites several prominent examples of economic and technological success in PTP. One is drawn from a comparison of the regulatory and public procurement policies pursued by the UK and Norway in their exploration and exploitation of North Sea oil resources (Cook & Surrey, 1982). Both countries used 'buy national' policies to make domestic firms the main beneficiaries of economic opportunities in the development of the oil resource, and in both countries state-owned corporations were established to lead this activity.

In the UK, however, the most technologically advanced and profitable segments of the supply industry came to be dominated by subsidiaries of foreign (mainly US) firms using imported technology. There was little effort on the part of either regulators or buyers, including the British National Oil Company, to enhance the technological capabilities of British suppliers or to move them into more sophisticated areas of production.

Norway, in contrast, pursued a policy of 'Norwegianization'. Thereby, the state-owned oil company, Statoil, had a mandate to build up the technological capabilities of domestic supply firms to a point where they could compete internationally. Statoil did this through direct public technology procurement, which it combined with other

[9] For a review, see Dalpé (1987).

measures, such as the promotion of international joint ventures and support for industrial R&D based in Norway. Other oil companies were required by regulators to follow similar practices. As a result, Norwegian firms not only gained a growing proportion of supply contracts in Norway's offshore oil industry. They also acquired competencies needed to compete successfully in other countries.

Another notable example of successful PTP was the development of long-face coal mining in the UK, involving supplier companies, the National Coal Board's R&D laboratories and mining companies (Townsend, 1976). In this context, the National Coal Board played a leading role as an equipment user with superior technological capabilities. During the 1960s and 1970s, the UK coal mining machinery industry became a leading exporter within its sector as a consequence of this innovation process.

To summarise, there are arguments and bodies of evidence both 'for' and 'against' the use of public technology procurement as an instrument of innovation policy. These considerations have informed theoretical and practical debate about public purchasing as a means of stimulating innovation. However, this is a debate which has not been addressed in European Union policy making and in the development of the EU rules governing public procurement. For the most part, both the debate and the formation of a new regulatory regime within the European Union have been more concerned with public procurement in general than with the use of public technology procurement as an innovation policy instrument. In addition to the historical reasons suggested in section 1.2 of this chapter, this may be due in large part to the fact that the 'economics of innovation' does not enter directly into the underlying theoretical rationale of the EU procurement rules. Let us now consider that rationale and its implications for innovation.

1.4 Auction Theory and the Regulation of Public Procurement [10]

We have already noted that the EU regime regulating public procurement is characterised by a strong 'free market' orientation firmly rooted in standard economic theory. For its theoretical rationale, then, the EU procurement regime draws upon a large literature on public procurement produced by neo-classical economists. The model of public purchasing usually employed in such work is that of a monopsonistic buyer (the public agency) confronting an oligopoly of potential suppliers (producer firms) who possess information that is not available to, or known by, the buyer. The problem facing the buyer is to select the best (i.e., least expensive) supplier. The solutions available to the buyer are conceived as 'auctions'.

In this situation, the asymmetry of information becomes a crucial problem, one that can not be resolved by the conventional market mechanism (Akerlof, 1970). Potential suppliers have more information about the item being procured than does the buyer. The suppliers can be expected to hide information relevant to costs and quality, thus

[10] We acknowledge here our colleague Martin Husz (Department of Technology Studies, Austrian Research Centre Seibersdorf). This discussion refers to points made in Husz's more extensive work on *Auctions as Procurement Mechanisms*, included as Appendix B of Edquist and Hommen (1998).

obtaining information rents, or they can establish formal or informal cartels and co-operate against the procurer. The buyer is therefore compelled to design a pricing mechanism that will require potential suppliers to produce the item at a reasonable cost. The buyer has this possibility as a monopsonist.

The alternative designs available to the procurer can be described as auction models. Following the work of Arrow (Arrow, 1985) on adverse selection mechanisms, auctions can be conceived as mechanisms whose inputs are bids and whose outputs are decisions on winners and payments (McAfee & McMillan, 1987). There are a number of different design criteria that may be used in auction models: public *versus* secret bidding; acceptance of highest bid or second highest bid (lowest or second lowest offers, respectively, in the case of procurement); different stages of bidding, i.e., one-step *versus* recurrent bidding (as in ascending auctions). Some basic assumptions must also be made in designing auctions, as to whether bidders are: risk-neutral or risk-averse; have independent or correlated valuations of cost; and tend to bid symmetrically or asymmetrically (depending on cost structures and beliefs).

Four basic types of auction models have been identified (Vickrey, 1961). (1) The *English* auction is an open-bid, first price, ascending-bid auction in which payment is equal to the winner's bid. (2) The *Dutch* auction is an open-bid, first-price, descending bid auction, in which payment is equal to the auctioneer's bid that is first accepted. (3) The *First-Price, Sealed-Bid* auction is a one-step auction in which each bidder submits a secret bid, the highest bid wins, and payment is equal to the bid. (4) The *Vickrey* auction is a second-price, sealed-bid, one-step auction in which each bidder submits a secret bid, the highest bid wins, and payment is equal to the amount determined by the second-highest bid.

These various auction models may be analysed by applying to them different sets of the basic assumptions briefly referred to above. Assuming independent valuation, payment as a function of bids, symmetric, risk-neutral bidders and non-collusion, the English auction and the Vickrey auction yield equivalent dominant equilibria (Vickrey, 1961). On average, though, the outcome of all four auctions is equal according to the revenue equivalence theorem (Milgrom, 1989). Choice of an optimal mechanism can be facilitated by the revelation principle, which dictates that there should be direct reports of bidders' valuations and that they should have sufficient incentive to reveal their true preferences (Harris & Townsend, 1985).

Under standard assumptions, any traditional auction can be chosen as long as a reserve price is set that will maximise competition (Riley & Samuelson, 1981). If the further assumption is made that the bidders are risk-averse, then the auction should be a First-Price, Sealed-Bid auction (ibid.). Under conditions of asymmetric bidding in procurement, if domestic contractors have a lower productivity than foreign ones, they should be favoured to increase competitive pressure on the latter but they (any of the former) should not be given high odds of winning (McAfee & McMillan, 1987).

If it is assumed that the beliefs of bidders are correlated, then the procurer should provide as much information as possible to make beliefs more realistic, and any other auction will be superior to the First-Price Sealed-Bid auction (Milgrom, 1989; Milgrom & Weber, 1982). The latter can be improved by paying for the procurement in the form of royalties (McAfee & McMillan, 1986; McAfee & McMillan, 1987). In cases of collusive bidding or cartels, reserve prices should be increased and sealed or secret bidding should be practised (McAfee & McMillan, 1987). Alternatively, negotiations should be closed (Stigler, 1964). If in later procurements quantity and quality can be varied depending on price, the auctioneer should do this to increase competition and total surplus while minimising procurement costs (Hansen, 1988).

The EU procurement rules, which govern public, not private, procurement, appear to follow the recommendations of 'auction theory' fairly closely. The rules prescribe three basic procedures of source selection: the open, restricted and negotiated procedures. The preferred procedure is the 'open' one. Corresponding to the 'First-Price, Sealed-Bid' auction, this procedure is one of unrestricted tendering, according to established rules of advertisement, closed bidding and contracting (Business International Ltd. 1991: 27). It applies primarily to the purchase of existing, standardised supplies, works and services. Contracts can be awarded on the basis of 'the most economically advantageous offer' – a criterion that takes into account not only cost but also technical merit, the reliability of the tenderer, and what might be termed transaction costs.

The EU procurement rules make the open procedure – a First-Price, Sealed-Bid auction – a normal practice for both 'regular procurement' and 'technology procurement'. This accommodates assumptions of risk-averse bidding and also allows the already high odds of winning enjoyed by domestic firms to be counteracted to some extent by foreign competitors. In the latter respect, the rules comply with 'auction theory's' advice concerning asymmetrical bidding.

In cases of technology procurement, the rules make allowance for other types of auctions: the so-called restricted and negotiated procedures (the latter being a negotiation rather than a true auction). Development projects are more likely to be dealt with under the restricted procedure. This allows for invited tendering and provides more latitude for procurers (particularly utilities) in processes of pre-qualifying prospective suppliers and advertising contracts. It is justified by "a need to maintain a balance between contract value and procedural costs, and by the specific nature of the goods to be procured" (Business International Ltd. 1991: 27). The negotiated procedure is highly exclusive and is most likely to be pursued in highly innovative development projects. Innovation is, in fact, one of its primary justifications. The negotiated procedure can also be used for technical or artistic reasons, or to protect exclusive rights, when the goods can only be provided by a particular supplier. Additionally, its use can be justified in cases of extreme urgency, or where a change of suppliers would not be feasible for technical reasons. (Business International Ltd. 1991: 28)

The two alternative procedures just mentioned respond to auction theory's advice concerning cases of correlated beliefs. In both, the auctioneer is obligated to make all relevant information available to bidders. The restricted procedure allows for reserve prices to be set and secret bidding to be practised. The negotiated procedure, as its name suggests, allows for closed negotiations. Thus, the rules enable procurers to follow anti-collusive strategies. There is no prohibition on variation of quantity and quality in successive auctions to increase competition and minimise costs. In these respects, the EU procurement rules might be considered to approximate 'best practice' according to 'auction theory'.

There are, however, some inherent problems involved in applying 'auction theory' to public *technology* procurement, as distinct from regular public procurement. While auction theory may be appropriate to instances of regular public procurement, some of its main assumptions are highly questionable in the case of public technology procurement.

Applied to the analysis of public technology procurement, auction theory tends to assume that the asymmetry of information (mentioned at the outset of this section of the chapter) stems from the indeterminate character of innovative (i.e., previously unknown) products and the possibilities of strategic use of private information or collusion on the part of an oligopoly of suppliers. In other words, the potential suppliers of an innovative product are assumed to know more about it than the buyer, and they are expected to take advantage of their superior knowledge. These conditions dictate that in public technology procurement the procurer, who has the advantage of the first move, must design a fixed mechanism for pricing that will lead potential suppliers to develop and deliver the product or system being procured at a competitive cost. Thus, well designed procurement rules are supposed to minimise the burden of public technology procurement on taxpayers.

For these reasons, the EU procurement directives pressure public agencies to conform to a norm of non-interactive, 'market' relations in public procurement and other dealings with their suppliers. As the EU directives on public procurement are introduced into formerly excluded sectors (see below), they make 'open' tendering – i.e., First-Price, Sealed-Bid auctions – the normal procedure to be followed by the responsible public agencies in awarding contracts to suppliers. 'Restricted' and 'negotiated' tendering – respectively, the second and third of the procedures described above – can only be used under special circumstances, which must be justified to the appropriate regulatory authorities and, ultimately, to the European Commission.[11] The use of these procedures is thus closely circumscribed. In particular, the negotiated procedure – i.e., the one most appropriate to highly innovative development projects – is applicable only under exceptional circumstances (explained above).

The EU directives on public procurement are also highly restrictive with respect to the scope of action that they allow public agencies in the use of public technology procurement as a means of initiating innovative development projects. Over the past decade, EU legislation in this area has progressively widened the application of the directives on public procurement to cover many formerly 'excluded' sectors.[12] These sec-

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[11] Until 1992 the EC's main mechanism for ensuring compliance with the procurement rules was the administration of remedies imposed by the European Court of Justice. This approach proved to be unwieldy and ineffective. In the 1990s, a more decentralised approach has been adopted, in which Member States administer Community Law. The rationale was to avoid "apoplexy at the centre and paralysis at the extremities" by achieving closer cooperation of Member States through the harmonization of national procedures for examining complaints (European Commission, 1992).

[12] The current EU procurement rules were developed in the early 1990s, as part of a larger effort to consolidate a single 'internal market' for public purchasing in Europe. It was argued in this connection that the opening up of hitherto nationally protected internal markets in areas of public sector ownership such as railways, power generation, and telecommunications equipment would reduce over-capacity, and facilitate rationalisation in the form of mergers and investments in new technology (WS Atkins Management Consultants and Associates 1988: 7).

tors have included energy, transport, and telecommunications. These are infrastructural sectors that have, in the past, tended to constitute 'natural monopolies', usually subject to management by public agencies and closely regulated by national authorities.

'Natural monopolies' of this kind are, of course, precisely those sectors in which specifically *public* technology procurement has played an important role in the past and can be expected to do so in the future. They have also tended to be highly protected markets, in which there has often been nationalistic purchasing for strategic reasons. The EU's unambiguous purpose in 'opening up' the excluded sectors and bringing them into the 'Single Market' has been to break down protectionist barriers around these sectors. The rationale has been to provide for international competition for supply contracts that will lead, over time, to the restructuring of the affected supplier industries on a 'European' scale. This approach to creating economies of scale in the supplier industries depends on restricting the scope of action with respect to strategic purchasing by public agencies operating at the national level.

Thus, in compliance with the advice of auction theory, the general trend in the public procurement activities of public agencies in member states of the EU is towards international competition (within the bounds of the EU), and away from (national) protectionism. The trend is also away from close relationships with specific suppliers and towards arm's-length dealings with a broader range of suppliers in an increasing number of public sector domains. The framework nature of EU legislation in this area does not completely prevent the development of national strategies to encourage technologically-oriented procurement actions. The existence of the three different forms of tendering procedures introduces a certain degree of flexibility in the enforcement, and it does not *a priori* discourage the use of public tenders for the stimulation of sophisticated technological demand with clearly defined socio-economic, environmental, or military objectives. Nevertheless, the EU legislation has definitely restricted both the scope and character of innovative public technology procurement.

In subsequent parts of this discussion, we consider innovation theory as an alternative to auction theory. We explicitly consider innovation theory and research as the most appropriate basis for developing policies and regulations concerning public technology procurement. We further consider that innovation theory and research also provide strong grounds for a critical perspective on current EU policy perspectives regarding public technology procurement.

The theoretical and research literature reviewed below indicates that successful examples of public procurement aimed at achieving important technological innovations involve close collaboration and interactive learning between users and producers – phenomena that are not fully considered in auction theory and the EU procurement rules. The literature also indicates that, contrary to auction theory's assumptions, buyers must often be more knowledgeable than suppliers about innovative (i.e., previously unknown) products. Before proceeding to consider these and other aspects of an alternative to the dominant EU perspective on public technology procurement, however, we will first consider, in the next part of this discussion, the varieties of public technology procurement and their relation to other instruments of innovation policy.

2. DIFFERENT KINDS OF PUBLIC TECHNOLOGY PROCUREMENT

We will now proceed to discuss the relations between public technology procurement and other innovation policy instruments. Policy can influence both the supply and demand sides of innovation. Both the supply of knowledge, competence, etc., and qualified demand are important determinants of innovation, and hence can be related to innovation policy.

2.1 Types of Innovation Policies and Policy Instruments

As just indicated, policy issues and instruments can be divided into the supply side and the demand side. Examples of supply side policy relate to R&D, education, firm competences, the establishment of institutions which influence communication between firms and between firms and universities, etc. Examples of demand side policy include public technology procurement, laws, regulations, standards and other institutions which may influence the development and diffusion of technologies.[13] The supply and demand side innovation policy instruments are illustrated in the four-field table shown in Figure 1.

The most common supply side policies often have to do with generation of knowledge, or science and technology. Public funding of research and subsidies to private R&D efforts are the most common examples of such policy. However, there are other options such as emphasising the diffusion and use of existing knowledge by encouraging co-operation and trust (Foray, 1997). One method of doing this is the Swedish system of technological attachés abroad, who report home to Sweden on the existence and use of new technologies in technologically advanced countries. Both of these policy instruments are shown in Figure 1.

Another method of diffusion is developing co-operative arrangements for technology transfers between universities and companies. Building such longer term relationships between firms and universities can involve both benefits and risks. The benefits have to do with transferring information about new technological opportunities and new user wants. The risks have to do with the potential for conflict between the culture of industry and that of the university. For example, the introduction of material incentives and secrecy into the academic community might eventually erode its ethical standards, decrease the speed of scientific progress, impair its contribution to economic welfare, and frustrate its broader social purposes. This is one example of how public policy can stimulate product innovations through new instruments or through new use of existing instruments – and the problems that may be involved in doing so.

One important demand side innovation policy instrument, which has historically enhanced product development very efficiently, is public technology procurement. In Figure 1 we make a distinction between 'developmental public technology procurement' and 'adaptive technology public procurement'. We will now discuss that distinction.

[13] When referring to 'institutions', we employ the following definition: "Institutions are sets of common habits, routines, established practices, rules or laws that regulate the relations and interactions between individuals and groups" (Edquist & Johnson, 1997: 46).

	Technology Policy Instruments Operating on:	
	The Supply Side	**The Demand Side**
Technology Development	**(1) R&D (Research and Development) Policy** (Public Funding of Research)	**(4) Developing Technology** (Developmental Public Technology Procurement)
Technology Diffusion	**(2) Accessing Technology** (Technical Attachés)	**(3) Adapting Technology** (Adaptive Public Technology Procurement of Goods and Services)

Figure 1. Technology Policy Instruments

(Adapted from Edquist 1994: Figure 1)

2.2 'Developmental' and 'Adaptive' Technology Procurement

The distinction made here means that we do not include under the heading of public technology procurement only 'developmental' public technology procurement, i.e., cases where completely new products, processes or systems are created. Cases of 'adaptive' public technology procurement are also included. In such cases, the product or system procured is not new to the world but still new to the country of procurement. Emphasis is put on the fact that the system needs adaptation to local circumstances – not simply that it is new to the country. In such cases a formal contract between the procurer and the supplier should also have been written.

Together, 'developmental' and 'adaptive' public technology procurement constitute what we call an 'extended ideal type' of public technology procurement. The majority of cases studied in the public technology procurement literature are of the first kind, although the second category is just as interesting and important. Much innovation is incremental and is here represented by the 'adaptive' category. Including such procurement increases the scope for a public technology procurement policy.

'Adaptive' cases should also include R&D or at least (incremental) innovation on the producer side. At a minimum, the products, processes or systems are adapted to local circumstances, or to the buyer – which includes some amount of R&D or technical change. This is, for example, the case for software compatibility. The capability of making such adaptations is taken into account when the supplier is selected. Both kinds of procurement should therefore be called public technology procurement (PTP).

'Public procurement', then, is a term reserved for cases where public authorities buy ready made 'simple' products such as pens and papers – where no R&D is involved. Only price and performance of the (existing) product is taken into consideration when the supplier is selected.

Hence, we have three kinds of public procurement, two of which we call public technology procurement. In order to distinguish these, we will call the 'developmental' kind 'developmental public technology procurement'. The 'adaptive' sort will be labelled 'adaptive public technology procurement'.

2.3 Procurers as End-Users versus Procurers as Catalysts

We will also introduce a distinction between cases where the procuring agency is also the end-user of the product or system and when it is not. In the 'classical' cases, the buying agency, e.g., the electricity authority, the railway company or the PTT (public telegraph and telephone company) will use the product procured itself. It simply uses its own demand to influence innovation.

Alternatively, the agency may serve as a catalyst, co-ordinator and technical resource to the benefit of the end-users. This latter kind of procurement has been practised by NUTEK (The Swedish Board for Industrial and Technical Development) with energy saving objectives. This 'catalysing' approach is quite different from the more conventional kind of PTP that NUTEK, in its earlier incarnation as STU, practised in the Swedish attempt to develop a school computer.[14]

An example of the 'catalysing' approach is NUTEK's activity in energy-saving, involving the procurement of new refrigerators in the early 1990s.[15] The requirement was that much less freon – which damages the atmosphere's ozone layer – should be used in production and that the refrigerator's energy use should be considerably lower than with earlier designs. A bidding contest was announced where the prize was an order of at least 500 refrigerators – which went to the company which could satisfy the demands. A design which could meet the demands was presented by the Electrolux company within a relatively short time. This example illustrates clearly that innovation policy through technology procurement can have other objectives besides economic ones; in this case the goal was environmental.

In the case discussed it was not a question of using the public agency's own demand as it was in the cases of trains and telephone exchanges. NUTEK was not the end user of the products that were developed. Instead support was given to the buyers – builders and administrators of apartment buildings – so that they could influence the suppliers. Here it concerned products for mass markets. As well as serving as a catalyst and technical resource, NUTEK also served the role of 'organising' the demand into a customer group.

The 'catalysing' model of public technology procurement exemplified above is a way of "empowering the users". This can be generalised by giving resources directly to the users. These resources could then be employed by the users to specify their own

[14] The school computer case is discussed in a case study by Thomas Kaiserfeld (Chapter 4, this volume).

[15] This case is discussed in relation to a broader theoretical framework and policy context by Hans Nilsson (1996).

requirements and then to procure products meeting these requirements from potential suppliers.

A central role of both kinds of public technology procurement is to articulate demand. Hence the state agencies serve as sophisticated customers. They take societal problems and needs as their point of departure. However, scientific and technological progress is necessary to solve the problems and satisfy the needs being focused upon.

2.4 Procurement, Demand Articulation and Policy Co-ordination

Since public technology procurement takes societal problems and needs as its point of departure and, accordingly, is a demand side policy instrument, it is likely to be effective in identifying and articulating new demands. Therefore this instrument might be a particularly powerful one in an overall policy of supporting the development of *new products*.[16]

We have shown in other work that product innovation – particularly in R&D intensive goods and services meeting new or unsatisfied consumer needs – is an essential means of creating employment (Edquist, Hommen, & McKelvey, 1998). Public technology procurement could thus be a powerful instrument not only for solving specific societal problems but also for addressing the more general societal problem of high unemployment. Powerful instruments are certainly needed – in a European situation of the coexistence of massive unemployment with large unsatisfied needs.

It is also important to relate developmental public technology procurement and adaptive public technology procurement to other kinds of innovation policy instruments mentioned in Figure 1. For example, public technology procurement can sometimes in a natural way be combined with R&D subsidies as part of a demand-induced process of technical change. The organisation of research projects might be closely related to a procurement case. For example, it could be helpful in preparing for procurement deals.

Such research projects could focus on special 'needs and technology areas' as candidates for public technology procurement, e.g., 'infrastructure for information technology', 'urban traffic systems', long-distance passenger transportation systems in Europe, 'the clean car', etc. The research projects would normally have an interdisciplinary composition and could include behavioural scientists, economists, engineers, natural scientists and innovation researchers – depending on what the character of the projects demands. Drawing on this competence, such research projects should deal with questions about what is *motivated from the needs point of view* and what is *socially desirable*. The research projects it should also investigate whether it is *technically possible* to satisfy the needs by technical development within reasonable *economic limits*. In this way, results should be reached which could be a basis for the formulation of functional demands. It is a matter of getting the relationship between needs and production to work better in the long term.

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[16] Other demand side innovation policy instruments might also strongly influence product innovation.

With respect to policy co-ordination in public technology procurement, it is useful to distinguish between 'direct' and 'indirect' forms of innovation policy. *Innovation policy* involves all public action "influencing technical development" in its speed, direction, or diversity "so that socio-economic problems could be solved and societal needs could be met" (Edquist, 1996: 152). *Indirect* innovation policies "are closely related to the public influence on ... framework conditions" (Edquist et al., 1998: 43). In public technology procurement, such conditions would include, for example, the institutional context, or rules and procedures, governing procurement processes. *Direct* innovation policies are those interventions in innovation processes "where a public organisation is directly involved in the interaction" (Edquist et al., 1998: 43). Public technology procurement is itself an example of this kind of policy action.

Public technology procurement, as a direct innovation policy, should ideally be carried out in conjunction with complementary forms of indirect policy. In practice, however, direct and indirect forms of innovation policy, can sometimes be opposed to one another, or work at cross-purposes. Under circumstances where indirect policies, such as rules and procedures, do not constrain public agencies to pursue innovative goals in technology procurement, public technology procurement might be implemented in a manner that is counter-productive from the standpoint of innovation. For example: "If orders are given to a single company with whom [it] has a long term relationship, there is a risk that the procuring [agency] becomes 'locked' into a collaborative arrangement which leads to the development of inferior products and firms" (Edquist, 1996: 156). This risk is especially high when there is a restriction in public technology procurement to dealing solely with domestic suppliers and there is little or no priority given to meeting international standards in order to be competitive in other countries.

2.5 Procurement and Standard Setting[17]

The relation between the innovation policy instruments of standard setting and public technology procurement is also a very important and interesting aspect of policy co-ordination. Standards can be regarded as 'institutions' in the sense of 'things that pattern behaviour' of organisations when they are involved in innovation processes.[18] One example is the formulation of the NMT 450 standard for mobile telephony by the Nordic PTT's, which defined a standard very early compared to other regions and countries. The technical standard was very specific and gave the supplying firms something to work against in their development work. This is one important reason why mobile telephony took off early and rapidly in the Nordic countries, that the current density of mobile phones is very high in these countries, and that two of the three large global

[17] We are indebted to our colleague Christopher Palmberg (Group for Technology Studies, Technical Research Centre of Finland) for many of the ideas discussed in this section of the chapter, as well as for its inspiration.

[18] The relations between institutions, organisations and innovation processes have been discussed in Edquist and Johnson (1997).

players (Ericsson and Nokia) in the mobile telephony equipment industry developed in these countries.[19] Because of the close relation between public technology procurement and standard setting in some cases we will below briefly touch upon the large literature on theory and praxis of standards.

To begin with, it is useful to distinguish between cases where standard setting occurs in close connection with public technology procurement, and those where standard setting is simply a matter of regulating products and product markets. For example, there may be standards set by public agencies for products which are not purchased by any public agencies. In this type of case, standard setting may be regarded as a purely regulatory activity with no relation to procurement. However, there is often some degree of overlap between these two activities. Even in regular public procurement of existing goods and services (i.e., those which can be purchased off the shelf) public agencies as 'buyers' will be constrained to observe whatever standards have been set by public authorities.

Where an emerging or evolving technology is involved, either or both purchasing and standard setting by public agencies may – or may not – decisively influence the technology's further development.[20] There may also be cases in which these two instruments are used together, so that the setting of a new standard serves to define the technical specifications of a technologically 'new' product or system that is being purchased by a public agency. Where this close co-ordination occurs, it may be legitimate to refer to standard setting as an aspect of public technology procurement (PTP).[21]

Much of the discussion in the literature concerns intermediate kinds of standard setting – i.e., those which are neither 'purely' regulation nor 'effectively' PTP. Of these, standardisation affecting the development of emerging or evolving technologies has attracted the most attention and is most pertinent to the present discussion. For the most part, recent debate has concerned technologies for which the pubic sector is a large and influential purchaser, but for which there is also a (potentially, at least) large market in the private sector. In the case of information technology (IT), therefore, the policy issue addressed has been how to manage public sector purchasing of IT, through standard setting and other means, in such a way as to "receive the most benefit" in other (private) sectors of the economy "without impeding the desired efficiency gains in the government operations themselves" (Cowan 1995: 201).

With regard to standard setting, at least, one response to this issue has been to insist that the role of governments and public agencies in the standardisation process

[19] Note that this standard-setting was of importance very early in the development of the technology and defining the standard took ten years. Later standard-setting has gone more rapidly, has had larger numbers involved, and has led to more open standards, which allow for greater flexibility of design.

[20] Rankine (1995), for example, cites a number of instances where government attempts to set standards for the development of information technology have either failed or proven to be ineffectual — in some cases because they were at odds with government buying practices, in others because the standards set did not adequately represent the needs of users.

[21] Case studies on telecommunications in the Nordic countries indicate that this use of standards as functional specifications in PTP was what occurred in the formulation of the NMT 450 standard for mobile telephony by the Nordic PTTs (Fridlund, Chapter 5, this volume; Palmberg, Chapter 6, this volume).

should be minimal. This *first position* is against standard setting by governments and public agencies. Governments and public agencies should only "reflect their needs as users, rather than ... speak for the needs of non-governmental users" – because the latter function "can often be distorted by political objectives, as well as by the abuse of government procurement powers" (Rankine 1995: 193 - 194).

There is a *second position*, which accepts standard setting by governments and public agencies. In this perspective, it is recognised that even if public agencies were to refrain from setting standards *de jure* the market weight of the public sector would still lead to *de facto* standard setting. The public sector's status as a large user means that its purchasing decisions can often have major consequences in terms of the establishment of one technological standard or another. Therefore, rather than abdicating their responsibilities, governments and public agencies should make "careful" choices leading to adoption of "good" standards (Cowan 1995: 214).

The *second position*, which accepts standard setting by governments and public agencies, finds considerable support in recent literature on the economics of innovation dealing with technological 'choices' (or competitions). There is wide consensus that markets tend to 'lock in' on one of several options in technology, due to positive feedback effects of initially influential choices (Arthur, 1988; Foray, 1989). 'Bandwagons' are formed – and they may be bandwagons for either superior or inferior technologies. Since the public sector is often a very large user, its purchasing decisions can have decisive consequences for steering this process towards the adoption of one technology standard or another. It is not a matter of setting standards or not. Public agencies as buyers of new technology therefore face an implicit challenge to set standards that are 'right' in a qualitative sense – i.e., that codify a correct anticipation of user needs. Standards can be set informally, through the simple exercise of buying power, or the process can be formalised (Schmidt, 1992). The second strategy is favoured, for example, by the EU (European Commission, 1997: 37).

The *first position*, against standard setting by public authorities, emphasises the usual ineffectiveness of the 'informal' strategy – i.e., that of influencing standards through the weight of uniform public purchasing, without also establishing 'formal' standards – on the grounds that the normal tendency of public agencies (especially large ones) is to act in a fragmented way (Rankine, 1995). It cites examples of how governmental attempts at achieving central co-ordination can fail. In addition, this position is sceptical about the abilities of public agencies to set 'good' standards. Rather than compensating for the tendency of markets to under-supply experimentation in the early life of a technology, a premature standardisation initiative by a public agency can exacerbate this problem. However, this argument does not address those cases where standard setting and other regulatory activity by governments and public agencies can have a beneficial effect on industrial innovation. This tends to occur "when standards are set that challenge current practices and provide a clearer pointer to the types of user needs for which firms should attempt to cater" (Geroski 1990: 183).

The caution against premature standard setting is, nevertheless, a valid one within limits. There are other reasons, as well, for governments and public agencies to take a non-interventionist approach to standard-setting. Economic 'globalisation' has created both opportunities and incentives for governments and public agencies to take a more passive approach to standards – that is, simply to adopt world standards and require domestic (or other) suppliers to observe them (OECD, 1991). Costs – including development costs – will be lowered and multiple suppliers of a given technology will be forced to compete on price. And, setting a standard other than the world standard (if one exists) may disadvantage domestic producers.[22]

Of course, passivity by governments and public agencies with regard to standards may do nothing to advantage domestic producers either. One way of balancing these priorities is to adopt national standards that do not conflict with world standards but rather encourage compatibility between different technological systems. Such standards permit, and may promote, the development of so-called 'gateway' technologies (Cohendet and Llerena 1997: 236 - 238).[23] This solution allows for the importation of foreign technologies and the export of complementary or equivalent domestic technologies, thus resolving a potential trade dilemma.

Finally, and notwithstanding the considerations raised by non-interventionists, there may be compelling reasons for governments and public agencies to attempt 'early' standardisation in certain, strategically important cases. For example, the early establishment of a 'good' national standard for an emerging technology can be crucial to developing a large domestic manufacturing base and capturing a large share of world markets for that technology (OECD 1991: 95n). Governments and public agencies will have the strongest justifications for doing this where technological specialisations peculiar to their own national systems of innovation are involved. In such cases, there will also be good grounds for the use of public technology procurement (PTP) as an instrument for the further development of these technological specialisations.

There are parallels to be drawn between issues raised in the discussion of standards and questions addressed in section 1.3 of this chapter, which discussed 'failures and problems' in PTP. Both discussions suggest that there are sound reasons to consider PTP in relation to private technology procurement, i.e., where two private organisations are involved in the development process. In the next two sections of this chapter, therefore, we will deal, among other things, with similarities and differences between public technology procurement and private technology procurement.

3. TECHNOLOGY PROCUREMENT IN CONTEXT: ASPECTS OF THE 'DEMAND SIDE'

Recognising that public technology procurement is one viable instrument of innovation policy among others and indicating the circumstances under which PTP can prove to be particularly useful and effective does not mean either apologising for public technology procurement or conducting missionary activity on its behalf. Nevertheless, there is some danger that even the most objective and disinterested discussion of public

[22] This argument, however, tends to overlook the fact that *someone* must first establish a world standard. It remains necessary in some technologies — e.g., telecommunications — to set world standards for reasons of compatibility. If private actors are not able to do this, standard setting by public agencies may be called for.

technology procurement, and demand-side innovation policy more generally, may be viewed in this light. This risk stems in large part from a predisposition on the part of both the attentive public and policy-makers to view demand-side interventions by public authorities with great suspicion. There is thus a tendency to neglect "that government regulation often has a beneficial effect on industrial innovation, and is not, as popular discussion would have us believe, wholly inimical to progress" (Geroski 1990: 183). It is matched by similar neglect that "procurement policy is, in general, a far more efficient instrument to use in stimulating innovation than any of a wide range of frequently used R&D subsidies" (ibid.: 183).

Demand side innovation policy and public technology procurement often appear, then, to be ideologically charged topics. Public technology procurement, especially, is often associated, fairly or unfairly, with protectionism, monopoly and even corruption. Apparently, what is often most objectionable or provocative about the term 'public technology procurement' is the word 'public', which is associated with 'government'. We will devote much of this part of the discussion, therefore, to an examination of 'technology procurement' – that is, generic technology procurement in which 'government', in the form of one or another public agency, is not the buyer – and how it is affected by various economic and technological factors. In other words, we will devote all of part 3 to a discussion of *private technology procurement*. The main factors considered include demand structures, circumstances affecting the choice of procurement procedures or mechanisms, and considerations related to the technology life cycle. We will then relate key points made in this discussion to a policy perspective on the 'demand-side' that favours neither protectionism nor monopoly. Subsequently, in part 4 of this chapter, we will return to arguments concerning public technology procurement. There, we will address the same issues in the various sections and subsections of that part of this chapter, relying strongly on the basis of the discussion of 'private technology procurement' in part 3 of this chapter.

3.1 Technology Procurement in the Private Sector

While technology procurement does occur within the private sector, it is not the dominant practice in many markets. In consumer markets, especially, demand-pull is seldom a force for innovation, since individual producers tend to have greater (more concentrated) control over these markets and more information about them than do individual users. In such markets, products may be improved or modified by producers in response to changing patterns of demand, but the role of users in exercising 'demand-pull' tends to be reactive rather than pro-active.[24] In some consumer market contexts,

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[23] "Gateway technologies are technological solutions of compatibility used when irreversible processes of adopting different technologies have made the interactive learning mechanism inefficient for allowing natural compatibility. Setting up norms within the network of different local systems of innovation during the stage in which the technology is being created seems to be the key to the diffusion process." (Ibid.).

[24] Producers, on the other hand, may actively engage in market research.

though, users may take a more active role, demanding changes in products through organised 'customer initiatives'. The market for paper products is one well-known example of this sort of development, and the market for detergents is another.[25]

Demand pull more often induces innovation in markets for investment products, even though it is difficult to exercise and "requires an articulation of customer will" (Nilsson, 1994) The most concentrated and forceful expressions of customer will are found in industrial markets, which are associated with high levels of 'buying power'. In such settings, effective demand-pull will often take the form of technology procurement.

From a 'systems' perspective on innovation, technology procurement is an important form of user-producer interaction (Lundvall, 1988). Building upon insights central to the 'chain-linked' model of innovation (Kline & Rosenberg, 1986), a systems-oriented view of innovation accords great importance to the 'demand side', rather than concentrating primarily, if not exclusively, on the supply side, as in the overly simplistic 'linear' model (Edquist, 1997: 20 - 22).

A systemic view of the innovation process explicitly recognises the potentially complex interdependencies and possibilities for multiple kinds of interactions between the various elements (or 'stages') of the innovation process (Edquist, 1997a: 20 - 22).[26] This perspective is consistent with a view of technology procurement as a matter of interaction between users and producers, leading to innovation based on 'interactive learning' (Lundvall, 1992: 8 - 10). Such interaction is not only a matter of price signals and quantities bought and sold. It contains other kinds of information and also knowledge, and it can initiate learning processes (Edquist & Hommen, 1999).[27]

3.1.1 Defining and modelling private technology procurement

Although it is seldom recognised as such, technology procurement is widely practised between private organisations in industrial markets. The practice can be defined as "the procurement by a buyer of products, services or systems, which at the time being are

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[25] Thus, Nilsson (1994: 2) comments, "during the last few years we have experienced demand-pull as a factor of growing importance when working with goods having impact on the environment". He notes that in Sweden from 1990 to 1994 there was a build-up of market shares for environmentally adapted detergents from less than 1% to approximately 70%, and that the market for environmentally adapted paper held, as of 1994, a market share of approximately 60%.

[26] The chain linked model as originally developed referred to stages in a process, rather than elements or components of a system. Thus, while certain types of organisations or organisational sub-units could be associated with certain stages — for example universities or other research organisations with the 'research' stage, and the marketing or distribution departments of firms with the 'distribute and market' stage — the model did not refer explicitly to interactions among organisations as elements of a system. Instead, it referred only to feedback paths connecting stages. In this sense, the chain-linked model fell short of a 'systems of innovation' (SI) approach, which focuses on interdependencies among organisations.

[27] See Edquist and Hommen (1999) for a more detailed account of how 'interactive learning' theory, together with closely related ideas such as the 'chain-linked model' (described above), has contributed to the development of a broader 'systems of innovation' perspective on the role of the 'demand side' in processes of innovation.

not available on the market and for which some element of technical development is needed" (Granstrand 1984: 9).[28]

Procurement contracting may be accomplished through several different buying procedures, including closed (or sealed bid) tendering, negotiated tendering, and direct contracting with no tenders. There are a number of identifiable steps in the procurement process, though they may not always follow the same order. There are also numerous forms of technology procurement. Variation in procedures and contracts is affected by factors such as volume and frequency of orders, complexity and pace of technological development, the number and relations of buyers and sellers, and their respective competences.

There are some well established general models of buying behaviour that are applicable to the practice of technology procurement (Choffray & Lilien, 1978; Robinson, Faris, & Wind, 1967; Sheth, 1973; Webster & Wind, 1972). Technology procurement departs from these models mainly by adding some further stages and sequences of contingent decision making. It is more similar in some ways, therefore, to the interactions between buyers and sellers that have been modelled for systems and plant selling (Bergström, 1980; Mattson, 1978).

Granstrand (1984) uses a 'transaction costs' framework to identify technology procurement as a special form of buyer-seller interaction. His analysis begins with two ideal-typical cases of involvement that are polar opposites – a 'customer-active' paradigm in which the buyer is fully integrated "backwards" into R&D and production for internal use (full vertical integration) and a 'manufacturer-active' paradigm in which this form of integration does not exist (a 'normal' market situation). These two polar cases can also be called, respectively, the 'fully integrated' form of interaction and the 'market' form of interaction. Between them, it is possible to identify a third, intermediate form corresponding to the relations involved in technology procurement. Namely, this is "a (buyer/seller) co-operative paradigm or, alternatively expressed, a quasi-integrated ... form" (Granstrand 1984: 19).[29] This third form is then compared with the first and second.

The first analytic comparison of the *co-operative* paradigm of interaction (private technology procurement) is with ordinary purchase contracting in a *market* form of interaction. Here, Granstrand finds that "the attractive feature of technology procurement is its potential to smooth peaks in the perception of risk, essentially by shifting some part of the risks from seller to buyer by affecting uncertainties and sharing the cash flows" (Granstrand 1984: 22). Normally, perfect markets make innovation too risky for producers. But commercial uncertainties are greatly reduced for producers if buyers' specifications can be met. Technical uncertainties are reduced for the buyer by realism in technical specifications. While the buyer's economic uncertainties are actu-

[28] This definition parallels our own definition of public technology procurement (part 1) but does not include the word 'public'.

[29] Other, less formalised models of buyer-seller cooperation or quasi-integration for innovation and new product development are also possible within this framework (Granstrand and Jacobsson 1983; Williamson 1975: 205 - 207).

ally increased to some extent, they are compensated for by an overall decrease in the level of total uncertainty and risk resulting in reduced transaction costs.

The second analytic comparison of the *co-operative* paradigm of interaction (private technology procurement) is with procurement within a *fully* vertically *integrated* organisation. In this instance, Granstrand finds it more difficult to conduct an analysis of uncertainty reduction but accomplishes this by 'splitting' the vertically integrated organisation into buyer and seller components. This results in a reduction of total risk-bearing ability without any necessary improvement in terms of efficiency. The implication of this analysis is that "the disadvantages of a large organisation (internal procurement bias, organisational persistence and loss of entrepreneurial incentives a. o.) are substantial in innovative work, thus calling for some degree of disintegration or use of market mechanisms instead of administrative ones" (Granstrand 1984: 25).

The results of the second analytic comparison (just above) are consistent with other work in the 'transaction costs' tradition pointing to the disadvantages of large organisations with respect to innovation and the need for the introduction of greater flexibility into vertically integrated organisations, particularly at later stages in the development of an industry (Phillips, 1980). The results of the first analytic comparison (further above) indicate that "perfect" markets are normally unable to generate product innovations. This is also a centrally important point of 'interactive learning' theory (Lundvall 1985). This approach differs from transaction costs analysis primarily in that it refers less to the problems of (un)certainty and risk and focuses more on the qualitative aspects of interactive learning, communication flows, and knowledge creation.

The interactive learning approach opposes standard economic theory's perspective on innovation in order to relate innovation as a learning process to the dynamics of 'organised markets'. The main point of departure is a critique of the orthodox view of innovation as a process of "learning-by-doing" that (ideally) takes place within firms situated in perfectly competitive markets where firm behaviour is adjusted according to signals in the form of prices and quantities (Arrow, 1962). In such a world, cost-reducing process innovation (e.g., learning-by-doing) induced by price signals is possible and can even take place simultaneously within all producer units.

However, "it should be obvious that perfect competition does not induce product innovation" (Lundvall 1985: 17). This is because in an anonymous market, where all communication takes the form of price signals, producers can not acquire information about user needs not already served by the market. Conversely, users have no means of assessing new products, especially complex ones. In the 'real world', however, product innovation is ubiquitous, comprising the majority of important innovations and indicating the existence of (non-anonymous) user-producer relations (Pavitt, 1984). This necessitates an explanation of product innovation as a phenomenon associated with 'imperfect markets'. Moreover, "a user-producer perspective introduces the need for qualitative information about new use-values used as inputs and about the needs of users" (Lundvall 1985: 69).

Up to this point, the argument is essentially the presentation of a strong case for vertical integration. If perfect competition militates against product innovation by restricting access to information about user needs, the logical solution will be for a producer to integrate with a user. The producer will then be able to acquire the necessary information about new technical opportunities and the user will become more competitive in relation to other users. This dynamic undermines the anonymous market and "gives rise to concentration both on the producer and the user side of the market" (Lundvall 1985: 20).

However, the product innovation made possible by a partial integration of users and producers and the concomitant creation of a market characterised by 'small numbers' would result in unacceptably high levels of uncertainty and potential for 'opportunistic behaviour', since innovating units would have much better information about new products than potential users. Trends towards vertical integration would be further reinforced, and complete vertical integration in the long run would reproduce one of the main effects of perfect competition: "All innovations should be in-house process innovations" (Lundvall 1985: 68).[30] For product innovation to occur, there must, therefore, be limits to vertical integration. These arise from the competitive need for both users and producers to maintain broad access to information about product capabilities and user needs, respectively. Vertical integration restricts such access, particularly for users. The main flaw of perfect competition is over-compensated for, resulting in an equivalent problem.

The answer posed to this apparent paradox is the solution of "organised markets". This involves a regulation, by mutually agreed to (i.e., consensual) "codes of conduct", of economic exchanges between users and producers. It diminishes opportunities for "cheating" and rewards "trustworthiness" while increasing possibilities for the flow of information between users and producers. The quality of such information, moreover, is improved through co-ordinating mechanisms such as user associations.

In the organised market, then, trustworthy producers are rewarded by users with reliable information, and relatively stable relationships develop between users and producers. This theoretical solution presents a world in which product innovation is made possible by rendering the market 'non-anonymous' while at the same time avoiding the pitfalls of complete vertical integration: "This vertical 'semi-integration' ... is a more easily reversed relationship that will not have as strong a negative impact on the flow of information as full integration" (Lundvall 1985: 28). Thus, organised markets allow for the existence of elements of hierarchy, but demand their coexistence with countervailing elements of co-operation – i.e., "mutual trust and responsibility" (Lundvall 1985: 29).

Broader implications of this theoretical formulation only become apparent when the 'learning' dimension of organised markets is brought into clearer focus (Lundvall, 1988). In markets where products are simple and relatively inexpensive, the theory does not expect either market organisation or learning to be pronounced, but it anticipates that both will be important in markets where products are complex and their use-value characteristics change rapidly. In such cases, the requirements for direct co-operation and exchange of qualitative information between users and producers will lead to the

[30] This would only be true for industrial markets. There would still be atomised consumer markets, for which there could be product innovation.

establishment, through such interactions, of specialised channels and codes of information (Arrow, 1974). The strong association between complex technologies and differentiated communications systems has, in fact, long been well established in organisational research on innovation (Burns & Stalker, 1961; Tushman, 1977).

3.1.2 Exemplifying private technology procurement

Although there are few systematic empirical comparisons of technology procurement with other forms of buyer-seller interaction, there is a large literature on alternative modes of contracting and subcontracting between buyers and suppliers and their relation to competitive strategies within various industries – for example, the automotive industry (Holmes, 1986). Some of these studies are particularly relevant to technology procurement (Grant & Gadde, 1984). Here, we draw upon one such study to exemplify and illustrate the practice.

Hellman (1993) describes the three-year co-operation between Toyota (as customer) and Nippon Steel (as supplier) which led to the latter's production in 1983 of a new type of corrosion-resistant steel sheet. The introduction of this innovation into its production process allowed Toyota to make significant improvements in anti-corrosive protection for autobodies. It not only benefited Toyota but also strengthened the competitive position of Nippon Steel.

Nippon Steel is the world's largest steel maker with a 30% domestic share in Japan's crude steel production. During the 1970s and 1980s, however, the company faced poor market conditions and undertook a major rationalisation, as well as an aggressive product diversification initiative. Central to the company's strategy for product innovation was a policy and organisational structure supporting long-term co-operation agreements with key customers. Toyota was during this same period not only the number one automotive manufacturer in Japan but also a main customer of Nippon Steel and a pioneer in the use of coated steel sheet. Toyota had acquired considerable expertise and competence in this area, complementary to competences and proprietary knowledge that had been developed within Nippon steel.

Discussions between the two companies, each of which was in search of a partner for technology development and both of which had collaborated in the past, led to a proposal from Nippon Steel for co-operation with Toyota. This led, a year afterwards, to the establishment of a joint R&D group. In the ensuing year, both companies participated in refining functional specifications and conducting laboratory tests and product trials, though they followed a division of labour that reflected each firm's special expertise. Co-ordination between the two firms made it possible for Nippon Steel to retool its production facilities prior to Toyota's formal decision to use the new material in automotive manufacture. This resulted in "a very rapid change, compared to the time it usually takes to introduce a new material in the automotive industry" (Hellman 1993: 10).

Although only a very simple contract governed the initial collaboration between the two companies, a more comprehensive agreement concerning exploitation of research results was concluded before large-scale use of the new product commenced.

This agreement met Toyota's demands that Nippon Steel license the patent rights to other Japanese steelmakers, allowing Toyota to continue its policy of maintaining multiple suppliers of all components and materials.[31] In return, the contract allowed Nippon Steel to be Toyota's sole supplier for a period of 18 months. The agreement gave Toyota, over the long term, the benefit of competitive sourcing. It also benefited Nippon Steel by stimulating the growth of the Japanese steel industry as a whole via patent licensing. "For Nippon Steel, it is better to get a smaller share of a rapidly growing market than having a monopoly position in a small and slowly growing market" (Hellman 1993: 11).

One 'lesson' to be drawn from this case is that close, long-term co-operation between a supplier and a customer in the development of a technologically new product need not preclude 'competitive' sourcing on the part of the customer and competition with other producers on the part of the supplier. This type of supplier-customer relationship is not uncommon in many industrial markets – including the market for steel (Håkansson, 1987). For example, the history of the Swedish steel industry – and, more generally, the European – also features long-term development co-operation and stable relationships between suppliers and large customers.[32] Conversely, countries whose steel industries have lacked these kinds of relationships have tended to lag behind in more advanced production and product technologies. For example, the MIT study, *Made in America*, attributed much of the US automotive industry's poor performance in adopting advanced coating technologies to traditionally tenuous links between American steelmakers and auto producers (Dertoutzos, Lester, and Solow 1989: 103). Thus, too strong an orientation towards "perfect" competition may, at times, undermine important sources of national competitive advantage.

3.2 Technology Procurement and Demand Structures[33]

We have already noted that private technology procurement does not occur in all markets, but only in some types of 'buyer markets', which are characterised by certain structures of demand. Here we will consider the relations between different kinds of demand structures and private technology procurement. Attention to demand structures, their determinants and effects on innovation processes has been emphasised in many systems-oriented approaches to the study of innovation. In the 1980s, for example, the 'chain-linked model' suggested that reforms of the financing and management of innovation in the US were a necessary response to "the very high costs for the develop-

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[31] This policy is similar to the 'second sourcing' policy of the US Department of Defence, as discussed earlier in section 1.2 and later in subsection 4.2.1 of this chapter.

[32] However, these relationships have tended to be less extensive and more informal in character than the rather unique combination of legal contracts and formalised project organisations, such as joint R&D committees, found in the case of Nippon Steel and Toyota.

[33] We are indebted to our colleague Christopher Palmberg (Group for Technology Studies, Technical Research Centre of Finland) for many of the ideas discussed in this section of the chapter, as well as for its inspiration.

ment of new products, the shortening product life-cycle times, and the forces tending to squeeze out independent entrepreneurs in some heavy industrial sectors" (Kline and Rosenberg 1986: 303 - 304). The demand structures of these sectors as 'buyer markets' for innovative investment products were in danger of being dominated by large firms with a propensity for making "small, cumulative, evolutionary changes that reduce costs and bring better fit of the[ir] product to various market niches"; conversely, these demand structures were also in danger of eliminating the complementary influence of smaller, more entrepreneurial organisations that were "very effective at high-risk, radical innovation" (ibid.: 304).

Rothwell and Zegveld (1982: 93 - 99) distinguish three basic types of demand structures within which technology procurement might occur.[34] These 'market types', which refer to different configurations of demand (rather than supply), are: monopsony, oligopsony, and polypsony. According to standard definitions, monopsony refers to "the situation when there is only a single buyer in a market", oligopsony to "a type of [buyer] market in which there is a fairly high degree of concentration" (i.e., a few buyers), and polypsony to a very diffuse market in which there are many buyers with no large shares (Bannock, Baxter, & Rees, 1986).[35]

The use of concepts and models of demand structure in mainstream economic analysis is often essentially static in character. A 'systems' perspective, however, is quite different from that of standard economic theory. The latter has tended to neglect both product innovation and the structural character of interfirm relationships (Andersen 1992: section 4.5.1). Its primary focus has been on process improvements achieved through "learning by doing" in competitive markets where there are no fundamental differences among firms (Arrow, 1962). Relationships between buyers and sellers are here assumed to be standardised to the extent that price signals are sufficient to convey all of the relevant information required by the parties to any transaction (Hayek, 1948). In contrast to this orthodox view of an "extreme degree of flexibility" in the relationships of the economic system, 'systems' approaches to the study of innovation devote much greater attention to issues of "stability" and "'linkage' structure" (Andersen 1992: 82).

The relevance of demand structures for a systems-oriented analysis of technology procurement is that they indicate different kinds of relatively stable linkage structure. A 'systems' view of demand structures makes possible an analysis of dynamic processes of knowledge creation and learning occurring within differentiated communication systems possessing different structural or 'relational' characteristics. Such an analysis goes far beyond mainstream economic theory's use of concepts of demand structure, which is mainly concerned with how these structures may affect the way that 'buyers', using only information about prices, select among 'suppliers'.

[34] These distinctions are made by Rothwell and Zeveld in the course of discussing technology procurement as an instrument of innovation-oriented public policies — or, what we have defined as public technology procurement. However, the basic concepts employed in the discussion are also fully applicable to cases of technology procurement 'without government'.

[35] Polypsony — 'many buyers' — is one, though certainly not the only, condition of perfect competition.

3.2.1 Monopsony

Monopsonistic markets are, of course, those in which "demand pull" is most highly concentrated – a necessary, though not sufficient, condition of effective technology procurement (Mowery & Rosenberg, 1979; Parkinson, 1982). However "pure" monopsony seldom occurs in the real world, except in conjunction with certain "natural monopolies" – which have all, or nearly all, been publicly controlled in most countries. Thus, there is much evidence and analysis available for a discussion of technology procurement under monopsonistic conditions in public sector "natural monopolies" (Dalpé, 1994; Faucher & Fitzgibbons, 1993). However, relatively little is known about technology procurement under monopsonistic conditions in the private sector, due to its comparatively rare occurrence.

The strong association of monopsonistic demand structures with 'natural monopolies' indicates that monopsonists in industrial markets are often monopolists on other markets – for example, consumer markets. In the telecommunications industry, for instance, service providers that operate as monopolists vis-à-vis the users of telecommunications services also act as monopsonists vis-à-vis the suppliers of telecommunications equipment.

'Natural monopolies' are sometimes owned privately, and the firms that control them can exert a major influence over their technological development. Monopoly can also come into existence temporarily in the private sector on the basis of innovation. Systems perspectives on innovation recognise the linkage between monopolistic and monopsonistic tendencies in the private sector and dwell upon their implications for innovation. Their usual point of departure is the Schumpeterian concept of an entrepreneur as the *sine qua non* of successful innovation processes. In order to innovate, the entrepreneur – which is often "a major business firm" in the case of complex technologies requiring extensive resource mobilisation – "has to perceive the [future] need, identify the necessary ingredients, secure the resources that may be missing initially, and communicate ... vision to the relevant agents – capitalists, suppliers of raw materials, people with the required skills, etc." (Carlsson and Stankiewicz 1995: 40 - 41)

The systems-oriented theory of "development blocks" (Andersen, 1992; Dahmén, 1970; Edquist & Lundvall, 1993; Stenberg, 1987) suggests that monopsonistic entrepreneurs are required for the evolution of networks formed in relation to innovative products.[36] The theory recognises that in such processes there is a basic developmental problem of 'critical mass' to be overcome, the solution of which requires vertical integration and co-ordination of information flows between users and producers through the centralising agency of an exceptionally capable 'entrepreneur'. The same point is also made in 'network analysis', which is a complementary systems-oriented approach (Gelsing, 1992; Håkansson, 1987; Håkansson, 1989; Håkansson, 1990; Håkansson & Lundgren, 1993).

In the analysis of the formation of networks around new (or 'novel') capital goods, it has been argued that there is often no means of centralised communication between

[36] A similar theoretical conception was the later theory of "growth poles" (Perroux, 1969a; Perroux, 1969b).

producers and a broad range of users (Teubal, Yinnon, and Zuscovitch 1991: 382). The absence of an agency capable of these functions not only slows the pace of product innovation dependent upon user-producer interaction – i.e., learning. It also limits producers' capability to match product types to new users – i.e., market creation (Teubal, Yinnon, and Zuscovitch 1991: 386). To overcome these barriers, the entrepreneur requires extraordinary capabilities with respect to the co-ordination and scope of R&D in a 'new market' environment where the expansion of sales opportunities through the gathering and diffusion of relevant information can be extremely difficult.

A special emphasis of 'development block' theory is that the need for linkage and co-ordination arises in the context of structural economic tensions emanating from 'gaps' in technological development (Dahmén 1988). These are indicated, not only by price and cost 'signals' but also by other forms of communication among actors in economic networks. "In both cases, the challenge is in 'gap filling' which tends to eliminate structural tensions but may also lead to new tensions by overshooting, as technical and other solutions sometimes run ahead of the immediate goal" (Dahmén 1988: 6). From the standpoint of innovation, then, a continuing drive towards monopsonistic market power vis-à-vis producers on the part of a 'focal entrepreneur' representing diverse user needs is justified, perhaps demanded, so long as the development potential of the core technology has not been exhausted. However, when "development blocks have reached a state of saturation and, perhaps, overaccumulation" monopsonistic entrepreneurs become candidates for "forced adaptation or creative destruction" (Andersen, 1992: 89 - 90).

Empirical instances of monopsony or near-monopsony in "high technology" industrial markets located in the private sector tend to bear out this perspective. A well known and well studied historical example is the domination of the US telecommunications sector by the very large private telecommunications operator, AT&T. AT&T's monopoly over the provision of long-distance telecommunications made it a monopsonist with respect to the demand for certain types of telecommunications equipment. Porter (1990) credits AT&T with having made "large scale investments" and providing (through activities such as technology procurement) "stimulus and investment" contributing to the development of American infrastructure as "arguably the most advanced in the world" (Porter 1990: 297). AT&T was in this respect an exemplar of the lead role played in technology development by privately owned (and often monopolistic) companies in "communications, power generation and transportation" (Porter 1990: 297).

However, a prolonged lack of domestic rivalry eventually caused AT&T to suffer a loss of dynamism and innovation. This not only resulted in "the provision of less innovative products or services to domestic customer industries" but was also "reflected in less advanced and sophisticated needs for inputs" (Porter 1990: 664). Thus, monopsony began to stall innovation. This situation contrasted dramatically with more recent developments: "Telecommunications services are a hotbed of improvement and innovation in America today after the breakup of AT&T, for example, despite some misplaced early concerns" (Porter 1990: 664).

This judgement is shared by D. Mowery (1995). The latter author draws attention to the "the adoption of new technologies by mature industries, a phenomenon that has sparked productivity growth and even the appearance of new products ... in these industries" (Mowery 1995: 3). He attributes much of the current "renaissance" of US competitiveness to "the ability of the US market to sustain a position as the home of the largest mass of 'lead users' in information technologies in particular" – and in this connection he makes special note of recent "rapid deregulation of the domestic telecommunications system" (Mowery 1995: 19 - 20).

International evidence lends further support to this interpretation of the US experience. Other countries have followed the US example in deregulating and in some cases privatising telecommunications, with positive effects on the rate of innovation among telecommunications operators and their suppliers (OECD, 1996a; OECD/ICCP, 1996). Although the continued existence of public telecommunications operating monopolies in many countries has slowed the pace of innovation and its diffusion, "countries such as Japan and the United Kingdom experienced a twofold increase in employment in the mobile cellular phone service market after moving from a duopoly to a competitive market and Australia experienced a three-fold increase when moving from a monopoly to a competitive market" (OECD 1996b: 108).[37] By similarly transforming formerly monopsonistic structures of demand for telecommunications equipment, the restructuring of public telecommunications operators (PTOs) has also led to increased technology procurement. For example, "specialist expertise needed for core telecommunication operations (e.g., software development) is also outsourced ... creating new jobs in and beyond the telecommunications sector, but reducing direct employment by PTOs" (OECD 1996b: 116). Supplier industries have, as a result of such trends, experienced considerable growth in employment (Glassman, 1993).

On the whole then, the more recent evidence from the US and other telecommunications sectors indicates that, despite the advantage conferred by highly concentrated demand-pull, or 'buying power', (fully developed) monopsony is not the ideal demand structure for effective technology procurement.[38] One of the main disadvantages associated with this type of demand structure is that in later or mature stages of development, the interactions of monopsonistic entrepreneurs with their suppliers tend to take on a highly routine character, mirroring the entrepreneurs' monopolistic interaction with their clientele. Product innovation is abandoned in favour of standardisation and price reduction.

3.2.2 Polypsony

Polypsony is much less favourable to the 'articulation of demand' than monopsony. Here, there are many buyers and none have very high concentrations of buying power. Technology procurement, as we understand the term (see subsection 3.1.1, this chapter), is by definition very unlikely to occur within this type of demand structure. This is not to say that it is impossible. The 'many buyers' might conceivably organise them-

[37] What is described by this source as a shift to 'competitive markets' is really a shift to oligopoly.

[38] This finding agrees with the account given in subsection 3.1.1 in this chapter of the disadvantages for technology procurement under conditions of complete vertical integration.

selves into one or several large buyers. This is done, e.g., in buyers' co-operatives. The NUTEK case of 'catalysing' public technology procurement mentioned earlier, in section 2.3 of this chapter, involved this kind of organisation of concentrated buying power on the part of normally diffuse end-users within a mass market.

As explained in the introductory section of part 3 of this chapter, the lack of concentrated buying power in polypsony means that producers normally tend to have more control over the market than do users. The obvious example is markets for consumer goods. Occasionally there are 'customer initiatives' organised around demands for improvements to products – the demand for 'environmentally friendly' household goods, for example – but it is normally producers, not users, who attempt to tailor product designs to perceived changes in consumer demand.[39] This is product innovation based on 'market research', not 'technology procurement' (Rothwell 1994: 635 - 636).

The conventional pattern in supply and demand interactions underpinning the development of manufactured goods for such markets is thus one of "supply-push", not "demand-pull". Manufacturers will often attempt to assess customer response through various kinds of market research. Customers may also try to seek out better products, but in many cases their search will not coincide with that of the manufacturer. Both parties may be aware that the technology could be improved, but doing this on a competitive, mass-production basis will depend on the direct coincidence of manufacturer and customer awareness. The problem is one of 'timing'. Usually, markets will eventually act to resolve this kind of problem, but in some important cases, such as energy efficiency, situations can arise where "optima will not be sought, nor maintained, under normal market conditions" (Nilsson, 1994: 7n).

Another problem with polypsonistic demand is that of user competence. Much of the existing evidence suggests that users corresponding to those who would typify buyers in a truly polypsonistic demand structure generally possess low levels of technical competence. As a rule, they have a severely limited capability to make enlightened choices about functional specifications. Thus, even those opponents of representation of users by public authorities, who champion instead the technical wisdom of free markets, tend to hold a rather low opinion of the individual consumer as a user. One expert, for example, says of these "level 3 users" of information technology that they "have little or no interest in the technology involved apart from considerations of safety, ease of use and other ergonomic factors" (Rankine 1995: 180).

'Professional' users tend to be more competent and more capable of "controlling" their suppliers than individual consumers (Lundvall, 1991). Therefore, one solution to the problem of user competence in polypsonistic settings is for professional users to procure new technology on behalf of individual consumers. In this connection, an ensuing process of "market transformation" is also needed. Following the introduction of new products with superior performance characteristics, it is also necessary to ensure "penetration to the market", by securing or testing market uptake and response,

[39] See, however, section 2.3 of this chapter, where we discuss the 'catalysing kind' of PTP as a policy response to problems generated by this type of situation.

and to ensure that "partners in dissemination are participating in, rather than slowing down the process" (Nilsson, 1996: 7).

'Systems' approaches to the study of innovation have, for the most part, dealt with relations among organisations, and they have addressed 'polypsony' primarily in the form of so-called 'networks of innovators' (Freeman, 1991). In particular, Håkansson's (1989) work on industrial networks has been cited as an important influence (Carlsson, 1995; Gelsing, 1992). Due to its interest in studying patterns of linkage structure among firms and other organisations within polypsonistic settings, a major theme in this school's exploration of industrial networks devoted to collaborative development of new technologies has been the investigation of 'vertical' and 'horizontal' relations within networks.

In this approach, it is recognised that all user-producer (or customer-supplier) relations constituting inter-firm *networks* must, by definition, involve some degree of vertical integration (although, by definition, vertical integration can never be 'complete' in the case of an *inter-firm* network). Therefore, the term 'horizontal' is used to describe networks based on other kinds of relations – including, for example, the "co-operation between rivals" or "informal know-how trading" discussed by von Hippel (1988). This usage has generated a basic distinction between 'trade' networks with a strong vertical aspect and 'knowledge' networks with a strong horizontal aspect (Gelsing 1992: 120).[40]

Network analysis has demonstrated that product innovation in polypsonistic markets is associated with a drive towards the consolidation of 'buying power' and 'demand articulation' on the part of users, leading to tendencies towards vertical integration. Håkansson's (1989) research has suggested that "horizontal" development relationships formed primarily for the purpose of product innovation, are intended to develop both new markets and new 'vertical' development relationships (user-producer relations) (Håkansson 1990: 378). Market creation, in the sense of developing "organised markets", is thus a major concern of networks formed around technological innovations within polypsonistic settings.

Teubal, Yinnon and Zuscovitch's (1991) work on network analysis addressed the relationship between networks and market creation, with particular reference to "the user-producer relationships characterising ... many emerging capital-goods markets" (Teubal, Yinnon, and Zuscovitch 1991: 381). In their argument, an 'entrepreneur', in the form of a focal organisation, was considered essential to market creation. While 'collective learning' often depends on networks, networks without focal organisations are likely to remain in "a low level equilibrium trap" (Teubal, Yinnon, and Zuscovitch 1991: 382). An organised articulation of demand is required to resolve the co-ordination problems involved in market creation. Concentrated 'demand' exercised by an entrepreneurial 'focal organisation' is equivalent to the formation of a core of innova-

[40] "The specification to be made here refers to the distinction between trade networks and knowledge networks. The trade network consists of relations between users and producers and the flow of information is connected to flows of commodities with a certain price. The knowledge network focuses on the flow of information irrespective of its connection to the flow of goods. The knowledge network must pay equal attention to information exchange between users and producers on one hand and competitors on the other." (Gelsing 1992: 120)

tive users sufficiently large to dissolve the "trap". This argument refers back to our earlier discussion of 'entrepreneurship' under the heading of 'monopsony'. It also points to the relevance of the 'catalysing' kind of technology procurement (see section 2.3, this chapter).

To conclude, technology procurement is difficult, though not impossible, under polypsony. Users have to be "co-ordinated", and their competence must increase. A successful example of entrepreneurial activity directed to such ends is NUTEK's role as a 'focal organisation' in the 'catalysing' type of technology procurement, first discussed in section 2.3 of this chapter. (However, this is an example of public, not private, technology procurement.)

3.2.3 Oligopsony

Given that technology procurement is very difficult in the context of a truly polypsonistic demand structure, and given also that monopsonistic demand structures, despite their high concentration of "demand-pull", ultimately tend to inhibit product innovation, oligopsony might be the 'ideal' demand structure for effective technology procurement.

In oligopsony, there are several large buyers. Though none of these large buyers completely controls the market, all have fairly high levels of buying power. Private technology procurement is a relatively common practice within such settings and much of the available evidence suggests that oligopsonistic demand structures are highly favourable to product innovation through technology procurement. In subsection 3.2.1 of this chapter we discussed the recent transition from monopsony to oligopsony in markets for telecommunications equipment, resulting from the transition from monopoly to oligopoly in telecommunications service provision. We pointed out that this restructuring has increased the need for more advanced and sophisticated technological inputs into telecommunications operating systems, thereby stimulating product innovation.

Oligopsony appears to offer incentives to firms to engage in competition based on innovation. We have illustrated this point with the example of private technology procurement given in subsection 3.1.2 of this chapter. There, it was shown that a supplier and a customer firm who had realised great short term benefits from close collaboration in product innovation through technology procurement both had strong incentives to maintain a less exclusive relationship between buyer and seller over the longer term. This arrangement allowed the buyer to benefit from efficiencies created through competitive sourcing, as well as avoiding technological 'lock in'. It also enabled the supplier firm to benefit from the longer term growth of its industry, both indirectly and directly. The firm was able, for example, to license its patents to competitors.

Oligopsonistic demand structures allow one oligopsonist to function as a 'quality leader' capable of *de facto* standard setting that will influence the decisions of other oligopsonists. Thus, the procurement activities of a single oligopsonist may have decisive effects on others and also for the suppliers to these firms, in terms of the direction and rate of innovation in technological development (Arthur, 1988; Foray, 1989).

This point (and its policy implications) was discussed at length in section 2.5 of this chapter. Oligopsony also favours the formation of 'co-operative' relationships between firms, in particular those forms of 'quasi-integration' that are most conducive to product innovation (Granstrand, 1984). (See subsection 3.1.1, this chapter.)

In theory and research contributing to the development of 'systems' approaches to the study of innovation, the dynamics of technology procurement occurring within the context of oligopsony are best captured by von Hippel's (1988) empirically grounded theory of variation in the functional sources of innovation. This theory challenged the long-standing assumption that "product innovations are typically developed by product manufacturers" and replaced it with a model of a "distributed innovation process" in which product innovations could originate from any one (or combinations) of at least three distinct (functional) sources: suppliers, producers and users (von Hippel 1988: 3 - 5). The theory held that the "source" of innovation would vary according to the share of temporary benefits, or "economic rents", that firms in each category could expect from a potential innovation (von Hippel 1988: 6, chap. 4).

In exploring strategic implications of the effects of incentive structures on "distributed innovation processes", the theory identified the "lead user concept" as one of the most viable means of "shifting the sources of innovation" in those product markets where the locus of innovation naturally resides with users, rather than producers. This strategy meant altering the normal patterns of interaction and information exchange among users and producers within a given product market so that the modified incentive structure resulting from these changes would induce more rapid and successful product innovation (von Hippel 1988: chap. 8).

The main policy example given in this connection was that of the US semiconductor industry, which lost much of its market share in the production of 'leading edge' computer memory chips to Japanese competitors during the 1980s. Among US policy-makers, it was alleged, the common wisdom was that US semiconductor process equipment firms "should somehow be strengthened and helped to innovate so that US semiconductor process equipment users (makers of semiconductors) will not also fall behind" (von Hippel 1988: 9). However, the finding that users, rather than producers, were the developers of most innovations in semiconductor process equipment (von Hippel 1988: Table 1-1), indicated that the problem had a reverse causality and suggested that it could best be remedied by assisting US users to resume innovation at the 'leading edge' (von Hippel 1988: 122).

This was a strategy which relied upon the dynamics of international competition among the relatively few large buyers of 'leading-edge' computer chips to supply the primary incentive for product innovation, in the form of innovation-based "rents" accruing to buyers. The main point was to shift the geographical locus of innovation at the leading edge by increasing the probability of achieving such rents for certain oligopsonistic 'users' of chips – namely, those based in the US. This, in turn, would advantage the oligopoly of producers based in the US. Thus, the overall result of the proposed reorganisation of the existing incentive structure affecting the demand side would be not only to encourage the emergence (or re-emergence) of "lead users" of advanced computer chips in the US, but also to create (or re-create) a specific kind of relationship, conducive to further innovation, between the users and producers of semiconductor process equipment. That is, one where (as previously) "US equipment manufacturing firms ..., owing to geographic proximity to the innovating US users, were typically the first equipment builders to gain access to the innovation" (von Hippel 1988: 121).

3.3 Technology Procurement and Technology Life Cycles[41]

The practice of technology procurement illustrates the very close connection between two aspects of innovation that are often treated separately. On the one hand, there is the development of a given technology, in which the producers can be viewed historically as progressing through the various stages of a life-cycle. On the other hand, there is the adoption of a technology, in which the buying decisions of users can be viewed as following stages of diffusion over time. Models of the technology life cycle tend to represent these two processes as mirror images of one another. They also tend to suggest that the only significant procurement decisions in the development of a technology are those made by first or early adopters, in the initial stages of the technology life cycle. However, a closer look at recent theory on technological evolution indicates that significant procurement decisions can also be made in the later stages of a technology's diffusion. There is thus in private technology procurement a distinction to be made which is equivalent to that we made in section 2.2 of this chapter between 'developmental' and 'adaptive' public technology procurement.

3.3.1 The conventional model

The conventional model of the technology life-cycle, as developed by Utterback and Abernathy (Utterback & Abernathy, 1975) is well known. It describes how, for a given industry, the type of innovation (product vs. process), the location of innovation, and the barriers to innovation change over time. It also relates these changes to an account of changing relations between and among sellers and buyers (or producers and users).

The model begins with a 'fluid' phase of technology-competition, in which there is a high level of product innovation and a low level of process innovation. A fairly large population of producing firms within the industry, each with a distinctive product concept, is in competition to capture sufficiently large shares of a new market. In addition to technological uncertainties, therefore, there are also market uncertainties, constituting a major problem for product developers. Thus, on one hand, "[t]he main source, or stimulating factor, of innovation in this phase is insight into user needs" (Hidefjäll 1997: 20). On the other hand, "many potential customers will not be able to perceive the relevance and value of the innovation" (ibid.: 20).

[41] We are indebted to our colleague Lena Tsipouri (Centre of Financial Studies, University of Athens) for many of the ideas discussed in this section of the chapter, as well as for its inspiration.

In a subsequent, 'transitory' phase of the technology life cycle, the technology-competition is resolved in favour of one or another 'dominant design', which is then allowed to mature as a product-concept (Utterback 1994: ch. 2). In effect, this is accomplished through the procurement decisions of influential early adopters. Subsequently, market uncertainty decreases for the (one or a few) winner(s) of the technology-competition and greater attention can be given to investment in product development and production technology. The profile of process innovation is raised dramatically, while that of product innovation enters into a decline, becoming increasingly minor in character. Eventually, there is a shift to a 'specific' phase in which the industry structure becomes highly concentrated and both product and process innovation decline. Here, "the primary stimulus of innovation comes from the need to reduce costs and improve quality in production"; there is "little room for major innovations, which may disrupt the smooth and efficient production machinery or make given investments appear as sunk costs" (Hidefjäll 1997: 21).

In broad outline, the technology-life cycle model presents an account of technology development in which being 'first' matters – especially at the point where a dominant design emerges. It is the producing firms first associated with the product-concept winning the technology-competition and the influential early adopters whose procurement decisions first lead to the establishment of a dominant design who gain the greatest advantages. For the original producers of dominant designs, the market "takes off" and they, rather than imitators, are in the best position to profit from market growth by making the transition to standardised, high-volume production (Utterback & Suarez, 1993). The early adopters are the first to master the ideas and approaches that govern subsequent problem solving with the technology (Clark 1985: 245); they can therefore realise greater benefits from the technology than the laggards for whom they have set the agenda. This account has been discussed as a 'unidirectional' Schumpeterian perspective in which the dominant economic factors and the key actors may change over time, but not the technology (Silverberg, 1990a).

3.3.2 Further theoretical development

There are, however, important variations on this basic story-line. For example, the idea that technology life-cycles can be reversed and restarted, through the occurrence of either 'competence-enhancing' or 'competence-destroying' "technological discontinuities" has been introduced (Tushman & Anderson, 1986). The first type of discontinuity tends to consolidate the dominant position of established firms, while the second type poses a threat to them from new entrants to their industry.

The idea that technology, though strongly influenced by 'demand-pull', retains an evolutionary dynamic somewhat autonomous from the influence of market forces has been elaborated in the related concepts of internal 'inducement mechanisms' and 'focusing devices' (Rosenberg, 1976) and 'regimes' and 'natural trajectories' in the development of technologies (Nelson and Winter 1977: 57). These elements have been brought together in Dosi's (1982) influential model of technological paradigms and technological trajectories. In this model, the 'supply-side' is initially responsible for creating a paradigm – "the 'universe' of possible modalities" – but the demand-side subsequently makes progressive gains in importance, by acting (through means such as technology procurement) to select developmental trajectories within the paradigm, according to their "economic significance" (Dosi 1982: 155 - 156).

Dosi's (1982) formulation makes possible a more discerning perspective on the relations among and between sellers and buyers in the historical development of a given technology. According to the classic Schumpeterian narrative, both sellers and buyers of a new technology are motivated by the desire to capture temporary monopoly gains from innovation. The first adopter(s), whose buying decision to procure an innovative technology leads to the establishment of one or another seller's product-concept as a dominant design, will enjoy this same status within the buyer industry. The decisive influence of the demand-side, however, is exercised only at this time. After the dominant design has been established, an oligopoly of sellers comes into being that effectively controls the technology's further development.

The Dosi model agrees with this in part, describing a shift in the source of oligopolistic gains from (at first) Schumpeterian 'rents' on innovation to (later) the benefits of static entry barriers (Dosi 1982: 157 - 158). However, it also points to the continuing and growing influence of the demand-side in acting to select alternative developmental 'trajectories'. This was already reflected in earlier observations of how the technical evolution of an innovation is bound up with and related to its pattern of diffusion (Rosenberg, 1972; Sahal, 1981). On this basis, it is possible to conceptualise, in a systematic way, how a technology can undergo significant changes, not only because of the technology procurement decisions made by early adopters, but also by later ones.

These implications have been brought out more clearly in later applications of the Dosian perspective to the development of modelling frameworks for the analysis of technical change (Silverberg, 1987; Silverberg, 1990b; Silverberg, Dosi, & Orsenigo, 1988). In this work, the observation that technical change is an ongoing and uneven process leads to an evolutionary treatment of entrepreneurial technology replacement decisions based on the assumption that these require collective learning about 'paybacks' (Silverberg, 1987). This approach seeks to explain, among other things, why there are systematic differences in the 'payback periods' calculated by different entrepreneurs. To model the 'feedbacks' presumed to generate these patterns, it relies on the concept of technological trajectory (Dosi, 1982; Nelson & Winter, 1982; Sahal, 1985). On this basis, the so-called 'self-organisation' approach develops the idea that improvements or modifications to a technology that make it competitive within one or another market segment "could be represented as 'branchings' along an evolutionary 'tree' and allow for classification, taxonomy and rigorous definition of technologies in question" (Grübler, 1989). Thus, new 'bandwagons' can be identified within later stages of technology diffusion.

Within this framework, entrepreneurs face dilemmas regarding the choice between earlier or later adoption (Rosenberg, 1976). Early adopters will be, essentially, the procurers of new technology. In order to do this successfully, they must develop 'absorptive capacity' (Cohen & Levinthal, 1990). The competency or 'learning' levels of such firms must be exceptional, since they must be able to anticipate a sufficient payback to justify the adoption of a new technology (Silverberg et al., 1988). At the highest levels of competency and learning, 'first movers' will make the greatest gains from the introduction of new technology. At intermediate levels, "a second mover or imitator may be able to capture more of the benefits by letting early innovators bear an excessive share of the development costs" (Silverberg 1990a: 185). Or, at low levels of competency and learning, diffusion may fail altogether.

Thus, a sufficiently high level of competence and learning is an essential precondition for any diffusion to occur, or any benefits to be realised. In order to meet this requirement, firms may be compelled to pool what would normally be regarded by them as proprietary knowledge in a process of "collective invention" – i.e., "the free exchange of information about new techniques and plant designs among firms in an industry" through which "fruitful lines of technical advance (can be) identified and pursued" (Allen 1983: 2). Such efforts can be reproduced or amplified through certain forms of public policy such as the successful Japanese system of "pre-competitive co-operation and co-ordination" (Silverberg 1990a: 189).

3.3.3 Implications: 'adaptive' procurement

The theoretical revisions to the conventional model of the technology life cycle and the analytic framework reviewed above make it possible to speak legitimately of 'adaptive' as well as 'developmental' technology procurement. It is to be emphasised that the former is not simply a matter of diffusing an unchanged technology but, rather, a form of innovation in its own right – and one that has important economic consequences. The critical importance of high levels of competence and learning required for potential adopters to become 'early' procurers of a technology in the later stages of its development and diffusion reinforces this point. In particular, learning is required to gauge correctly the timing that will yield a sufficiently high payback to justify the adoption of a new technology. Once determined, the relationship between timing and benefit can provide the procurer with the basis for a strong negotiating position with suppliers and an accurate assessment of the competitive advantages to be gained from (relatively) early adoption.

3.4 Summing up the Demand Side: Porter

Porter (1990) has elaborated one of the most comprehensive views of the strategic importance of the demand side for innovation and technological development. For this reason, his perspective provides a useful framework for relating private technology procurement to other strategically important aspects of the demand side as a whole. It is used in this way below.

In addressing public policy, Porter (1990) is fundamentally concerned with private sector demand, including demand taking the form of private technology procurement.

His work therefore outlines a number of 'levers' that public authorities can use to improve the quality of domestic demand and so improve national competitiveness (Porter 1990: 647 - 653). With one main exception (i.e., the consideration of 'foreign aid and political ties') these levers correspond roughly to those aspects of the demand side that have been considered thus far. Porter's levers include: 'regulation of products and processes', 'buyer industry structure', 'stimulating early or sophisticated demand' and 'technical standards' (ibid.: 647 - 653). We will review his main points under these headings, relating them to preceding sections of this chapter.

3.4.1 Regulation of products and processes

With regard to the regulation of products and processes, Porter draws a fundamental distinction between regulation relating to standards and that relating to competition (Porter 1990: 647). A very positive view is offered of standards, which can "pressure firms to improve quality, upgrade technology, and provide features in important areas of customer (and social) concern" (ibid.: 647).[42] The regulation of competition is approved of only if it encourages domestic rivalry and new firms (ibid.: 647).

With respect to the regulation of competition, there is encouragement for policies allowing firms to outsource less productive activities but discouraging the export of highly productive domestic activities (ibid.: 647). Firms should be under competitive pressure promoting "innovation at home". In this context it is stressed that "Developing domestic suppliers produces more sustainable advantage than relying solely on foreign suppliers" (Porter 1990: 658). One means of accomplishing these purposes might be the institutionalisation of procurement mechanisms or auctions of the kind discussed in section 1.4 of this chapter – particularly, those appropriate to conditions of asymmetric bidding. According to 'auction theory', if domestic contractors have a lower productivity than foreign ones, they should be favoured to increase competitive pressure on the latter, but they should not be given high odds of winning.

There is also support for policies ensuring "vigorous domestic rivalry". This means strong anti-trust legislation, avoidance of policies supporting the emergence of 'national champions', and a strong policy against "horizontal mergers, alliances, and collusive behaviour" (Porter 1990: 663). However, antitrust law should not "be a barrier to vertical collaboration between suppliers and buyers that is so integral to the innovation process" (ibid.: 663). Such advice agrees well with the discussion of demand structure effects on innovation in section 3.2 of this chapter. It also agrees with 'auction theory's' advice (in section 1.4, this chapter) concerning the need to institutionalise anti-collusive procurement mechanisms. Porter's recommendations about the importance of non-exclusive forms of vertical collaboration are in keeping with the discussion in section 3.1 in this chapter of technology procurement as a form of 'quasi-integration' or partial vertical integration.

[42] We will return to this theme in subsection 3.4.4 of this chapter.

3.4.2 Buyer industry structure

Regarding buyer industry structure in fields such as health care, electric power, and telecommunications, Porter (1990: 650) stresses that "regulation or state ownership is beneficial to supplier industries if it encourages an industry to act as a more sophisticated buyer with more stringent and advanced needs". He considers, however, that this is seldom the case with state-owned monopolies, and that "In most instances, private ownership and exposure to competitive pressure create the best environment leading industries to play the role of demanding and anticipatory buyers" (ibid.: 650). The high innovation profile of the privately owned US health care sector is cited as a leading example here– although elsewhere Denmark's socialised health care system is credited with having stimulated the innovativeness and competitiveness of certain supplier industries (ibid.: 651). This perspective agrees well with some of the main points made in the preceding discussion of demand structure in section 3.2 of this chapter – in particular, the point that oligopsony generally has a more positive effect than monopsony on technology procurement leading to product innovation in supplier industries.

Porter's case against regulation supporting monopsony is that "it works against local suppliers if it retards innovation and introduces conservatism into purchasing decisions" (Porter 1990: 650). We have arrived at similar conclusions in our discussion of technology procurement as a form of economic relations in subsection 3.1.1 of this chapter. In subsection 3.1.2 of this chapter we discussed the empirical example of Nippon Steel and Toyota to illustrate the institutionalisation of barriers to vertical integration between suppliers and buyers in technology procurement. The effect was to create an incentive structure that counteracted tendencies towards producer inertia resulting from exclusive supply arrangements with monopsonistic buyers. Insistence by the latter on multiple sources of supply acts as a stimulus for further innovation, introducing competitive dynamics into the supply side that may ultimately lead to a transition from monopsony to oligopsony on the demand side.

3.4.3 Stimulating early or sophisticated demand

In view of the critically important role played by "early or sophisticated demand" in the development of technologically innovative products, Porter (1990: 651) places considerable emphasis on the need to "reduce the risk perceived by (producer) firms that demand will fail to materialise". Assurances of future demand are required to encourage a sufficient investment in R&D and production. Technology procurement, as we have pointed out in our discussion in subsection 3.1.1 of this chapter, is a form of economic arrangement that has "potential to smooth peaks in the perception of risk, essentially by shifting some part of the risks from seller to buyer" (Granstrand 1984: 22).

Of course, shifting risks from sellers to buyers still leaves the problem of risks to be borne by buyers. Porter therefore urges a "policy of providing incentives to buyers to be early purchasers of sophisticated products" – which, he considers, "is often more beneficial to innovation and to competitive advantage than directly subsidising firms" (op. cit.: 651). Subsidising buyers instead of producers subjects the latter to the discipline of having to meet the formers' demands, thus stimulating competitive rivalry among producer firms. Buyers are also helped to improve, and this "encourages the mutually reinforcing process in which a nation's buyers become more sophisticated and in turn stimulate local producers" (ibid.: 651). In our discussion of 'oligopsony' in subsection 3.2.3 of this chapter we drew upon von Hippel's (1988) theoretical and empirical work on innovation as a 'distributed process' to give an example of how the same basic principles were applied in an analysis of how to regain the 'leading edge' in the US semiconductor industry. What Porter adds to this particular perspective on the sources of innovation is that innovative competition among oligopsonistic users is closely linked to, and can be used to encourage, similar competition among oligopolistic producers.

Porter's perspective on early demand is also in essential agreement with our observations in section 3.3 of this chapter on the technology life cycle and its implications for technology procurement. According to the conventional model of the technology life cycle, those who derive the greatest benefits from technological innovation are the firms who first win 'technology competitions' as suppliers, and the influential early adopters, whose influential procurement decisions as buyers initiate the 'bandwagon' effects leading to establishment of a dominant design. Subsequent imitators among both buyers and sellers gain less and less benefit from the technology. The technology does not evolve; instead, it is eventually exhausted as an resource capable of generating significant economic 'rents'. This is the 'classical' Schumpeterian account of technological evolution, and it provides the basic rationale for encouraging 'early demand' in the form of 'developmental' technology procurement.

However, we have in subsection 3.3.2 of this chapter reviewed recent theoretical and analytical work that points to the continuing influence of the demand side in later stages of a technology's development, making possible further new branchings along a trajectory. In such contexts, the buyer's role in technological innovation continues to be decisive. Those buyers who become innovative procurers require particularly high levels of competence and learning. They must be able to specify the functional and technical requirements of the product. They also need to determine the correct timing and to negotiate with suppliers from a position of strength. If, however, they can (possibly through co-operative action) accomplish these things successfully, they can resolve the associated problems of risk and reap the post-Schumpeterian benefits. There is a case to be made, therefore, for industrial policy to encourage 'early demand' not only in 'developmental' technology procurement, but also in 'adaptive' technology procurement.

3.4.4 Technical standards

As noted earlier, in subsection 3.4.1 of this chapter, Porter (1990: 647) advances a positive view of regulation related to standards. He does not agree with the position that standards regulation is a counter-productive intrusion into competition. His case has two complementary 'pillars'. One is the argument that there are many standards related to social (e.g., environmental or health) concerns that firms can not be expected to set independently. However, they can become important sources of national competitive advantage since "selling poorly performing, unsafe, or environmentally damaging products is not a real route to competitiveness in sophisticated industries and industry segments" (ibid.: 648). Tough standards in these and other areas will require buyer firms to be demanding customers in technology procurement.

The other argument is that those standards which are most beneficial will not be laggard or anachronistic. Rather, what is to be desired are "stringent regulations that anticipate standards that will spread internationally". Such regulations "give a nation's firms a head start in developing products and services that will be valued elsewhere" (ibid.: 648). To have positive effects on technology procurement, public policy in this area needs to have a strong focus on improving demand quality "by providing accurate and complete information to buyers" (Porter 1990: 652). Standard setting also affects the rate of supplier innovation and buyer improvement in industry, since "when basic standards are set, firms then turn their attention to rapidly developing and improving products and processes to meet them" (ibid.: 652).

This position agrees well with some of the main points made in our discussion of standard setting in section 2.5 of this chapter. There, we distinguished between standard setting used as a means of defining functional specifications in public technology procurement and simple standard setting. The latter, we argued, can be viewed as an important demand-side policy instrument in its own right, since it will influence the buying decisions and technology procurement activities of private firms. We reviewed positions and arguments against and for 'interventionist' standard setting by public authorities. The position *against* holds that most important issues can and should be decided by negotiation among private economic actors (Rankine, 1995). In contrast, the Porterian perspective highlights those kinds of issues that are more readily decided by public authorities. The position *for* interventionist standard setting is, of course, very close to the Porterian one, and is supported by an extensive literature on the dynamics of technological competitions (Cowan, 1995).

Given the prevalence of 'bandwagons' (Arthur, 1988; Foray, 1989) it is important in terms of national competitive advantage that 'good' standards be set early, particularly in areas where a given country may hope to seize a strategic advantage for domestic firms by encouraging the appropriate kinds of technology development and procurement (OECD 1991: 95n). The standards most useful for this purpose will not be parochial or protectionist. And, to balance the concerns of developing 'national' industries and participating in a 'global' economy, standards favouring so-called gateway technologies' can be developed to resolve the trade dilemmas that public authorities may face (Cohendet and Llerena 1997: 236 - 238).

4. PUBLIC TECHNOLOGY PROCUREMENT REVISITED

Having dealt at some length in the preceding part with 'private technology procurement', we will now return to the discussion of our main topic – public technology procurement (or PTP). In the following sections of this chapter, we will relate the preceding overview of key aspects of private technology procurement to parallel aspects of public technology procurement. To this end we will organise the discussion under headings corresponding to those in part 3.

4.1 Organising Public Technology Procurement

In section 3.1 of this chapter we adopted a definition of private technology procurement that was highly similar to the initial definition of public technology procurement we gave in part 1. We then considered the nature of private technology procurement as a distinctive form of economic relations. In comparison with regular market relations, the special advantage of private technology procurement as a form of relations conducive to technological innovation was shown to be its potential for shifting a part of the burden of risk from sellers to buyers and achieving a general reduction of transaction costs. In comparison with vertical integration, it was shown that the main advantage of private technology procurement is that it allows for greater efficiency and flexibility than full vertical integration, thus avoiding problems such as bias towards internal sources of supply, organisational 'lock in', and loss of entrepreneurial initiative. These are often cited as 'faults' of public technology procurement (Dalpé, 1994).

One clear implication of the above analysis for public technology procurement is to warn against protectionist policies or favouritism leading to the establishment of an effective monopoly of supply. This is the functional equivalent in PTP of full vertical integration in private technology procurement. Such monopolies can be detrimental, over the longer term, to both technological innovation and economic efficiency. However, some analysts argue for 'protectionism' in public technology procurement when it shelters potentially important 'infant industries' – i.e., "provides an assured market for new products and processes, particularly early in product life-cycles when commercial possibilities are, at best, hazy" (Geroski 1990: 189).

Protectionism in PTP is not justified in maintaining national champions or protected national suppliers in what are essentially mature industries. This is often done on the grounds that a single, large established firm is supposedly the best organisational framework for the integration of any complex R&D project (Graham, 1988). But protected markets for established firms and industries erode competitive incentives for the 'champions' and provide public authorities with "no substantive basis upon which to evaluate their performance" (Geroski 1990: 194).

In subsection 3.1.2 of this chapter we considered a prominent example of private technology procurement that involved two large firms both situated in mature industries – steel and automobile manufacturing – in the development of a new technology (Hellman, 1993). In the case examined, the procurer worked extremely closely with the supplier until the technology had been successfully developed, but then insisted on entering into a contractual arrangement that would grant the supplier an effective monopoly of supply for only a limited period of time and assurances of contracts for only partial supply of the product thereafter. The contract also stipulated that the supplier should make the technology available to other potential suppliers through patent licensing. This ultimately benefited the supplier through market growth based on the overall expansion of its industry.

Policies such as these in public technology procurement could help to eliminate some well known problems. First, they would eliminate preferential treatment leading to entrenched monopolies of supply for large, established firms. This would encourage the entry of smaller, rival firms whose efficiency and capacity for successful commercialisation are demonstrably greater, creating competitive conditions that would spur (capable) champions on to higher levels of technological and commercial achievement (Baldwin & Scott, 1987; Cohen & Levin, 1989; Kamien & Schwartz, 1982; Scherer, 1980). Second, they would encourage substantial inter-firm 'spillovers' in supplier industries, resulting in industry and market growth through the exploitation of new commercial possibilities (McKinsey and Company 1988; Rothwell and Zegveld 1985: 119 - 120). And third, they would encourage the development of more flexible organisational arrangements than the giant, vertically integrated firm in supplier industries, through such means as decentralisation, specialist subcontracting and the formation of precompetitive consortia (Ergas 1987; Maddock 1983: 7).

There is, however, a caution against taking the prescription for the restoration of competition too far and resorting to 'perfect' market relations. Public technology procurement, as we have defined it, would be extremely difficult if not impossible to accomplish under these conditions, since it would preclude public agencies taking an active role in the innovation process as buyers. This would make interactive learning between organisations impossible – although it is crucial for most innovation processes.[43] It will be recalled that the special virtue of technology procurement as a form of economic relations is that it distributes risk more evenly between buyer and seller, and establishes special forms of communication between them, thus facilitating innovation that would otherwise not be carried out by the sellers.

There are alternative mechanisms by which public authorities could ease the burden of risk borne by technology sellers or suppliers. They are, for the most part, supply-side solutions, such as R&D subsidies. While they are certainly more consistent with market relations, however, supply side solutions such as these have their own serious drawbacks. Thus, survey evidence indicates that R&D subsidies are unduly expensive (Folster 1989; Stoneman 1987: 202) and are often used to finance projects of an inferior quality that are unable to attract private sector financing (Rothwell and Zegveld 1982: ch. 6). Moreover, the rate of return on publicly funded R&D tends to be extremely uncertain and is often exceedingly low (Stoneman, 1987). In contrast, the evidence for public R&D contracts indicates clearly that "government procurement as

[43] Innovations in products for consumer markets may be an exception.

a whole has a positive and substantial effect on private R&D investment" (Lichtenberg, 1988). Thus, there is a strong, though qualified, economic case to be made for the effectiveness of public technology procurement as an instrument of innovation policy. That case is related, as we have emphasised, to the active role played by public agencies as buyers. This provides, among other things, for quality control and "the expression of a clear, consistent set of needs towards which innovative efforts can be directed" (Geroski 1990: 189).

4.2 Demand Structures and Public Technology Procurement[44]

In section 3.2 of this chapter we discussed the structure of demand in private technology procurement. The discussion was organised on the basis of the well known classification of 'monopsony', 'oligopsony' and 'polypsony' as demand structures. This classification was originally applied to PTP by Rothwell and Zegveld (1982).

4.2.1 Monopsony

In our discussion of monopsony, in subsection 3.2.1 of this chapter, we made the point that this condition – domination of the buyer market by a single large buyer – seldom occurs, except in the case of certain "natural monopolies". Though these natural monopolies have usually fallen under public ownership, we were able to examine at least one important case of effective private-sector monopsony (AT&T). We demonstrated that monopsony provides one essential condition for effective technology procurement – i.e., an extremely high concentration of buying-power or 'demand-pull'. But it has the drawback of encouraging the development of rigid and non-innovative relations between buyers and sellers, due to the lack of competitive incentives and market opportunities for the development of new technological products or systems. This has been a key argument for the deregulation of mature industries, such as telecommunications.

The literature on the practice of public technology procurement makes similar points about the structure of so-called 'natural monopolies'. Some of the main concerns about monopsony in PTP seem to revolve around the tendency for monopolists (public or private) within these sectors not only to 'lock-in' to one or another technological trajectory but also to reproduce the same effects in the suppliers towards whom they act as monopsonists (Kanz, 1993). The fairly common practice in public technology procurement of sole-source buying can thus lead to the creation of monopoly on the supply side (Ponssard & Pouvourville, 1982; Williams & Smellie, 1985). And, "If there is only one supplier in a certain market there is considerable danger of an incestuous relationship between it and government, leading to a lack of competitive pressure on this

[44] We acknowledge here the contribution of our colleague Christopher Palmberg (Group for Technology Studies, Technical Research Centre of Finland) who put forward many of the ideas discussed in this section of the chapter.

firm and, quite likely, lack of technological performance" (Rothwell & Zegveld, 1982). This is the well-known problem of 'national champions' discussed above in section 4.1 of this chapter. Aversion to risk-taking, a penchant for 'quick fixes', and the desire to avoid electoral backlash from 'picking winners' can exacerbate this problem (Cohen & Noll, 1991).

Notwithstanding these considerations, the high concentration of public demand has been clearly recognised as a strong potential catalyst in technological development (Dalpé, 1987). The condition of monopsony in public demand for new technology is common in large scale projects (Faucher & Fitzgibbons, 1993), which are characterised by high levels of cost and risk together with long-term schedules (Cohendet & Lebeau, 1987) and also by their indivisibility (Shulman, 1980) and structuring effects on the productive system (Faucher, 1990). Examples include: hydro-electric and other energy projects, communications satellites, and new aircraft.

A Canadian survey of such projects found technological innovation to be "most dynamic in projects with high demand concentration", the most technologically innovative projects to be those occurring "fairly early in the development of the industry", and the highest levels of innovative activity to be associated with "projects for which there existed a critical mass of technical, financial and organisational resources" (Faucher and Fitzgibbons 1993: 182). Critical mass could be achieved through a variety of arrangements, including not only complete vertical integration within single organisations but also "strategic alliances" between the public and private sector. However, the pattern with respect to demand structure was an unambiguously positive relation between innovativeness and effective monopsony, complemented by "quasi-market ... arrangements ... organised to control the economic and technical risk associated with the projects" (Faucher and Fitzgibbons 1993: 183).

Monopsonistic conditions in PTP, then, may be justified from the standpoint of innovation under certain circumstances, including an early stage of industry development, a high potential for innovation, and a high level of technical risk. Properly managed, they can be used to develop important sources of competitive advantage within national economies, as a comparison of the UK and Norwegian experiences with North Sea oil has indicated (Cook & Surrey, 1982).[45] The best-known example of this remains the role played by the US Department of Defence (DoD) in the development of the US semiconducter industry. Key aspects of the DoD's role included a combination of R&D subsidies and informed technology procurement. In technology procurement, "policies of dual sourcing helped in the diffusion of semiconductor technology and the DoD's favourable attitude toward purchasing from new technology based firms accelerated NTBF [New Technology Based Firm] formation and growth rates" (Rothwell 1994: 645). Through the adoption of similar policies, public sector monopsonists can avoid the creation of monopolistic or protected supplier industries.[46]

[45] See the earlier discussion of this example in section 1.3 of this chapter.

[46] In such industries, "Well entrenched vested interests have an almost congenital propensity to support the status quo and their often well financed attempts to maintain it can ossify industry structure and cause performance to stagnate" (Geroski 1990: 190).

4.2.2 Oligopsony

Oligopsony, in which there are a number of large buyers in the market, was identified in subsection 3.2.3 of this chapter as possibly the ideal structure for technology procurement. In public technology procurement, oligopsony is a fairly common condition. This is partly due to the fact that different public authorities may make different procurement decisions. A notable example of 'oligopolistic' tendencies within the public sector is the US federal government's attempt to achieve complete interchangeability of all computer equipment it purchased through the creation of a standard input/output interface (Rankine 1995: 188 - 189). There was strong industry opposition to this policy, based on fear of losing the competitive advantage vested in each system's distinctive architecture. Against the proposed strategy of declaring only one of these competing interfaces to be the standard for all US federal government agencies, the manufacturers argued that this would prevent them (the agencies) from purchasing the most advanced technologies. This view was "shared by many of the agencies" (Rankine 1995: 189).

Oligopsony in public technology procurement is a feature of many 'infrastructural' sectors where a public authority or public agency may share the market with private firms. Rothwell and Zegveld (1982: 93) point to the example of the US electric utilities, which comprise an oligopsonistic market for capital goods related to electric power generation and transmission. They then go on to discuss the TVA (Tennessee Valley Authority). TVA's role in purchasing goods of this nature has exemplified how "analogous to the role of the 'price leader' in the theory of oligopoly, one of the oligopsonists can play the role of 'quality leader'" (Rothwell and Zegveld 1982: 93).

The role of 'quality leader' can, however, be lost by public agencies due to conditions of industry maturation and globalisation under which the needs of public buyers begin to diverge from those of private ones. This has apparently been the case for UK defence spending in the electronics market, of which it was observed some ten years ago that it could no longer serve as the "engine of electronics industry growth" in the private sector (McKinsey and Company 1988: 75). This was because "Only when Defence electronics procurement is so massive and so 'leading edge' as to create fundamental new technologies ... is there a chance that defence spending can find civic market success" (McKinsey and Company 1988: 75).

Similarly, in the US, the Department of Defence (DoD), which in the 1960s and 1970s played a leading role in the development of the US electronics industry, has in the context of industry maturity and internationalisation "evolved from being a microelectronics technology leader ... to adopting a largely technology follower position" (Kanz 1993: 71). Due to specialisation and obsolescence, DoD's current requirements are "seriously mismatched with commercial priorities", and even the establishment of a new component supplier base will involve "further isolation from mainstream micro-electronic technologies and commercial business methodologies" (ibid.: 71). Suggested remedies include: planning based on the recognition of "long-term, probably permanent, interdependencies among components makers" within an increasingly global industry; "increasing use of commercial standards, practices, and components, wherever feasible"; and revision of the field support service and logistics system "to permit flexibility ...and ... enhance the substitutability at higher assembly levels of components" (Kanz 1993: 72). Through such means, DoD might be able to maintain its previously successful strategies of 'technology leveraging' and 'force multipliers' (ibid.: 72). As this example shows, an influential public sector buyer within an oligopsonistic market needs to address a wide range of issues concerning product standards in order to maintain or re-gain the role of 'quality leader'.

4.2.3 Polypsony

In subsection 3.2.2 of this chapter we pointed out that technology procurement as such is often a practical impossibility under polypsony, the type of demand structure characterised by many buyers. In section 2.3 of this chapter, however, we drew a distinction between cases of public technology procurement where the procuring agency is also the end user and cases where the procuring agency acts as a catalyst, co-ordinator and resource to the benefit of other users. Some of the most successful examples of this type of PTP have been situated in highly polypsonistic consumer markets where it has been possible to identify important societal needs that were not being met by normal market mechanisms. There appears to be an emerging role for this type of PTP which 'organises' the demand of customer groups in fragmented markets (Nilsson, 1996).

Shorter product life-cycles mean that producers for "fragmented" markets will have to "interact with a broad and representative range of users during the product specification and development processes, in order to be able to identify functional segmentation at an early stage and plan accordingly" (Rothwell 1994: 637).[47] Public technology procurement of the 'catalysing' kind is one mechanism whereby user needs which are not prominent at the current time but which might soon constitute important sources of functional segmentation can be articulated and brought into the process of product design and development. It can also be used to improve the competitiveness of industries at an early stage in their development. One example of this is Japan's creation of a quasi-governmental rental agency, the JECC, that aided the growth of a domestic market for computers by rapidly extending the range of domestic users, thereby assisting the development of the Japanese computer industry (Anchordoghy, 1988).

In section 2.3 of this chapter, we referred to the experience of NUTEK, a Swedish public agency which has "empowered users" in a number of instances where products for mass markets were involved. The NUTEK experience also provides examples of the economic case for the use of this type of PTP as a policy instrument (Nilsson, 1996). As we pointed out in subsection 3.2.2 of this chapter, a need for this kind of intervention can arise in situations where a "pay-back gap" occurs within markets (Nilsson, 1994).

[47] The term, 'functional segmentation', used here, is explained as follows: "markets can ... be differentiated on a functional basis, and market segmentation can increase as technology develops, i.e., as the number of options the supplier is capable of offering increases and as new users and new uses emerge" (Rothwell 1994: 637).

A prominent example of the 'pay-back gap' occurs in the case of energy efficiency. It may be possible to reduce energy consumption more cheaply than to increase energy production. However, the different economic perspectives of suppliers and end-users create a situation in which "the suppliers calculate and act with a lower rate of return than the users" (Nilsson, 1994: 12). This 'pay-back gap' takes the form of a tendency within the market "to overspend on supply and to disregard the demand opportunities" (ibid.). The risk involved in taking the latter course becomes lower as the degree of supply monopoly becomes more pronounced, so suppliers' incentives to participate in the enhancement of energy efficiency might be decreased by measures such as deregulation that would emphasise their role as profit-maximisers (ibid.: 12). For this reason, organising the demand side is a more viable policy intervention than deregulating or privatising the supply side. Under such conditions, the 'catalysing' kind of PTP is justified in theory, though its degree of success remains to be proven in practice.

4.3 Technology Life Cycles and Public Technology Procurement[48]

In section 3.3 of this chapter we discussed technology procurement in relation to theories and models of the technology life cycle. Our discussion was organised according to a distinction, which we first made in section 2.2 of this chapter, between 'developmental' and 'adaptive' technology procurement. Although the discussion in section 3.3 of this chapter did not concern public authorities as procurers of new technology, it is possible to make this application.

4.3.1 'Developmental' public technology procurement

In subsection 3.3.1 of this chapter we discussed the well known conventional model of the technology life cycle (Utterback & Abernathy, 1975; Utterback, 1994). According to the conventional model, the decisive influence exercised by the demand side in the development of a given technology occurs at a fairly early stage in the life-cycle. A 'bandwagon' is formed as the consequence of the influential buying decision(s) made by one or a few major adopters to procure one of a number of competing 'product-concepts'. Subsequently, product innovation declines and the focus is on refining process techniques for large scale production of the product. The initial winners of the technology-competition and the early adopters who decide its outcome are presumed to reap the greatest economic rewards from subsequent development of the technology (Utterback & Suarez, 1993).

The conventional model of the technology life cycle thus presents a strong theoretical rationale for the use of public technology procurement at an early stage, rather than at a later stage, in the development of a given technology. There is also abundant

[48] We acknowledge here the contribution of our colleague Lena Tsipouri (Centre of Financial Studies, University of Athens) who contributed many of the ideas discussed in this section of the chapter.

empirical evidence to support this outlook. A comprehensive survey of large scale projects involving the development of new technology in one country has found that "public procurement is generally more effective as a positive factor in technological production in earlier stages of the product cycle when technical uncertainties are highest", while in later stages "the shift in emphasis focuses on economic risk, often resulting in less innovative activity" (Faucher and Fitzgibbons 1993: 182).

Other work has shown that public technology procurement has been especially influential in the development of pioneering innovations in technology: "This seems to suggest that government orders are oriented towards high performance products, quite often in an early stage of their product cycle" (Dalpé and DeBresson 1988: 11). For these reasons, Rothwell (1994: 646) ends an extensive review of the literature on public technology procurement with the unambiguous conclusion that PTP "has its greatest impact when the technology is newly emerging".

The diminishing impact of PTP in later stages of an industry's development would appear to be one of the main historical lessons of the US Department of Defence's evolution from 'technology leader' to 'technology follower' in the now mature US electronics industry (Kanz, 1993). However, the growing divergence between military and commercial technological trajectories may be as important a factor (in such cases) as the late developmental stage of the industry. This is what the evidence from other US industries owing their initial 'take-off' to military public technology procurement also suggests (Geroski 1990: 188). Indeed, as Rothwell (1994) observes, "there has been some concern that emphasis in the SDI programme on developing highly sophisticated radiation-proof semi-conductor devices might be leading to a divergence between US civilian and defence technological trajectories in this area" (Rothwell 1994: 646).[49] He goes on to conclude that PTP's "potential for stimulating the growth of infant industries seems significant in areas where evolving public and private sector technologies are not too divergent" (ibid.: 647).

4.3.2 'Adaptive' public technology procurement

These considerations bring us to the case to be made for 'adaptive' public technology procurement. In subsection 3.3.2 of this chapter we considered later theoretical revisions to the conventional model of the technology life cycle – in particular, Dosi's (1982) formulation of 'technological paradigms' and 'technological trajectories' and Silverberg's (1990a) 'self-organisation' approach to the analysis of diffusion processes. The Dosi formulation indicates that the demand side can have a continuing influence on the development of technologies, giving rise in later stages of diffusion to new evolutionary 'branchings'.

Silverberg's (1990a) approach provides techniques for modelling such processes and emphasises the need for especially high levels of 'collective learning' about pay-

[49] The acronym, SDI, used here, refers to the Strategic Defence Initiative launched in the US by the Reagan administration.

backs to resolve the entrepreneurial dilemma of choice between early and late adoption. Early adoption can be highly beneficial to the entrepreneur and essential to broader processes of economic growth and development, but where it involves genuine technological innovation it requires exceptionally high levels of 'absorptive capacity' and the ability to bargain with suppliers from a position of strength. Herein lies a strong justification for what we have called 'adaptive' public technology procurement.

Less-developed countries in Europe (and elsewhere) are generally interested in the early procurement of technologically complex products and systems that can improve their infrastructure and contribute to economic growth and the enhancement of social conditions. Particularly within the EU, transfer payments make it possible for them to make such purchases at a relatively early stage in the development and diffusion of these products or systems. This relatively early adoption of diffusing technologies, together with the inevitable requirements for modification and adaptation to local circumstances, generates strong potentials for technological product innovation in what would normally be considered the mature stage or 'specific phase' of technological development.

Situations such as this deserve close study and analysis, not only because of their high degree of interest from the standpoint of theory and research on innovation, but also because of their strong relevance for public policy. As the 'self-organisation' model described in subsection 3.4.2 of this chapter suggests, countries that engage successfully in 'adaptive' public technology procurement will need to assess their technological opportunities very closely, in order to achieve the correct timing. If they can do so, however, they will stand to gain favourable prices from suppliers and a leading position among competitor nations, due to improved infrastructure. There may be other benefits as well.

4.4 Stimulating Early or Sophisticated Demand through PTP

In section 3.4 of this chapter, we considered the main elements of Porter's (1990) policy perspective on the 'demand-side' and its importance with respect to innovation and the development of 'competitive advantage'. Throughout, we maintained a focus on the relation between various aspects of the demand side and (non-public) technology procurement. Here, we will not review that entire discussion. Rather, we will focus on the one recommended demand side policy instrument that we have hitherto left undiscussed. We refer, of course, to public technology procurement.

In Porter's (1990: 644 - 647) view, public technology procurement is the most direct means that public authorities have of influencing demand conditions, but it can, according to Porter, work either for or against national competitive advantage. Protected markets, usually associated with public or private monopolies that also act as monopsonies, generally work against innovation and competitiveness. Among the domestic firms that benefit from such protection, "innovation and upgrading ... slow down" and "products and services diverge in quality and cost from those demanded internationally (Porter 1990: 645). We have made similar points throughout this discussion – for example, in sections 3.2, 3.4, and 4.2 of this chapter.

Porter (1990: 646) also makes the argument that defence procurement, though it represents a major and early market for some types of sophisticated goods, is often a mixed blessing: "Not only is defence demand often distracting but the goals of a defence agency diverge from those best suited to upgrade industry" (ibid.: 647). We have shown with reference to the US experience that this was not the case in the earlier development of some major "sunrise industries" in the US (subsection 4.2.1, this chapter), but has become increasingly true of the later stages of their development (subsection 4.2.2, this chapter).

However, the perspective we outline here extends well beyond taking a critical view of public sector practices commonly associated with PTP, such as protectionism and defence contracting that disregards civil needs. Public technology procurement, according to Porter (1990: 645 - 646), can be a "positive force" for national competitive advantage under several circumstances. In what follows, we will briefly relate the conditions he specifies to relevant aspects of theory and research contributing to a 'systems' perspective on public technology procurement. In doing so, we will simultaneously elaborate the 'rationale' for PTP. Integrating Porter's 'management' principles for the organisation of public technology procurement with conceptual approaches that can provide deeper insight into the practices he recommends, we will develop a 'systems' view of linkages between 'competitiveness' and 'innovation'.

4.4.1 Providing Early Demand

The first of Porter's (1990) conditions for an effective contribution to national competitive advantage by public technology procurement is that it should "provide early demand for advanced new products or services, pushing its local suppliers into new areas" (ibid. 645). We outlined the basis of this argument in subsection 3.4.3 of this chapter. Earlier, in subsection 3.2.2 of this chapter, we considered how 'network analysis' can be applied to the condition of 'polypsony' that often occurs in markets for advanced new products and services. Such analysis can indicate a need for the involvement of public agencies as entrepreneurs in the formation of new markets.

Network analysis (Håkansson, 1990; Håkansson & Lundgren, 1993) has developed certain implications of the concept of 'organised markets' (Lundvall, 1985) by pointing to the dynamic tension between vertical integration and horizontal technological collaboration among 'learning' organisations (users, producers, and others) in the creation of new product markets. Some analysts have used this approach to argue that a focal organisation providing vertical linkages between users and producers is often necessary to overcome a 'low-level equilibrium trap' facing networks formed around emergent technologies (Teubal et al., 1991). Markets, this argument holds, are only likely to allow the emergence of a focal 'entrepreneur' at a relatively late point in the development of a network based on new technology, given the many *ex ante* co-ordination problems that would have to be solved.

For these reasons, and especially where the further development of a given technology can be shown to have beneficial consequences for economic welfare, a case can be made for public intervention to resolve the co-ordination problems involved in market creation. This would involve an organisation or articulation of demand resulting in, or equivalent to, the formation of a core of innovative users sufficiently large to overcome the problem of otherwise inadequate 'critical mass'. A public agency could perform this role through PTP either directly, as a 'lead user', or indirectly, as a 'catalyser'. In both cases, the public agency, as a focal entrepreneur, would have to represent both the broad range of diversity in user demand and a high level of sophistication in user competence.

4.4.2 Setting Stringent Product Specifications

Porter's (1990) second condition is that "government agencies should set stringent product specifications and seek sophisticated product varieties rather than merely accept what domestic suppliers offer" (ibid.: 645). We made this case in section 2.5 of this chapter and returned to it in subsection 3.4.4 of this chapter. Earlier, in subsection 3.1.1 of this chapter, we pointed out that technology procurement, both as a practice and as a special form of economic relation (Granstrand, 1984), can be usefully explained from the perspective of 'interactive learning' theory (Lundvall, 1988; Lundvall, 1985). This theory's appraisal of the role played by the demand side in product innovation suggests reasons for public 'articulation of demand'.

Interactive learning theory, as we have seen, is a demand-oriented perspective that places more emphasis on the *quality* of demand than upon its simple *quantity* (Lundvall, 1985). Policy-oriented work in this tradition suggests that the important role played by demand should be taken as a basis for strategic intervention in the innovation process (Lundvall, 1988). First, it considers that the tendency of producers to dominate the innovation process might be as great a problem as any lack of user competence. Second, it argues from such reasons that satisfactory innovation may depend on initiatives to establish or restructure user-producer relationships – for example by sustaining existing linkages or by supporting organisations formed to promote new linkages. Third, a closely related consideration is that in periods of sudden technological change, established user-producer relationships may have to be transformed to overcome inertia reinforced by vested interests in existing organised markets.

These aspects of interactive learning theory point very directly to public technology procurement as a policy instrument enabling public agencies to establish new patterns of demand by acting either directly as a user or indirectly on behalf of users in the development of innovations and the creation of 'organised markets' conducive to innovation. This is not only relevant for "traditional" PTP but also for the 'catalysing' kind of PTP, where the public agency does not represent final demand but serves instead as a co-ordinator and supporter. (See section 2.3 and subsection 4.2.3, this chapter.)

4.4.3 Anticipating International Demand

Porter's (1990) third condition is that "Government specifications should be set with an eye to what will be valued in other advanced nations" (ibid.: 645). This was argued with reference to issues concerning standards in section 2.5 and subsection 3.4.4 of this chapter. In addition, we considered in our discussion of 'oligopsony' in subsection 3.2.3 of this chapter an example drawn from theory and research contributing to a systems-oriented 'distributed process' model of innovation (von Hippel, 1988). It showed how public policies apart from standard-setting could be used to encourage domestic firms to act as 'lead users' in setting leading-edge standards for domestic producers, thus contributing to international competitiveness of domestic industry. But the 'distributed process' perspective also suggests a more direct role for public agencies as standard-setting lead users.

As we have noted, the distributed process model (von Hippel, 1988) has identified different potential sources of innovation and revealed that the locus of product innovation certainly does not always reside with product manufacturers. Instead, it is 'moveable' and can be strategically shifted by altering incentive structures and re-ordering relationships between users and producers. This can be done indirectly, by inducing a 'lead user' strategy to restore or advance the innovative competitiveness of producers. But 'lead user' strategies can have a direct application in public technology procurement. It should be recognised in this connection that both approaches depend on the modification of existing incentive structures, and both imply a wider restructuring of existing relationships between users and producers.

4.4.4 Facilitating Innovation

Porter's (1990) fourth condition is that "Government procurement that makes innovation easier works to the benefit of a nation's industry" (ibid.: 645). This is, of course, one of the main arguments of this discussion. It is also one of the main emphases of the systems-oriented 'network', 'interactive learning' and 'distributed process' perspectives considered immediately above. In addition to these, another systems oriented perspective that points to an important role for public authorities in facilitating innovation is the 'chain-linked' model of innovation (Kline & Rosenberg, 1986), a predecessor of 'systems' approaches that we referred to in section 3.1 of this chapter.

The chain-linked model, as previously observed, has placed a strong emphasis on the crucial role played by the 'demand-side' in the innovation process, developing a main focus on product markets and product innovation (Kline & Rosenberg, 1986). It advances the perspective that the 'management of innovation' (including public policy) should recognise the complementary strengths of different types of firms and seek to co-ordinate their efforts through the creation of viable 'chains of innovation' involving linkage structures among firms and other actors. These principles can be directly applied in order to 'ease' innovation in public technology procurement.

4.4.5 Including Competition

Porter's (1990) fifth condition is that "Government procurement must include a strong element of competition if it is to upgrade the local industry" (ibid.: 645). We have made the same argument throughout this discussion – for example, in sections 2.5, 3.2 and 3.4 of this chapter. In subsection 4.2.1 of this chapter, we made this point with explicit reference to public agencies acting as 'monopsonists' in public technology procurement. Earlier, in our discussion of private sector monopsony in subsection 3.2.1 of this chapter, we related this perspective to the systems-oriented theory of "development blocks" (Andersen, 1992; Dahmén, 1970; Edquist & Lundvall, 1993; Stenberg, 1987).

Development block theory refers to the essential importance of competitive dynamics in the form of innovation-induced 'structural tensions' giving rise, through disequilibria, to the formation of a broad set of interconnected producers and users of products, developing interactively, often with the aid of knowledge-producing organisations (Dahmén, 1988). A development block (DB) will include in its most complete form a whole chain of production, as well as independent sources of knowledge. It is a large-scale framework for 'interactive learning'.

Essentially, development blocks are vertically integrated (but still horizontally evolving) user-producer networks formed around radical technological innovations. They differ from 'networks' *per se* primarily in that they have successfully overcome the problem of 'critical mass'. Significantly, 'development blocks' can be discerned *ex ante* as well as *ex post*. Their identification and analysis can therefore be used to guide public policies for economic development based on technological innovation. Competition-oriented public technology procurement (or PTP) is, of course, one important means through which this might be accomplished where no 'natural' entrepreneur is present – especially where the technology in question is extremely complex and the demand for resources and influence is large.

5. SUMMARY

In the later parts (3 and 4) of this discussion, we have considered various aspects of the 'demand-side' and its importance for innovation and technological development. We have also related this discussion to public technology procurement. The policy-oriented discussion of PTP in part 4 paralleled a similar treatment of private sector technology procurement carried out in part 3. We also linked the discussion in part 4 with our earlier discussion, in part 2, of different kinds of public technology procurement. We have shown in the course of this discussion that public technology procurement is not necessarily linked with protectionism, monopoly and favouritism. We also hope to have demonstrated that, as Porter (1990) argues, public technology procurement can be a "positive force" for innovation and the development of competitive advantage. We have indicated the conditions under which PTP is most likely to play this role as a powerful instrument of demand-side innovation policy. We have also indicated where this use of PTP may be inappropriate, and other policy instruments – or none – may be used instead.

In these respects, the perspective that we have developed on public technology procurement is quite different from the perspective underlying the current regime of EU directives governing public procurement. We described this regulatory regime and its theoretical rationale in part 1. There, we argued that the EU procurement rules have restricted public technology procurement, both in terms of limiting the scope of action available to public agencies and in terms of diminishing the possibilities of interactive learning between public agencies and their suppliers. These arguments concerned the *regulatory* aspect of EU policy. We also drew attention to the fact that EU policy on public procurement has neglected the *strategic* aspect of public technology procurement (i.e., its use as an instrument of innovation policy). The historical reasons for this 'oversight' have been reinforced with a theoretical rationale provided by mainstream economics in the form of 'auction theory'. But 'auction theory' is a body of work that does not consider public technology procurement as a process of innovation.

The 'innovation theory' perspective that we have elaborated on public technology procurement not only points to the severe limitations of 'auction theory' as a basis for the regulation of PTP but also draws attention to the organisational requirements of effective public technology procurement. In these respects, the 'innovation theory' perspective provides important foundations for the development of a strategic approach to public technology procurement – something that is now absent from European Union policy regarding public procurement. We will return to this issue after having complemented the theoretical outlook elaborated here with the insights provided by empirical case studies of public technology procurement as an innovation policy instrument.

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OVERVIEW OF CASE STUDIES

C. Edquist, L. Hommen and L. Tsipouri

INTRODUCTION

Part II of this volume, because of both its size (by far the greatest part of this book) and the central importance to our work of empirical evidence, merits its own introduction. We provide this in the form of the present Overview of Case Studies.

The Overview first discusses (in part 1) the rationale for our selection of cases. Subsequently (in part 2), it addresses questions concerning generalisation from cases. Finally (in part 3), it presents a synopsis of the case studies. After stressing the importance of differentiating between 'developmental' and 'adaptive' public technology procurement, this part of the discussion presents summaries of two groups of case studies.

The final part of this Overview is also its most extensive. Our two groups of case studies – three from Sweden and six on telecommunications – represent 'national' and 'sectoral' contexts respectively. Each case is briefly summarised here. The summaries all highlight one or another aspect of the distinction between 'developmental' and 'adaptive' public technology procurement. This key distinction also figures importantly in our later discussions, in Part III, of Conclusions (Chapter 11, part 4) and Policy Implications (Chapter 12).

1. SELECTION OF CASES

The case studies that we present in this part (Part II) of the volume are cases of innovative public technology procurement carried out in response to perceived societal needs, combined with perceived requirements for 'demand side' intervention by public agencies responsible for meeting these needs. These cases occurred in a number of countries that are now EU member states. Namely, these countries are: Austria, Finland, France, Greece, Italy and Sweden.

Three cases are drawn exclusively from Sweden and concern the development of different technologies at different times: the procurement by Swedish public agencies of high speed trains and school computers in the 1980s, and of high voltage, direct current (HVDC) transmission systems in the middle decades of this century. An additional six of our case studies represent all of the countries mentioned above and concern the development of digital switching systems (as well as Finnish and Swedish mobile telephony) in the telecommunications sector during the later decades of the post-war period.

As this list shows, all of our cases deal with large-scale (i.e., national – level) public sector infrastructural projects.[1] A possible exception to this rule is the case of "The Computer in the School". From a systems of innovation perspective, however, school computers can be regarded as a technical component of the 'knowledge infrastructure'. This term, according to Smith's (1997) definition, refers to "a complex of private and public organisations whose role is the production, maintenance, distribution, management, and protection of knowledge", and which possesses "technical and economic characteristics that are not dissimilar to those of physical infrastructure" (Smith, 1997: 94 - 95).

The theoretical discussion in Chapter 1 provides a basic rationale for this type of case selection. It points out that effective technology procurement depends on a high concentration of buying power and a comprehensive 'articulation of demand'. These conditions often tend to occur in conjunction with certain 'natural monopolies' – which have all, or nearly all, been publicly controlled in most countries (see Chapter 1, subsection 3.2.1). Sectors of this kind are, of course, precisely those in which specifically *public* technology procurement has played an important role in the past and can be expected to do so in the future. According to existing theory and research, this is especially likely to be the case with the development of new technology in certain contexts. Specifically, these are in large scale projects characterised by high levels of cost and risk, long term schedules, indivisibility, and structural effects on the productive system (ibid., subsection 4.2.1). Our cases of public technology procurement conform to these criteria.

Another criterion met by the selection of cases is the representation of both 'developmental public technology procurement' and 'adaptive public technology procurement' – terms defined briefly in our Introduction and explained more fully in Chapter 1 (section 2.2). As shown in the following synopsis of case studies (part 3 of this Overview), many of our cases concern developmental public technology procurement. However, some deal with cases of adaptive public technology procurement. In most there is a mix of 'developmental public technology procurement' and 'adaptive public technology procurement' elements. Thus, our selection of cases indicates a broad scope for public technology procurement policies.

As mentioned in our Introduction, the selection of cases also includes instances of both "success" and "failure". However, it is important to note in this connection that "success" and "failure" were not determined according to a uniform standard applied to all cases. Although we contemplated this strategy, we rejected it because a common

[1] A widely accepted definition of 'infrastructure' refers to "structural elements of an economy which facilitate the flow of goods and services", such as "communications, and transport ... housing, sewerage, power systems, etc.". It recognises that such facilities "are usually, though not necessarily, provided by public authorities and may be regarded as a prerequisite for economic growth in an economy" (Pearce, 1986: 204).

definition of 'success' could not be arrived at. In the absence of a common definition (of success), we judged each case to be a success or failure 'on its own terms'. That is, every case of a public technology procurement process was considered in relation to the particular objectives that were established for it. The evaluative question asked was, 'did the procurement process fail to realise its self-declared objectives or not?'. On this basis, it became possible to recognise comparable cases of failure and success without imposing a normative standard on any of the cases.[2]

Finally, as already mentioned, the selection of cases also covers several different countries. This group includes both larger and smaller national economies (e.g., France *vs.* Finland) and more-developed and less-developed ones (e.g., Sweden *vs.* Greece). It also encompasses a wide variety of institutional settings. Thus, common themes, conclusions and implications emerging from the analysis of the case studies can be expected to be applicable across a similar diversity among member states within the European Union as a whole.

2. GENERALISATION FROM CASE STUDIES

Case study research and analysis is commonly confronted with objections to its limited capacity for "generalisation". Such objections are, more often than not, based on a misunderstanding of case study methods, combined with a view of "generalisations ... as an end in themselves" that is tied to "a conception of social science as the search for order and regularity" (Sayer, 1992: 100). In other words, what is often (wrongly) demanded are *statistical* generalisations. These are statements of frequency with respect to relationships among variables occurring within a 'representative sample' that can be readily generalised to a larger 'population' or 'universe'.

Case studies are not, however, properly intended to make statistical generalisations. Rather, case studies produce *analytical* generalisation, in which "the investigator is trying to generalise a particular set of results to some broader theory" (Yin, 1994: 36). Thus, the object of case study research is not to select 'representative' cases from which it will be possible to generalise directly to a wide universe of other cases. Instead, cases are selected for the purpose of generalising findings to 'theory', after testing to determine whether the results of initial cases can also be found to occur in comparable cases. This use of *replication logic*, as it applies to our analysis, will be further discussed in Chapter 11 (in Part III of this book).

Case study procedures involving further analysis based on structured comparisons among similar cases are particularly well suited for the development of 'typological' theory. Such theory is not generated solely by means of induction. Rather, it proceeds from the empirical 'grounding' or particularisation of general explanatory theories in

[2] In comparative policy studies, such use of "context" to compensate for the absence of "rules" for making comparisons is particularly appropriate where "situations may be so different that existing behavioural methods do not apply, but at the same time there may be striking similarities and differences of behaviour that we want to examine systematically" (Ashford, 1992: 13).

analytically relevant cases. This leads to a clearer specification of "typical patterns and ranges of variation" (Diesing, 1971: 195 - 196). What results from this analytical-inductive approach to theory development is thus "rich, differentiated theory", which is cast in the form of contingent generalisations.[3] Thereby, it possesses a capability for more discerning explanations than those offered by formal deductivist theories. Moreover, this kind of theory "also has far greater practical value for policy-makers, because it enables them to make more discriminating diagnoses of emerging situations" (George, 1979: 59).

The generalisations from the case study analysis that we present in Part III of this book are thus intended to further theory and policy developed from a Systems of Innovation perspective. The general theoretical perspective 'grounded' in the cases is outlined in considerable detail in Chapter 1 (Part I of this book). The particular themes or dimensions drawn from that perspective for the systematic comparison of public technology procurement across cases are subsequently identified and explained in Chapter 11 (in Part III of this book).

The general 'type' of case that we consider here concerns a recent process of public technology procurement taking the form of a large-scale project in public infrastructure development. It also deals with a procurement process occurring within a country that is now an EU member state. The 'contingencies' addressed are identified in the case studies themselves and further discussed in Chapter 11 (Part III of this book), which analyses and presents our main findings and conclusions from the case studies.

3. SYNOPSIS OF THE CASES

As mentioned above, our cases fall into two main groups. First, there are three cases drawn exclusively from the country of Sweden. Taken together, they provide varied perspectives on the process of public technology procurement within one 'national' system of innovation. These studies provide a basis for sectoral comparisons within a national context. The second group of case studies deals exclusively with the telecommunications sector but documents public technology procurement in a number of different countries. The telecommunications case studies thus make possible national comparisons within a common sectoral context. We summarise the two groups of cases below, in sections 3.2 and 3.3 of this chapter, respectively.

Prior to presenting the summaries, we draw attention to a further important distinction that can be made among the cases. This is the differentiation that we have made, conceptually, between developmental public technology procurement and adaptive public technology procurement. (These terms are defined both in our Introduction [part

[3] 'Contingent generalisations' indicate how general rules, or propositions, are modified by different kinds or 'types' of circumstance, as in the following illustration: "Contrast, for example, a general explanatory theory such as 'war is the result of miscalculation' with a richer, more differentiated theory comprised of contingent generalisations that identify the different conditions under which different types of miscalculations lead to different types of war outbreaks" (George, 1979: 59).

2] and in Chapter 1 [section 2.2].) As indicated in our later discussion of Policy Implications (Chapter 12 in Part III of this book), the distinction between these two types of public technology procurement proves to be a significant basis for comparison. It assumes great practical importance in relation to key differences in 'systems of innovation' such as, for example, their relative degree of 'maturity'.

3.1 'Adaptive' versus 'Developmental' Public Technology Procurement

The evidence and analysis presented in the several case studies of public technology procurement in telecommunications and other sectors show that including both 'development-oriented' (developmental public technology procurement) and 'adaptation-oriented' (adaptive public technology procurement) cases is rewarding. They also point to analytic and empirical problems involved in constructing and maintaining a rigid distinction between developmental public technology procurement and adaptive public technology procurement.

Many of the cases address adaptation- rather than development-oriented procurement. In particular, the Austrian and Greek cases deal with clear instances of 'adaptive' public technology procurement. The French and Italian cases deal with processes involving elements of both development-oriented and adaptation-oriented public technology procurement – the former predominating in the French case, the latter in the Italian. The Nordic cases are also mixed, though they deal primarily with 'developmental' technology procurements in various sectors. The following summaries consider the balance between 'development' and 'adaptation' in the various studies.

3.2 Swedish Cases

The Swedish X2000, a tilting high speed train, is discussed as an adaptive public technology procurement case. The design was, in some respects, unique and it incorporated some major innovative components, with a potential to generate new dominant designs, but it lost out in an international technology competition. The project would have been a case much closer to developmental public technology procurement than adaptive public technology procurement, had it been implemented as early as originally envisaged by the Swedish railway industry in 1969. But the very long time elapsed between this vision and the first deliveries turned it into a more conventional project from the point of view of technological change.

Overall the X2000 project was a moderate success: It succeeded in technical terms and industrial delivery, and fulfilled its role in increasing the competence of the supplier, ASEA (later ABB-ADtranz, and now ADtranz). Nevertheless, it failed to create a strong Swedish presence in the international high speed train market. The case study demonstrates the importance of time in turning a potential developmental public technology procurement into adaptive public technology procurement. It also shows that within adaptive public technology procurement there are different grades of advance of knowledge, since the X2000 had a more innovative character than the typical adaptive public technology procurement telecommunication cases in Austria and Greece.

The procurement of High Voltage Direct Current (HVDC) transmission technology in Sweden belongs to the most successful cases studied and constitutes an ideal developmental public technology procurement with follow-ups leading into a broad sectoral and geographical technology transfer. This makes it a case with additional adaptive public technology procurement elements over and above the initial developmental public technology procurement success. Over a very long period of time, 'adaptive' technology procurement both preceded and followed the 'developmental' procurement of HVDC.

After a long proto-procurement phase between 1919 and 1939, the actual technology procurement phase began in 1940 and the first procurement contract was signed in 1949. The decision for the final construction was taken in 1953 and the first part of the transmission started in 1954. Ultimately, it wasn't until 1961 that the HVDC technology matured and took its first steps in the European and international market. Developmental public technology procurement was justified by the need for two major technological solutions. After long experimentation during the 1940s, the producer, ASEA, could face both critical problems and combine them into a reasonable HVDC transmission for the first time.

The adaptive public technology procurement that followed was related to demands of the user (a public utility) for reduction of cost, improved efficiency and better regulation. The HVDC case being both developmental public technology procurement and adaptive public technology procurement suggests in its description that a successful developmental public technology procurement is often followed by possibilities for adaptive public technology procurement. Derived benefits were high for both the supplier, who gained an international reputation and major follow-up and export contracts from the 1950s onwards, and the procurer, who initiated at the same time a period of lower transmission cost that outweighed by far the initial budget increase. The supplier, in particular, had a practical monopoly on HVDC technology world-wide and could apply profit margins up to 20% until 1970.

The Compis project, aimed at developing a Swedish school computer, is another case of a development-oriented project and therefore a developmental public technology procurement. At the time the project was conceived, i.e., 1981, the personal computer for use in schools did not exist in the Swedish market and, with the specifications suggested, it did not exist in the international market either. Additional and new technology development was necessary so it really constituted an ideal type of developmental public technology procurement.

Time was also a crucial factor in the Compis project. The relative maturity of the basic technology and the existence of parallel design efforts by US producers, notably Apple, meant that the project was associated with a high level of uncertainty and a strong need to anticipate correct technical solutions, entering the market not only early enough but also with the right standards. In the end, Compis failed to realise its potential, due to problems with the selection of technical standards and problems of co-ordination and decision making that led to late delivery and premature discontinuation of the product.

3.3 Telecommunications Cases

There is a clear focus on developmental public technology procurement in the Swedish telecommunications study, but this is set in the context of a much longer history of 'switching relations' dominated by adaptive public technology procurement. Over a period spanning the greater part of this century, recurrent collaboration in the context of public technology procurement formed a 'Development Pair' between the public utility, STA (the Swedish Telecommunications Administration), and its main supplier, LME (the L.M. Ericsson company, later renamed Ericsson). In the formation of this Development Pair, therefore, 'adaptive' technology procurements of an incremental character and informal collaboration laid foundations for more formal 'developmental' procurement. Similarly, the Finnish study demonstrates that the analyst's selection of the period of time to be used as a frame of reference for the study of a particular instance of public technology procurement influences whether the procurement should be viewed as adaptive public technology procurement or developmental public technology procurement.

The French and Italian cases deal with processes of public technology procurement occurring over very long periods of time. They stress not the objective, but the subjective, aspect of time: how the possession of a short-term or long-term strategic perspective, or 'vision', on the procurer's part can decisively affect whether a series of related technology procurements will turn out to have a primarily 'adaptive' or 'creative' character. Both France and Italy set out to develop unique 'national' digital switching systems. Though France had a much earlier start than Italy, Italy's CSELT was in fact able to keep pace with the French CNET's development of the time-division switching technology. Yet Italy lagged far behind France in the modernisation of its telecommunications network during the 70s and early 80s. Moreover, the later development of the Italian system was based to a remarkable extent on the adaptation and diffusion of knowledge and expertise acquired from external sources. In France, however, the result was clearly a 'developmental' technology procurement, involving a much stronger development of original 'national' competence. This was due to the fact that France, unlike Italy, began with (and adhered to) a long term perspective or 'vision' of ending the domination of its domestic telecommunications sector by foreign subsidiaries and replacing them with a 'national champion' capable of competing on international markets with a superior technology.

The Greek and Austrian cases follow the pattern of the Italian one, at least insofar as they are narratives about 'catching up', rather than 'forging ahead'. However, they also point out in different ways that a lack of 'vision' is not the sole factor of explanation in accounting for failures to realise the full developmental potential of public technology procurement. Both of these public technology procurement processes were, from the outset, conceived of as 'adaptive' projects. However, they were also motivated by the desire to provide opportunities for 'development' rather than restricting their aspirations to 'adaptation' only.

The Austrian case study describes, for the most part, a 'success story' but a failure "to foster exports". This failure is attributed, primarily, to the over-riding conception of the Austrian public technology procurement process as 'export policy', rather than 'technology policy', witnessed by the failure to co-ordinate the procurement with other policy instruments. The Greek study deals with a case in which there was a better fit and co-ordination of policies, particularly in the design of the procurement mechanism. Yet, at the same time, the Greek case was also one in which long delays in the implementation turned the switches into a standard product procurement and the buyer lost every advantage in terms of timing. The delays are attributed to discontinuity and friction between formal and informal institutions, which stalled the agencies responsible for implementing the procurement.

The conflict between formal and informal institutions referred to in the Greek case was based on the desire of the administration responsible for implementing the procurement to avoid public controversy and notoriety. Thus, official public technology procurement initiatives and the formal rules and procedures for conducting them were stymied by Greece's informal rules for public procurement. These consisted of procedures for delaying or avoiding non-unanimous decisions in order to avoid publicity and thereby safeguard the integrity and public image of civil servants. In contrast, no such pronounced conflict between formal and informal institutions, but rather a complementarity between them, was evident in the Austrian case.

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2. PUBLIC TECHNOLOGY PROCUREMENT IN SWEDEN: THE X2000 HIGH SPEED TRAIN

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INTRODUCTION

This chapter describes and analyses the development of Sweden's high-speed train (HST), the X2000, as a case of public technology procurement. The case study is based mainly on primary data collected in recent (1997) interviews with some of the main actors involved in the procurement process, but it also draws upon relevant secondary sources. The analysis employs evaluative criteria defined from the standpoint of public policy (as elaborated below) and develops a critical perspective on the case that leads to more general policy implications.

To situate and characterise the case briefly, the procurement of the X2000 occurred during the mid-1980s, culminating the development of proposals, plans and technical preparations for a Swedish HST over a period of some 20 years (Flink & Hultén, 1993; Pålsson, 1987; SJ, 1969). Throughout this period, there was close collaboration between the Swedish state railway company, SJ, and the Swedish railway equipment manufacturer, ASEA, in joint research concerning a future HST (Andersson, 1983; Flink, 1992; Flink & Hultén, 1993). The eventual procurement was a case where the only existing user – SJ – also represented final demand for the trains. The market was also very concentrated on the supplier side and it can be questioned whether the chosen supplier, ASEA (now AD Tranz), had any real competitor, because of the way the procurement process was organised. The previous very close interdependence between SJ and ASEA is the main basis for this scepticism about competition.

Since the procurement of the X2000, there have been several changes in the corporate identity of the supplier. Originally, the supplier of the X2000 was the Swedish corporation ASEA and, more specifically, its division for the manufacture of railway equipment, ASEA Traction. However, shortly after the procurement of the X2000 was finalised in 1986, ASEA merged with the Swiss corporation, Brown Boveri, in 1988, to form ABB, a multinational corporation of which ASEA owned 50%. ASEA Traction then became ABB Traction. Several years later, in 1995, ABB together with Daimler-Benz founded the joint venture, AD Tranz, which was responsible for all business of ABB within the rail transportation sector. Thus, the supplier of the X2000 became AD Tranz, of which ABB owned 50%. In the beginning of 1999, ABB sold its part in AD Tranz to Daimler, which had (almost simultaneously) merged with Chrysler to form Daimler-Chrysler. Hence, AD Tranz is now wholly owned by Daimler-Chrysler.

One of the most notable aspects of the X2000 procurement was the length of time required for its completion. As early as 1964, the R&D department at SJ (Swedish State Railways) had considered the benefits of a high speed train (Flink & Hultén, 1993: 89). SJ's interest in developing a Swedish HST was due to the increasing competition from road and air transport during the 1960s. Furthermore, there was a general pessimism about the future of railways. This concern, together with a forecast indicating an increasing demand for fast reliable passenger transport, legitimised the vision of a high speed train within SJ. However, SJ took a very long time to realise this vision. The analysis presented here suggests that this delay was based in large part on SJ's initial lack of the competence required to carry out the train's procurement. The critical evaluation supported by this analysis points to certain negative competitive and innovative consequences for the producer of the X2000, AD Tranz (formerly ASEA). However, it also recognises some positive effects of the procurement overall.

One of the main problems experienced by the X2000 was the failure of the train as originally designed to win a significant share of the export market for high speed trains. The analysis presented here indicates that a major reason for this failure was poor timing. The X2000 did not fare well in this market because of its late development and introduction. In Europe, at least, the X2000 lost possible foreign sales most consistently to a competitor, the Italian 'Pendolino', that had the advantages of much earlier development and introduction to the market. It is reasonable to hypothesise that the competitor's greater success has mainly been due to these advantages. This argument can be linked directly to the explanation of delay on the part of SJ as being the result of an initially low 'buyer competence'. There are, of course, counter-arguments to this explanation of the X2000's lack of export success. These are addressed in the analysis that follows in later sections.

The societal and industrial aspects of the X2000 procurement case will here be addressed in terms of three main kinds of criteria. These are criteria related to: 1) Innovation Policy, 2) Industrial Policy and 3) Costs, Benefits and Profits.

Evaluation in terms of 'Innovation Policy' entails establishing what kind of technology procurement this case represented and determining whether or not it was successful in altering the direction of technical change, increasing technical diversity, or influencing the pace of technical change. The X2000 procurement process was a case of 'adaptive public technology procurement'. Although adaptive public technology procurement can have significant effects on technological change, in this case it did not result in any radical change in the speed or direction of technical change. Most of the elements in the train system existed previously, and a high-speed train with similar functions – the Italian 'Pendolino' – existed well before the X2000 was developed (Agerberg, 1996a; Giuntini, 1993). Thus, the procurement was not altogether successful from an innovation policy point of view.