Ratio Working Paper No. 119

Advanced Purchasing, Spillovers, Innovative Pricing and Serendipitous Discovery

Gunnar Eliasson

RATIO Näringslivets forskningsinstitut

ratio.se

Box 3203
103 64 Stockholm

Besöksadress:
Sveavägen 59, 4tr

Advanced Purchasing BC

2008-05- 11

Advanced Purchasing, Spillovers, Innovative Pricing and Serendipitous Discovery[1]

by

Gunnar Eliasson, KTH, 10044 Stockholm, and the Ratio Institute, Stockholm, Sweden
E-Mail: gunnar.elias@telia.com

Abstract

Advanced products such as aircraft distinguish themselves by a number of characteristics. Products are complicated and produced under very complicated circumstances, but also have a very long life. The purchase price, therefore, is a small part of total user cost of the product. Product value, hence, increases the more of cost efficient maintenance that has been built into the product and the easier it is to service and modernize.

Advanced products also distinguish themselves by featuring the additional collective characteristic of a "cloud of technology spillovers" available to external users in proportion to their competence to commercialize them. While the value of that cloud to society may be greater than that of the product itself the value to the user may be much smaller. The producer, therefore, faces a tricky pricing problem and the value he can capture depends on his ability to charge for the dual product.

I discuss *joint production* of products with rich spillovers in the context of *joint customership*, i.e. public purchasing of both products and the collective value generated by spillovers. I demonstrate that a win-win situation might exist between the two that improves with the commercial ability of the local economy to capture the value of the spillovers. Industrial participation programs can be made part of a sale to support the receiver competence of local producers to capture the spillover rents. Part of marketing the product, therefore, involves the ability to present a credible case for the economic value to society of the spillovers and to design a method of charging for them (*Innovative pricing*). A well designed, mutually beneficial contract should make both parties to the trade winners. This latter form of innovative pricing should be particularly attractive for developing countries.

The theoretical argument is illustrated with the case of downstream industrial business formation around Swedish Aircraft industry.

JEL Code; D23, D24, L15, L23, L62, M13, O31.

Key words: integrated production, competence blocs, joint customership, receiver competence, spillovers, organizational learning, technology diffusion.

Paper prepared for the

12th International Conference of the Joseph A. Schumpeter Society

[1] This paper draws directly on Eliasson (1995), the industrial policy discussion in Eliasson (2000a) and later complementary interviews and case analyses.
The paper has been discussed at a Ratio Institute seminar. Very useful comments from Nils Karlson and Dan Johansson are acknowledged.

Rio de Janerio, July 2-5 2008

1. Introduction

The modern economy has evolved ever more advanced, multidimensional and complex products that combine high levels of scientific and engineering inputs both in their design and in the processes for producing them. Such products pose special problems that require innovation in pricing, marketing, and property rights characterization, problems that have scarcely been recognized by economists, and whose special properties have yet to be adequately investigated and accommodated within the discipline. This paper identifies the essential features of complex high-tech multidimensional products and markets and provides a framework for understanding and assessing high-tech industry´s role in the market economy and its relationship to government. As an empirical case that illustrates and clarifies the central point, I use the Swedish aircraft industry.

2. The Pricing of complex and multidimensional systems products

Advance products such as aircraft distinguish themselves by a number of characteristics. *First* of all they are complicated systems products that are manufactured by complex processes, both of which result from large expenditures on research and development; cost efficient repair, maintenance, and upgrading are increasingly incorporated in their design to facilitate service and modernization. Such products therefore have a very long life. All these product features imply that the direct cost of production is only a fraction of the total value of the product to the potential user. Therefore, the price should include the value of services the product delivers over its life cycle. Following the logic of this characterization, producers have begun to change the property rights characteristics of their product; they increasingly own it and sell the services it delivers to the user, sometimes postponing some of the charges to later stages of the life of the product, and in this way recoup more of development costs. Military procurement of complex products are built on a similar ownership logic. The military customer   is often intimately involved in the product design and often contributes significant user knowledge, thereby directly influencing the definition of the product. Because of the considerable technical risk involved in developing such a complex product the military buyer/public customer often shares in the risks and contributes significant advance payments. After delivery the military owns the product, but its early involvement in the design process means that the life time cost of the product to the user can be minimized[2]. Civilian procurement of aircraft and aircraft engines and of other complex systems products have increasingly adopted a similar ownership logic. The role of the competent customer in shaping new technology development therefore must be seriously addressed in the analysis of economic growth, and, as we will see, the changing relative roles in that respect between public and private customers have to be specially considered.

The producer of compelx and expensive products often both retains ownership of the product , finances it and sometimes installs and services it and charges for the services generated by the product in use, say the engine of an aircraft. This complexity is further enhanced by the increasing practice of technologically advanced systems producers to focus their resources on the high end of the value chain developing and designing the product, outsourcing physical production and then returning to the customer to take responsibility for the running , the servicing and the upgrading of the product system. Swedish Ericsson has increasingly moved in that direction when it comes to its main product, mobile telecom systems . In both cases it is in the interest of the producer to design the product system such that the life time cost of using the product is minimized. With large parts of total production outsourced the interaction between the systems coordinator/ “customer” and its specialist

[2] This practice was   particularly elaborate during the development of the Swedish Gripen multipurpose combat aircraft that was initiated in 1980.

subcontractors becomes one of mutual learning of the increasingly important industrial technology of *distributed and integrated production* (Eliasson 1996b) that is currently carrying the globalization of world production, but that is also tending to shut out subcontractors, notably in developing economies that have difficulties mastering the necessary techniques of exact measurement, precision manufacturing of well defined components and quality control, and to observe delivery commitments.

Second, advanced products also distinguish themselves by being surrounded by a " cloud of related new technology " or so called spillovers. Thus, for instance, Swedish Ericsson probably would not have become the world´s leading mobile systems producer today without the technology spillovers from its military electronics arm (see case further on). In the Ericsson case the spillovers were picked up and profited from internally. To charge for spillovers picked up externally by other firms is , however, more difficult and often impossible because of weak property rights. This is where innovative pricing (Jonason 1999, 2001) and cooperative agreements come in so as to provide an indirect means of compensation to the producer.

In " advanced public purchasing" of the kind utilized for military aircraft, submarines, and public telecommunications systems the weak property rights problem can be to some extent attended to because of the dual interests of the public customer in both the product itself and " the cloud" (" joint customership"). Three circumstances, however, have complicated the problem extending the public dimension of these spillovers to the private sector: (i) previous public, or semi public activities like telecommunications are increasingly becoming privatized; (ii) traditional industry, private or semi private, increasingly uses advanced products of the kind we are talking about, for instance large commercial airlines, the media and entertainment industry and global transport systems; (iii) the existence of a hi-tech industry such as the very rare capacity to develop an entire generation of military fighter jets becomes a positive " quality brand " that spills over to the other industries of the same industry, and if cleverly attended to allows firms in that industry to charge more for their products. An upcoming semi public market , furthermore, is security that is intimately linked to military and defense technology. The defense against terrorism (see below) in fact has to effectively exploit current military technology. So, while the industrial domain rich in spillovers has expanded, the property rights and economic incentive problems associated with generating them have become more complicated.

A *third* factor concerning the value and pricing of spillovers is the ability in the local " capture market" to discover, evaluate and commercialize technological spillovers. The economic value of spillovers is directly dependent on that ability and the willingness of prospective users to invest in the commercialization of spillovers.

In that respect advanced public purchasing has certain unique and interesting features: the public customer has an interest in both receiving the product and capturing as large a value of the spillovers (for the country) as is possible. The product itself and its spillovers constitute - in effect - *joint production*. As a corollary, this implies that such products also involve *joint consumption* or *customership*.

Contrary to privately generated spillovers, both the product and the cloud of spillovers[3] now represent economic value to society at large and to its representative government. And the better the economy in commercializing spillovers the more such " social economic" value that is created. We explain this in terms of *competence bloc* theory. This is also one rationale for organizing industrial policy in the form of sophisticated public purchasing to obtain a well defined product, rather than in the form of direct subsidies of

[3] As I will explain below, spillovers do not only consist of new technology but also of educational services. Cf discussion of Table 1.

R&D, an input in the technology supply process without well defined uses. Public purchasing means that the economy receives something useful for its money, namely a product that functions plus the undefined spillovers.

Hence, the high-tech firm functions both as a supplier of demanded goods and services and as a de facto, but unintentional, private *technical university* in supplying technology to the economy without being able to charge for it. Since Governments across the industrial world are willing to pay for technical universities supplying similar, but more undefined technical and educational services one would expect governments also to be willing to pay extra for these more valuable spillovers that benefit the economy at large. Public purchasing of such products, hence, provides indirect public funding of that privately run university (Eliasson 1996b). Spillovers from advanced firms, furthermore, are probably superior to spillovers from technical universities since advanced public purchasing projects take the new technology closer to the market in the form of products that are demanded and that function compared to the unspecified technology supply that is generated by a technical university. When the public purchasing has been competitive the new technology, furthermore, is not only functional but also economically sorted and efficient. To achieve a desired and rational pricing of its products and services the producer engaging in public purchasing deals therefore needs a complementary marketing ability to demonstrate the economic value to the customer , or to society of the joint product, both the product itself and its spillovers. A potential to create a win-win situation between producer and customer exists, but even though the interest in seeing it realized is mutual, the practical tasks of identifying the opportunities, of realizing them and (therefore) of taking the initiatives rest largely with the commercial ability of the producer.

To summarize, the pricing problem consists in demonstrating to the customer the economic value of the intangible cloud of technological spillovers in addition to the user value of the product itself. The marketing strategy, to be efficient, therefore, may require active support of the customer ibn creating the competence needed to commercialize spillovers locally. Such a support could come in the form of well designed industrial participation programs and is in the interest of both parties to the transaction. In fact, the often large differences between social and private returns to R&D investments calculated (see below) illustrate the economic value of such spillovers. The new awareness also brought in through this paper is that this value depends positively on the local receiver competence, or ability to commercialize spillovers. Hence, a brief survey of the econometric spillover literature will follow below.

With this pricing discussion I have attached a double meaning to the concept of efficiency. It is economically inefficient for the production of advanced products and services not to market the dual product and to make arrangements to capture as much as possible of such value from the spillovers as possible. It is socially inefficient for the customer , and the public customer in particular, not to be concerned with locally capturing that value. Demands for offset trade signals an awareness of that possibility, but in practice has often been an inefficient way for both parties to the deal and especially so if short term employment benefits are asked for rather than economically filtered technology transfers.

3. Joint manufacturing of products and intangible spillovers

Let us define product characteristics in terms of

a) Functional requirements of user/ customer (FR.)

b) Production costs[4]

[4] This is all in terms of axiomatic design (Suh 1990) language. Functional requirements stand for a vector of product characteristics, and DP (Design Parameters) for the minimum of design parameters needed to achieve FR through the production and technology matrix {A}. Suh´s model recognizes the general industrial experience that there are many ways (many matrixes {A}) through which FR can be achieved but that industrial practice is not always such that the producer achieves specified FR at minimum possible costs. Incentives , competition and competent purchasing on the part of the customer may enforce minimum cost practice, but Suh`s model is a

c) Repair, servicing and maintenance attributes.

d) Updating potential.

e) Associated intangible spillovers.

Purchasing contracts are usually negotiated on a) and b). As an additional functional characteristic of the product c) is increasingly becoming an issue as the ownership of the product is redefined, for instance in the procurement of large aircraft engines, where the producer increasingly owns the product and charges for its use. The demands for updating potential (d) is a difficult question for the producer since as much as 70-80 percent of manufacturing productivity (Suh 1990, p. 41) is determined at early design phases. Intangible spillovers (e) are normally forgotten altogether in the pricing decision[5].

There are two types of uncertainty associated with the development and manufacturing of an advanced product.

(1) Performance to specification (*technological uncertainty*).

(2) Control of internal productivity and prices (e*conomic uncertainty*).

If the customer desires significant new technology development as part of product design great technological uncertainty is seen to exist. Normally the producer has no method of reliable calculation. When the producer has no real information advantage over the purchaser a (technological) risk sharing contract is the normal solution. In fact, in advanced public military purchasing, the customer is often a significant technology contributor who understands the product technology and the production organization well. Once product technology is under control costs of development and production become more easily calculable. Here, the producer has a clear information advantage. The balance between (1) and (2) is, of course, reflected in the contract.

With new, untested product technology one expects *cost plus pricing* to govern, with a large part of the risk being taken on by the customer. Since new untested technology should spill more technology when developed it would even be in the interest of a rational public

---

method to structure and make the production process and its choices clear both to the producer and the customer. In fact, in the case of purchasing of complex systems products the customer and the provider normally have to interact on the basis of a minimum common understanding of each other´s business. Suh´s method can help to structure that understanding.

5 and rarely entered directly into the contract, except sometimes as local employment commitments on the part of the seller. Such short-term commitments are normally an inefficient arrangement, often unrelated to the main contract and of little value to both parties.

purchaser to cover a larger share of the risk, since the public value of the spillovers becomes larger.

When functional requirements are standard, tested and normal, calculable flexibility is asked for and we have a case for *design-to-cost pricing*. The buyer sets a price and specifies the minimum product performance characteristics. The negotiation, or the competition then is about what more the producer can offer at that price.

One would expect rational producers not to do more than they get paid for. However, a generous contract might very well be designed to allow for experimentation with, for instance, new technology on the part of the producer, or for that reason taking on a higher cost domestic subcontractor because of the benefit of closer cooperation and fewer manufacturing errors. The purchasing contract between the Swedish defense materials procurement agency (FMV), the representative customer of the Swedish government and the IG- JAS industrial group formed in 1980 (and headed by Saab) to develop the JAS-Gripen multipurpose combat aircraft practiced design-to- cost pricing far more systematically than in other defense purchases and therefore left less leeway for high cost Swedish subcontractors than was the case with the purchase of the predecessor to Gripen, the Viggen jet fighter. This can be interpreted in two ways. In standard economic parlance the Government this time (through its defense materials procurement agency FMV) was both tough and competent. In terms of our logic one could also argue that Government was less willing to pay for the generation of spillovers.

One would also expect the producer, facing a tough negotiation on the purchasing (a and b) side to use his information advantage and accept a low price for well defined FRs, but save on (c) and resist demands on (d) and then capture part of the profit on later maintenance and upgrading. From the customer point of view this is, however, less efficient. As a rule spillovers are determined by the product specification and not negotiable (excluding offset requirements), but the less of new technology development associated with the FRs the smaller the cloud of spillovers. Hence, both the customer and the producer should get a better deal on the a and b side if it can give a credible presentation of the value of embodied low cost maintenance and upgrading, and above all on the intangible spillovers under (e), and offer support to the customer in capturing the spillovers. A rational public customer should focus on (e) and ask for support in capturing the spillovers. Obviously, having an information advantage the outcome for the producer/seller improves with its ability to present a credible story. Risk sharing and incentive contracts increase in importance when both parties are equally informed about the value of spillovers.

For instance, the Swedish Government and its representative purchaser (FMV) demanded[6] that the Jas-Gripen consortium should get the most efficient low cost subcontractors, thus minimizing the resources available to the subcontractors to develop new technology. Consequently contracts went abroad to foreign subcontractors of complex components that could modify already developed subsystems or components, for instance the landing gear. Only large subcontractors such as Ericsson and Volvo were able to take on large development projects and finance them internally, later to use the new technology in other projects. It is an interesting question to ask how well informed about the economics of advanced purchasing the public purchaser was when it squeezed the Jas-Gripen consortium so hard [under (b)] that less margin than before was available for product development, and, hence, most probably less spillovers were generated.

4. The Nature of Intangible Spillovers

Intangible spillovers are difficult to define since they only become visible as they are recognized and made use of. The pick up rate depends on the local receiver competence or absorptive capacity (Eliasson 1986, pp. 47 f, 1990a, Cohen-Levinthal 1990).

4.1 The existence and magnitude of spillovers

There is a large econometric literature demonstrating the existence of the cloud of spillovers around advanced firms, most of the literature originating in the US and being presented under the heading of "technological spillovers" or "general purpose technologies" (for an early survey see Eliasson 1997).

The main empirical story is that productivity in firms and industries increases with increases in investments in R&D, R&D intensity being normally defined as the proxy for being technologically advanced. But increases in productivity, although not as large, may also be registered in related firms. Bernstein and Mohnen (1994) studied (1) the effects of own R&D spending on own productivity, (2) the productivity effects in related US firms and (3)

[6] See e.g. Bill to Parliament *Prop.1979/80:117, p. 23 ff.* Also see Eliasson (1965, pp. 155f).

the productivity effects in related Japanese firms. They found that the Japanese firms were better than the "closer" US firms to exploit technology developed in advanced US firms .

In economic jargon technological spillovers are an externality, a term introduced by Alfred Marshall (1890) signifying that they cannot be explained within the standard (and static) economic model. In the wake of the oil crises of the 1970s and the following unexpected and long stagflation period many economists attempted to remedy this deficiency of mainstream economic theory under the ponderous title of "New Growth Theory" which they claimed to have endogenized and explained economic growth.[7]

The existence of positive externalities or spillovers or unaccounted for infrastructure capital means that output is being observed that cannot be linked to a corresponding registered resource input. This, for the same reason means that private and social rates of return to capital will differ because some of the capital input in production has not been properly accounted for. This is a common problem in economic accounting, notably when it comes to accounting for the presence of knowledge capital. During the early part of the post WorldWar II period economists discussed the technical residual or the mystic technology factor or total factor productivity (TFP) growth that "explained" a growing part of total manufacturing growth and by the early 1970s almost all growth, only to suddenly disappear as mystically as it had arrived during the 1970s (Denison 1961,1967,1979). Solow´s (1957,1959) production analysis marks the beginning of this discussion. Erik Lundberg´s (1961) so called Horndal effect added a degree of mystery to the observations that Arrow (1962b) attempted to clear up by his "learning - by - doing " model.

Unexplained technology generation was the standard explanation until Jorgenson and Griliches (1967) managed to more or less eliminate the technical residual or total factor productivity growth by correcting factor inputs in production as recorded in the national accounts. The J&G (1967) method comes close to our problem of measuring the value of spillovers. Their method, which is still controversial, is to impute the value of unaccounted for inputs from a hypothetical market value of the products[8]. When Jorgenson and Fraumeni (1992) applied the same method to the US education industry they found that US educational

[7] First man out was Romer (1986). At close inspection, however, growth in the "New Growth models" is also carried by an exogenous equilibrium trend, and hence do not embody much more endogeneity than the standard neoclassical growth models, e g those used by the Jorgenson workshop (see further below).

[8] The method has been criticized for being tautological , but the problem is rather the strong assumptions about the existence of a known external equilibrium that one has to make.

output accounted for far more of US production growth than previously estimated in other studies.

Similar results have been obtained from cost benefit based spillover studies indicating social rates of return on R&D investments far above the corresponding private returns, being in Canada as high as ten times (or more) the private return (Bernstein and Yau 1995). Nadiri (1993), contrary to common opinion, also found little evidence of decreasing returns to increased R&D investment, a conclusion that very much signaled the later superior economic performance of the US economy after 1995[9]. Nadiri thus concluded that R&D in Western firms generates great spillovers and that the large difference between social and private returns indicated significant underinvestment in R&D among these firms. The implication of this, he concluded, is that a nation that allows the opportunities to capitalize on that knowledge base in industry slip by will be on a losing track.

From this, however, does not follow that government should step in to increase its infrastructure spending on R&D, as is the argument behind most input based industrial policy. Measaured unexplained value creation is a market filtered output and a significant commercial resource input is needed to transform R&D spending into valuable output. *First*, advanced firms in these spillover studies normally have a high R&D intensity in production. *Second*, most studies are based on US data and describe a positive relationships between R&D intensity and productivity in own and related firms . A selection effect therefore afflicts most of these results. Effects of R&D spending on firm growth not only take a long time in showing, which means that firms engaged in R&D spending that have experienced positive results dominate the statistics. This is so because failed firms have either reduced R&D spending, reduced operations or dropped out of the market. The conclusion to increase R&D and you will automatically enjoy more economically valuable spillovers therefore does not hold as a policy guideline.

The strongest economic filtering of technology is to be found in the financial markets. The strongest industrial spillovers also appear to originate in privately financed R&D carried out in private firms where the allocation of resources have been through a double market filter. Publicly funded research carried out in private firms comes in second, and the lowest

[9] Later, Mun and Nadiri (2002) observed that IT externalities in US private industries over the period 1984 – 2000 were stronger than other externalities, and explained considerable parts of TFP growth, notably in service industries, that are characterized by significant interindustry transactions. One should add here that the introduction of distributed production across manufacturing industry should mean an increase in the same characteristics (Eliasson 1996b).

spillover effects are recorded for publicly funded research in publicly run research laboratories (Nadiri – Mamuneas 1994, Eliasson 1997, pp. 241 f). This, hence, is a negative result for university research and runs against the suggestions of Arrow (1962a) to improve innovative efficiency by establishing publicly run and financed industrial R&D laboratories that should then make the innovations available for free to firms. It rather supports the idea expressed by "*the advanced firm as a technical university*" of Eliasson (1965, 1996b) that it is more productive if R&D investments are decided on, carried out by and also financed by private firms (Mammuneas and Nadiri 1995).

Intangible spillovers come in different shapes. *First*, to exemplify from our case study, we have the closely related, within industry spillovers, one step beyond internal firm use (the *core industry* in the inner circle of Figure 1). Here, we would expect to find spillovers running back and forth between aircraft manufacturers and aircraft engine manufacturers. The more fragmented by outsourcing industry becomes the more important these spillovers, and the more urgent it becomes to find a way of mutual recognition and compensation. In public purchasing we also have a case of joint customership and it should become easy for Government to motivate a higher price for the product as a compensation for spillovers. Silicon Valley and the South German luxury car production cluster offer another case, that of a competence bloc populated with advanced firms that both benefit from the spillover source and contribute to it (Eliasson – Eliasson 2005a).

(Figure 1 in about here)

The next step (*second*) takes us further out to the second circle; related (to aircraft industry) technology including air navigation and safety, air traffic control etc.; a rapidly growing IT intensive industry. If unmanned air traffic becomes a reality this might constitute an important growth area, as would security industry in general and recent firm interviews conducted within this project indicate that the aircraft industry is moving in this direction.

Third, however, many devices and technological developments in the core aircraft industry find profitable applications all over engineering. It is no coincidence that a Swedish computer industry originated among the high quality users of numerical calculation techniques (industrial simulation) in Saab in the early 1960s. The Saab combat aircraft Viggen developed during the 1960s and first delivered in 1971 also used on board computerization extensively and developed technology that would later come to be used to support distributed manufacturing (See further below). This generic quality of aircraft technology makes it appropriate to say (as in Eliasson 1995) that *aircraft industry already today uses the technologies of future engineering industry.*

Finally we have the unpredictable serendipitous spillovers in the outer circle[10]. For instance, while it should not come as a surprise that a Swedish aircraft engine manufacturing activity developed within Volvo[11] as a spillover of Swedish aircraft industry, it is more difficult to understand that Ericsson mobile telephony owes a lot to military electronics development (see below).

The ability to capture the spillovers in the different circles also requires very different receiver competencies on the part of local industry. It also depends on the channels of diffusion of the same spillovers.

4.2 Diffusion channels

Table 1 lists the six main channels of technology diffusion. The most discussed channel is outright imitation – the Japanese way (Cf Bernstein and Mohnen 1994) – (item 5), when development costs are carried by US firms and the spillover rents captured by the Japanese firms. Econometric research – as mentioned - lends support to the existence of that channel of diffusion.

It is, however, important to emphasize that technology diffusion only to a minor extent is about the diffusion of "solutions" already developed ("patents"). The important form of diffusion occurs when a group of people has learnt to solve a particular type of technical problem and moves on to a new project or starts a new firm that can benefit from its experience. The most important avenue of technology or competence diffusion, therefore, is the *market for competence*, when people with competence move between jobs and firms (item 1). The same type of learning (item 3) occurs when firms/subcontractors learn from one another when working together. Increasingly, firms also acquire complementary technology (item 4) through strategic acquisitions.

(Table 1 in about here)

[10] The word serendipity originates in Horace Walpole's (ca. 1754**)** *The Three Princes of Serendip* who had an aptitude for making fortunate discoveries accidentally.
[11] Volvo acquired *Nohab Flygmotor* (founded 1930) in 1941. After a couple of name changes it is, since 1994, *Volvo Aero Corp*.

Another form of diffusion and/or activation of technologies (item 2) occurs through spin offs from larger firms. This is perhaps even more important than the movement of people, since it often means that winning technologies about to be shelved by conservative big business firms are activated by an understanding entrepreneur, often a group of employees within the firm, jumping ship to start their own business. Most of Silicon Valley, in fact, has that origin. At the same time university entrepreneurship, meaning the industrial exploitation of university research results, while probably being less important (Eliasson 1997, 2000b) has been more discussed in literature (Jaffe 1989, Nelson 1986, Stankiewitz 1986). University research to become industrialized requires strong support of a complete and broad-based competence bloc (next section).

Finally, research and internal learning in incumbent firms (item 6) is a not to be forgotten source of long run growth that involves considerable diffusion of technology within the company. The bulk of R&D expenditures in advanced firms is devoted to picking up internationally available complementary technology to integrate with their existing knowledge base, and only a small fraction to genuinely new technology development. The multinational firms are specialists in this field (Eliasson 1991a, 1997:12ff), and, supporting this , Keller (2001) observes that recent research shows the major source of technical change leading to productivity growth among OECD countries is foreign, not domestic.

4.3 Competence bloc theory and the critical role of the advanced customer

Creation, commercialization and diffusion of technology require market support. Incentives to create and commercialize have to be in place and projects have to be exposed to a maximum of varied and competent evaluation to minimize the risk of losing a winner and keeping losers for too long on the budget (Table 2A). A viable and complete *competence bloc* [12] is needed for this optimization of the selection process that results in the entry (Table 2B) of winning projects/firms and more competition from incumbent firms. The critical role in that selection of the advanced customer is unique to competence bloc theory.

Customer competence and contributions

The fundamental understanding of competence bloc theory is that in the long term the quality of products will be limited from above by the competence of customers to understand the

[12] Competence bloc theory was first formulated in Eliasson and Eliasson 1996. The currently most complete presentation can be found in Eliasson 2001a, 2005:Ch I, Eliasson and Eliasson (2005b, 2008) and in Johansson (2007).

qualities of the product, their willingness to pay and their contribution of user competence to the development of new technology[13]. A competent and wealthy customer base constitutes a competitive advantage of an economy.[14] The availability of specialist subcontractors within the competence bloc, furthermore, allows individual firms to enjoy economies of scale through the system. A complete competence bloc, hence, allows through its mixture of market and hierarchical coordination a dynamically efficient combination of innovative ability and industrial scale (Eliasson and Eliasson 2005b).

In the end this paper will highlight the different interests of the public and the private customer, in effect meaning that they regard the same product differently. A rational public customer should be concerned that the cloud of spillovers be commercialized locally to a maximum possible extent, indirectly making public purchases an instrument of industrial policy. The private customer cannot be expected to entertain the same social concerns, even though it may be interested in commercializing the spillovers alone or together with a partner, to the extent it makes (private) economic sense.[15]

(Tables 2A, 2B and 2C in about here)

Technology supply

The complete competence bloc features competent *customers* (item 1 in Table 2C) that contribute technology to producers by participating in development work. This is typical of aircraft industry. *Innovators* that combine old and new technologies into new composite technologies are important actors in the technology supply process (item 2). It makes economic sense to give innovators a technical definition even though Joseph Schumpeter (1911, 1942) was not clear on this point. [16]

[13] As argued by Day (1986) this latter interdependence of demand and supply poses difficult methodological problems in economic theory.

[14] The comparative advantage for a nation of an advanced local customer base was recognized already by Burenstam-Linder (1961).

[15] Again, to anticipate the industrial policy discussion below there will always be a general policy argument for supporting the development of local commercialization/receiver competence to capture spillovers from public and private procurement. It is more difficult to argue generally for more advanced public purchasing since it means arguing for a large public sector and it is by no means clear that the public purchaser is more competent as a customer than the corresponding private one. Only if the market is not responding to a private demand, or if the product is a clear public good will there be a rational argument for a representative public customer to step in, for instance in defense procurement. We leave this difficult issue at that here.

[16] This technical definition of the innovator has its origin in von Mises (1949). On this I prefer to think in terms of innovations as being generated by a technology system (Carlsson 1995) or a technology production function (Griliches 1979, 1984,1986)

But technology supply is not sufficient to guarantee economic growth. Technologies have to be identified and commercialized and this is the phase when critical project selection occurs, business mistakes are committed and large resources have to be mobilized.

Commercialization

Entrepreneurs (item 3) have to be present in the own firm or in the market to identify the commercial potential of some of these innovations. The entrepreneur, however, also needs funding, and for entrepreneurs in radically new industries the *venture capitalist* has to understand the commercial potential of what the entrepreneur has offered to provide funding at reasonable costs. The venture capitalist in turn will want to *exit* (item 5) and return to new ventures, and hand over the task of taking winners to industrial scale production and distribution to the *industrialist* (item 6). The exit markets are increasingly populated by private equity investors and the development of markets for complementary technology purchasing and strategic acquisitions that facilitate the industrialization process are becoming increasingly important as the distributed production technology of the global economy develops.

The functions of the competence bloc support each other synergistically. The degree of *completeness* of the competence bloc therefore determines the functionality of the entire bloc. Without functioning exit markets the venture capitalist has no way of capturing the full profit potential of his venture, except becoming an industrialist on his own. And he is normally not the competent person to do that. So the existence of competent industrialists to carry the winners selected at earlier stages on to industrial scale production influences the incentives of the entire system. But the entrepreneurs are dependent on the existence of venture capitalists and so on.

One competent venture capitalist is, however, not sufficient to understand and evaluate the entire supply of innovative propositions from an entrepreneurial society. Creative innovation supplies are always broader than the local supply of experience based commercialization competence (Eliasson 2005;:39ff). Hence many competing actors of each kind and with varied competences (the horizontal dimension of the competence bloc) are needed to maximize the exposure of each innovation to a competent evaluation.

Furthermore, the more winners that are carried through the competence bloc the larger the potential for learning and creating new combinations of technologies (innovation potential). When the *critical mass* for endogenous industrial development has been reached the competence bloc will become a strong attractor for new entrants looking for new complementary technology, but because of competition, only competent entrants, that also contribute competence to the bloc, will survive. A vertically complete and horizontally sufficiently varied competence bloc that has reached critical mass will minimize the risk of losing a winner. Formulated differently, a potential winner faces increasing returns to continued search for resources through a complete competence bloc. On the other hand the absence of a range of actors in each actor category may make the entire incentive structure supported by the competence bloc collapse.

As can be seen, the competence bloc has an end product market definition. Technology or technology systems (Carlsson 1995) , on the other hand, are an input that enters an economic evaluation process through the innovation slot 2 in the competence bloc (Table 2C). Spillovers are thus industrial, not technical, i.e. technologies supplied from the R&D process that have been sorted by commercial market criteria. Since successful and recorded spillovers have been tested in the market they embody both technology and economic or commercial knowledge. Technological spillovers – the common term – hence, is a misnomer. Competitive market selection, therefore, raises the productivity effects out of a given technology supply (Eliasson 1996b) and commercialization through a complete competence bloc is a means to achieve that. Effective industrial policy through competent public purchasing of advanced products, hence, needs the support of full fledged competence blocs that in turn support competition in the local economy and raise the economic value of spillovers from R&D spending in advanced firms .

5. The Value of Intangible Spillovers

The value of spillovers has a collective (social) and a private part. Both depend on the capacity of actors to build a business on them.

5.1 Receiver competence

The capacity to commercialize technology (*receiver competence* , Eliasson 1986, pp. 47f, 1990a, Cohen – Levinthal 1990) is both technical and economic. Hence, capturing the rent depends on (1) the possibility to link property rights to the spillovers, (2) the capacity to build a business on them and/or (3) the ability to charge for them (Innovative Pricing). Patents or copy rights are the most common ways to link property rights to spillovers. Vertical integration or joint ventures (items 3 and 4 in Table 5) are common attempts to capture the rents based on an asymmetric information or competence situation. Saab has done it internally (see next section) through starting fully owned companies on the basis of technologies developed around its aircraft business (e.g. *Saab Combitech*). Another way is to build a new division to appropriate own spillover technology [for instance *Data Saab*, see Eliasson (1998)]. A third way is to organize a joint venture with a group of internal innovators and contribute venture financing. Lacking ways of directly charging for their spillovers many large firms have started their own venture capital businesses to appropriate the rents from their own "spilled technology". Compensation comes in the form of capital gains or joint ownership. A fourth way is, of course, to let an internal inventor do it on his own, and charge a licensee fee for what has been developed in the company, or just (which is more common) to let the inventors/innovators take their ideas with them and do it on their own. Then the innovator/entrepreneur who commercializes the spillover will capture the profits in the form of capital gains if the spin off is a success. But this path or diffusion channel runs across markets and is a high-risk path. Success depends critically on the existence of a complete and viable competence bloc (item 2 in Table 3). Also here, however, a joint venture between the entrepreneur and the venture capital arm of his earlier employer is a possible and common solution.

(Table 3 in about here)

Receiver competence is, hence, critical for the value of spillovers. The more important receiver competence the less difficult the problem of charging for information. If the imitator cannot pick up your idea (knowledge) without your help you can sell the knowledge over and over again because you have to provide user (receiver) competence as well. Technology transfer programs and offset trade arrangements - if competently organized - are illustrations (item 5 in Table 3). The only really valuable offset trade to the receiver country is offset trade that involves support in implementing the industrial user competence in the local economy. The weak ownership to spillovers, however, changes character in the case of public procurement . Now a policy dimension is added to the procurement.

5.2 Capturing the rents from spillovers – joint customership and industrial participation programs as a joint policy and business opportunity

Spillovers diffuse because of the potential rents they carry. There are incentives for both parties to the transaction to capture these rents, but the difficulties are large because of weak property rights (for the producer) and lacking receiver competence (for the buyer)[17]. This very fact, however, establishes a situation of strong mutual interest. The situation of strong mutual interest is further strengthened if a Government is the buyer and a situation of *joint customership* prevails. We then have a case for explicit producer – customer cooperation as a general policy case. This policy opportunity is most appropriate for advanced industrial nations and has to do with the existence of complete competence blocs to support the capturing of "further out" (in the circles of Figure 1) spillovers. The larger the captive area the higher the probability that radically new technologies will be identified and commercialized. All Scandinavian economies are therefore more " efficient" in that respect than Sweden alone. The argument in Eliasson (1999) was that a joint Nordic purchase of submarines (The Viking Project) would increase the pick up rate of spillovers in the area as a whole. Europe at large, for the same reason, would create an even better such industrial policy opportunity, even though it would be difficult/ impossible to predict "which country" would capture which spillovers. In fact, and following up on the argument above competition among the countries to capture the spillovers industrially would raise the positive economic effects in the pick up area.

The cooperation case is focused on the inner circles in Figure 1. Here, the producing company contributes management competence and receives profitable cooperation within an industrial participation program in return.

The business opportunity is that there is a profit to be earned from making the spillovers valuable for the local or receiving economy. To do that the producer/seller has to support local receiver competence as a profitable business in itself. For a developing economy well designed off-set trade arrangements are a method to create such a mutually beneficial win-win situation. For this to be the case off-set trade has to be oriented towards capturing technology, acquiring industrial competence and developing related and new production. Hence, part of the innovative pricing (Jonason 1999) strategy includes the art of presenting a convincing

[17] The notion of weak property rights is discussed in a similar context in Eliasson and Wihlborg (2003).

case for the long-term industrial benefits of the deal.[18] Bundling the aircraft sale with an offset program designed to capture the spillovers locally is our example. Encouraging the establishment of local venture capital firms to induce foreign and local investors to establish on the basis of the spillover flow is another example. In one sense such an “agreement” means establishing a commercially based industrial park (Eliasson 2000a).

5.3 Boosting receiver competence through policy

Important for the value being delivered to the local economy (including spillovers) is the competence of the local economy to receive it profitably, i.e. to base new businesses on spillovers. The product being sold in the case study to be presented below, therefore, is the *hardware equipment itself plus the value of the spillovers*. This value depends on it being identified and matched by the local ability to nurse a profitable business around the spillovers. Looked at this way the local economy around an advanced product acquisitions program faces a positive sum game. This is the case irrespective of whether procurement is public or private. The policy task is, however, different.

It is in the interest of the public customer to see the spillovers commercialized. But while the public customer will be satisfied with only seeing the spillovers picked up, the private customers will only be interested and willing to “ pay extra” if they can earn a private rent from the spillovers. In the case of advanced public purchasing the role of the policy maker, therefore, is to make sure that the local receiver competence is satisfactory i.e. that the competence bloc is vertically complete and horizontally varied.

Hence, making full use of spillovers from advanced firms the local economy faces the general policy problem of supporting the *local receiver competence* to identify and commercialize winning technologies . At the same time it is in the interest of the advanced firm to establish in a local economy well endowed with industrial receiver competence, since that receiver competence raises the total value of its product (including spillovers) to the local economy. However, only in the case of public procurement is the weak property rights problem (to its spillovers) satisfactorily solved since the government/customer is then directly interested in

---

[18] Innovative pricing is a method developed to identify a base to price a product with weak property rights, for instance different kinds of digital services or (our case) spillovers that have to yield a return to make the whole product (aircraft and spillovers) profitable for the producer (see further Eliasson 1995: Ch. 15). Innovative pricing (IP) is needed in situations with difficult to define multidimensional products, many dimensions of which being unknown to, or unavailable for most customers but also constantly changing. IP then amounts to defining the base (the dimensions of the product) to charge for. Jonason (2001) uses the theory of the experimentally organized economy (EOE, see eg. Eliasson 1991b, 2001a) to accommodate the very common situation of products, the quantities of which cannot be defined because of the many quality dimensions, a phenomenon recognized as normal already by Hayek (1937).

seeing the economic value of its spillovers raised.. A broad industrial base, an educated and entrepreneurial labor force and a complete and varied competence bloc are supportive of that ambition. Even advanced industrial economies such as Sweden, however, may have a problem here. For industrially less advanced and developing countries the difficulties of taking advantage on their own of the opportunities created are overwhelming. It should therefore *be mutually advantageous for the advanced firm gearing up for large scale production and distribution and the receiving country to engage in a mutually advantageous industrial participation program aimed at both boosting local receiver competence* (of spillovers) and offering profitable business cooperation contracts to develop new businesses (cf. item 5 in Table 5). This gives a rational economic argument for offset trade arrangements, but only for contracts that trade long term industrial development for profitable business deals. The Jas-Gripen (Saab) sale to South Africa has created opportunities of this kind, when done right (Eliasson 2000b). Spillovers are a positive characteristics of an advanced product. They carry extra value for the buyer and the local economy that depends on the local receiver competence to create a business on it.

6. Capturing the Direct and the Serendipitous Spillovers – the Case of Sweden's Military Aircraft Industry [19]

Swedish aircraft industry will now be used to demonstrate through case presentations the economic implications of technological spillovers. Concrete examples are needed to understand the economic nature of such spillovers. I have chosen Swedish aircraft industry because of the wealth of observed technology supply from that industry, and the fact that I can draw directly on an earlier study (in Swedish, Eliasson 1995) and complementary updating.

The story begins with a brief account of the economic significance of the industrial spillover cloud around Swedish Saab over its history, beginning when *Svenska Aeroplan AB (SAAB*) was established in 1937 as a separate company by Bofors together with a subsidiary of Electrolux, to build military airplanes for Swedish defense. I move gradually outwards through the circles of Figure 1, beginning with the core products in the inner circle, the military aircraft.

[19] A much more detailed account is found in Eliasson (1995).

6.1. The Product

An aircraft is a complicated product with a very long life that requires an extremely complex and distributed production organization. The life length of the Swedish fourth generation multipurpose combat aircraft system JAS Gripen is illustrated by the fact that design of the aircraft platform began in 1980, the first prototype was flown in 1988, the first production aircraft was delivered in 1993 and redesigned and modernized versions of the plane are expected to still be in duty by 2035, perhaps even by 2045 . The versions then flying will look quite similar to the first aircraft delivered in the 1990s, but they are entirely different aircraft when it comes to performance properties. Embedded electronics and software make the difference. Hence, the New Generation Gripen first presented in April 2008 more or less looks the same as earlier versions, but has a stronger engine, can carry a much larger weapons load, has a 40 percent longer range, better avionics and above all the advanced electronics that makes all this possible. The New Generation Gripen is faster than its closest competitor the US Joint Strike Fighter (JSF) from Lockheed Martin , and is available at half the price.

An aircraft integrates advanced mechanical technology with electronics, sensor technology, hydraulics, new materials, communications systems etc (Table 4). In military aircraft weapons systems have to be integrated with the aircraft, communications systems modified and encryption technologies installed etc. As will be further elaborated below the upgrading of the fourth generation aircraft JAS Gripen from its initial and generally designed hardware platform is largely a matter of redesigning the electronic software embodied in the aircraft. Contrary to other fourth generation military aircraft the JAS Gripen software of the export version, the development of which began in 1995, even allows the aircraft to switch between fighter tasks, attack and surveillance in flight. Such flexibility in product design for customized uses is increasingly demanded of complex products in industry , from automobiles to telephone systems. In this sense aircraft industry uses already today the production technology of future engineering industry . This is one rational reason also for the advanced industrial nation to be concerned about having an inhouse aircraft industry. It functions as a technical university that delivers technology , education and training services free of charge to other firms in related industries and of a kind closer to production and user processes that the more academically inclined technical universities are incapable of developing and delivering (Eliasson 1996b). It is difficult and takes a very long time to develop such an industry. Only the five countries on the UN Security Council plus Sweden have the capacity to develop and build a complete military combat aircraft system. Two more countries should be added if we include also small civilian passenger aircraft[20]. This competence to develop a complete aircraft (with Saab in Sweden), including (see below) also a civilian regional aircraft , spills goodwill value to the entire Swedish engineering industry and might allow it to add a quality brand when pricing its products.

The long life of the aircraft means that to enjoy its services as a user, maintenance and repair services have to be delivered over its life cycle and the product will have to be updated and modernized now and then . In fact, the electronics of a modern military aircraft and a large commercial aircraft is normally replaced one or two times, sometimes three times during its often more than 50 year life span. The early definition of the product, hence, should include both the features that lower maintenance and repair costs and facilitate upgrading and modernization, and an understanding of the properties of the aircraft desired 50 years hence. Flexibility in basic structural design, hence, becomes an important product characteristic. Easy adaptability means product longevity, and product longevity means low life time costs for the user. This also means that the ability to manage product upgrades becomes critical for product life time costs. This partly explains why the user of very complex products often outsources the management of the product system over its life cycle to the producer. The producer understands the product better than the user. This began with aircraft and aircraft engines but is becoming common with expensive and complex products such as heavy trucks and telecom systems.

(Tables 4 and 5 in about here)

(But this is not enough. Compared to a university an industrial firm delivers technology embodied in products that both functions (is operational) and to some extent has been tested in a market for commercial viability and/or usefulness. This means that an aircraft that has gone through both a functional and a market test spills industrial knowledge that has a greater value for civilian production than spillovers that are only technological. This again means that technological spillovers is a misnomer. The spillovers documented econometrically around advanced US firms are industrial, i.e. both technological and commercial.[21] The commercial dimension of industrial knowledge also represents great economic value.)

Two critical parts of a globally competitive engineering firm are (1) advanced product design and marketing competence and (2) ability to organize *integrated production* over global

[20] They are France, Sweden, the UK, the US and perhaps China and Russia. Canada, Italy and Brazil have to be added if we include small civilian aircraft.

[21] Read commercially tested (in the market) technology.

markets. Product design, international marketing and organizational competence are typically developed in industry. Complex distributed and integrated production was pioneered in (military) aircraft industry (Eliasson 1996b). There is little of such hands on competence to learn in the classrooms of technical or commercial universities. Such knowhow diffuses as people move between jobs and firms in the market.

An aircraft, hence, is not only a very complex product. It is multidimensional in the sense that it is composed of (1) the product itself as a physical entity, (2) many years of service, maintenance and upgrading and (3) a "cloud of valuable spillovers" that unfortunately, for the producer, is close to impossible to charge for. Advanced firms, such as the aircraft manufacturers, therefore, generate different indirect (spillover) benefits over and above the product itself being purchased. In the short term local employment will be created, but this carries local value only if extra people employed cannot be gainfully employed elsewhere and the effects are only temporary. Sustainable production and export growth can only be achieved as a result of a sustainable increase in overall productivity growth generated by the spillovers.

In fact, spillovers around Saab are found in all four circles in Figure 1, and I will go through some of them in the form of brief case stories. There is, however, one overriding organizational competence that I have called "*integrated production*" (Eliasson 1996b) that is generic to engineering industry, that first developed in aircraft industry and currently is becoming the critical engineering technology associated with concepts such as modularization, outsourcing and distributed production and that is increasingly carrying the globalization of production in the world economy. The case presentations will be ex post in the sense that commercialized spillovers have been identified and their history and origin traced. Besides some historical observations most spillover cases therefore relate to Saab´s Viggen " third generation" supersonic aircraft that used digital systems and computers extensively to achieve functionality, that is still on duty in the Swedish airforce and was first delivered to Swedish military bases in 1971.

6.2 Civilian aircraft industry

The most obvious direct spillovers around Saab (in the first circle of core technology) are the large civilian (regional) aircraft project of Saab and aircraft engine production (item 1 in Table 6).

Civilian aircraft/projects have been attempted earlier in the life of Saab (that began in 1937), but tended to be shelved when a new generation of military aircraft had to be developed fast. The first serious civilian project was initiated in 1974. In the late 1970s Saab identified around 30 passengers as the optimal size for a small civilian passenger aircraft to be used for short distances. Saab was therefore fortunate to have had the right business idea when the US air travel market was deregulated in 1978 and had a fully engineered regional turbo prop plane (Saab 340) for 35 passengers ready for delivery already in 1984. Saab 340, therefore, soon became the world's most sold regional aircraft in its size range. A larger and quieter turboprop regional airplane for 58 passengers was developed and ready for delivery in 1994. Both the civilian aircraft and the military JAS Gripen projects were started at the same time, but this time the civilian project was realized because the Swedish Government demanded a civilian production project to complement the JAS Gripen project.

The market for civilian aircraft is, however, as political as the market for military aircraft and many countries, notably Brazil, Canada, France, Germany and Italy subsidized their aircraft manufacturers heavily to establish - such was the ambition - a local technological spillover source supporting industrial development. With a market distorted by heavy subsidies the commercial screening of the new technologies will be deficient (Eliasson 1995, 1996b) and the technological spillovers of dubious economic value to the nation. Without a government willing to pay handsomely for the spillovers the market for regional aircraft, however, went dead for private and not subsidized Swedish producers. We have a clear case for a need for innovative pricing, which was impossible in Sweden. Saab shut down its regional aircraft venture in 1999.[22] Saab´s civilian aircraft arm is currently refocusing to become a developer and supplier of advanced subsystems to the two large aircraft companies Airbus and Boeing. In this reoriented business Saab has been fairly successful in reemploying resources from the shut down regional aircraft venture.

(Table 6 in about here)

[22] An additional reason was that regional jets were becoming competitive. However, this would have been no reason for Saab to shut down its civilian aircraft activity had it had an opportunity to sell its turbo prop planes for a profit to finance the further development of a regional jet.

6.3 Innovative start ups around Saab – core technology

The civilian aircraft project could only be realized on the basis of technology and experience from Saab´s military production. Some aircraft technology links exist, but not to the same extent, to the automobile manufacturing that Saab began already in 1946, a business that after many ups and downs was sold to GM in two stages in 1990 and 1999. The efficient cockpit design of the military aircraft was in part transferred to the Saab automobile and the need to press together the legs and arms of the pilot when catapulted out of a crashing aircraft led to the development of a primitive airbag technology that was later in part transferred to the automobile safety firm Autoliv. During the years 1969 to 1996 Saab and the heavy truck manufacturer Scania were merged into one company Saab Scania with Swedish Investor as the main owner. This arrangement was, however, more financial than industrial and technological.

Saab has systematically attempted to develop new businesses on its own spillovers. A very early Swedish computer industry, first developed within Saab, became a separate division and was incorporated as a separate company in the 1960s, finally to be acquired by Ericsson in 1981. The Swedish computer industry, however, disappeared in the late 1980s with Ericsson's large Business Information Systems failure (see Eliasson 2001b and 1965, chapters 12 and 13).

A cluster of high tech innovative start ups developed around Saab over the years. Some of them, for some time were organized under the Saab Combitech umbrella company. Some of them developed military technology (like Saab Missiles) many of them civilian technology. Some of them are currently part of the earlier Celsius operation that Saab acquired in 2000, and Saab is selling some (notably Saab Marine Electronics) for good profit. Saab Aerostructures, as mentioned, has been successfully building up a presence as a specialized systems supplier to the large civilian aircraft manufacturers, and Saab has recently decided to use its military technology as the base for a move into the rapidly expanding civilian security market. The difficult management problem, however, has been to identify and carry radically different technologies spilled from the military aircraft business to successful industrial production and distribution within the parent's management umbrella.

6.4 Aircraft engines

Volvo Aero (item 3 in Table 6) is a winner within the inner circle of core aircraft technology in Figure 1. The history of Volvo Aero (earlier Volvo Flygmotor) is as old as the Swedish airforce. It was founded in 1930 to build combustion engines (from 1949 jet engines) on license for Swedish military aircraft. Volvo Aero increasingly modified the engine design and added own technology. A complete jet engine (called the Dovern) was developed in the mid-1940s by another Swedish company (STAL). But for some reason the STAL project was terminated before reaching industrial production. This military jet engine still exists in modified versions, among other things as back up electrical generators for ships, hospitals etc. Siemens acquired the business 2003 from ABB and is currently (SvD April 18. 2008) experiencing a booming demand for its turbines for steam generated electrical power based on solar energy.

Volvo Aero's management began worrying about the low civilian share of its production already during the 1970s (in 1970 only 5 percent) and began to systematically develop a civilian activity. This reorientation has been very successful and Volvo Aero civilian development and production of advanced components for the three large aircraft engine manufacturers (GE, Pratt & Whitney and Rolls Royce) currently exceeds 85 percent of sales. The reason for success (see Eliasson 1995, Ch. 10) may be the civilian production and marketing experience residing within the large Volvo group. Volvo Aero, furthermore, is also developing and producing gas turbines for a variety of civilian applications, including auxiliary power plants to hospitals. Energy efficient gas turbines, furthermore, are expected to capture new markets, for instance for home heating and perhaps also for automobiles.

6.5 Secondary related industrial spillovers from aircraft engines

Two related industry spillovers within the two inner circles in Figure 1 should be mentioned. *Volvo Aero Services* is a direct spillover from the license manufacturing of a modified version of the Pratt & Pratt & Whitney civilian JT8D engine for the military fighter aircraft Viggen. JT8D is one of the most used civilian jet engines. It is mounted on all DC9s (and all MD 80s) and on Boeing 727. Producing this jet engine on license meant that Volvo Aero "learned the engine" and soon became an efficient modifier and maintenance operator. Hence, Volvo Aero (and also Government owned FFV Aerotech, but to a less extent) gradually developed a new business serving this civilian jet engine and increasingly also other civilian jet engines. The market is huge. A large civilian jet engine has a service life of at least 30 years, normally much more. Its life cost [data for the Swedish military version of the JT8D engine; Eliasson 1995, p. 94] is one third for the engine purchase, one third for spare parts and one third for maintenance and repair. Again, to capture this business on the basis of spillovers requires considerable global organization and marketing competence.

The market for these large engines, furthermore, is rapidly developing into one for renting rather than selling the engines. Engine manufacturers such as GE own the engine, and the carriers rent engine services in terms of hours of use , speed etc. Taking a life long responsibility for the product means that its design incorporates efficient maintenance, repair and modernization features. (This technology was first developed in the industry producing military and defense products but is now increasingly used by other producers of large, advanced and complex products with a long life.)

Hydraulic pumps is another secondary spillover that became a winner (item 5, Table 6). The story illustrates the nature of entrepreneurship. The Viggen fighter aircraft needed a stronger fuel pump, and Volvo Aero engineers identified a design developed by US Sundstrand Corporation which had found no use for its invention. A license was acquired in 1969 and Volvo Aero engineers began modifying it for the Viggen. Somehow, they did not succeed and Volvo Aero faced the problem of how to recover the money invested in the license and the redesign. Even though the hydraulic pump was too weak for the military jet engine it was more than sufficient for heavy construction machinery. Volvo was first to grasp the significance of this and soon developed a global lead in the use of hydraulics in construction equipment. A separate company (Volvo Hydraulics) was started in 1983 and merged in 1992 with the Atlas Copco subsidiary Monsun Tison into VOAC Hydraulics that employed about 1000 people in 1995 when it was acquired by US Parker Hannifin.

6.6 Integrated production

Aircraft industry faced the need early to outsource advanced development and production. Too many technologies and too many components had to be integrated in too many different ways to make it possible for one firm to develop and produce an entire aircraft. Hence, the technique of modularizing the design and outsource entire complexes of components of the aircraft to subcontractors was developed. Integrated production (Fredriksson 1994, Eliasson 1996b) is the art of integrating all these activities efficiently in the design and manufacturing process. The more advanced the product the less likely that specialized subcontractors can be found in the local neighborhood. A global technology of organizing integrated production developed as did various standards to facilitate the design and manufacturing processes. Obviously, the competence to participate in such a globally integrated production system requires long organizational learning and experience accumulation. Such learning can only be efficiently organized through participating actively in a dynamically competitive subcontracting system (item 3 in Table 1).

(Table 7 in about here)

Integrated production has been made possible through the integration of C&C technologies and mechanical technologies. It makes a holistic view of both the product and of the production process possible (item 1, Table 7) as well as a geographical distribution of both product development and manufacturing. Simulation techniques (computational prototyping), furthermore, make "optimization" of complex designs (items 5 and 6) possible. For instance, maintenance and repair problems can be solved ahead of time (items 3 and 7) and costly ex post adjustments avoided (item 9). On the whole, C&C technology has made more efficient as well as flexible coordination in space, over geographical distance and over time possible. The economic benefits of this increased coordination capacity and flexibility are the largest for very complex and costly products that are produced under very complex circumstances using expensive subsystems and components, notably aircraft. On line design is part of this technology and in so far as aircraft production (both civilian and military) is concerned reliable encryption is a critical part of the technology, as is precise measurement and quality control. And it is difficult to get all subsystems and components to fit when brought together for final assembly from different places in the world. This appears to be the main reason for the recent (2007/08) delivery delays of Airbus 380 and also for Boeing´s Dreamliner. The organizational technology of distributed and integrated production was first developed in aircraft industry and is now diffusing to other advanced parts of engineering industry. It is increasingly becoming a critical competence element determining the ability of firms to participate in the globalization of production increasingly built on modularization, very precise measurement and strict quality control and outsourcing. Industrially developing economies also risk being shut out of the industrial learning process associated with being integrated within the emerging global production system if they do not get the opportunity to team up as a subcontractor with a Western firm. This establishes integrated production as a separate and critical engineering organizational technology.

6.7 Ericsson Mobile Telephony – a serendipitous spillover

The reorganization of Ericsson into the world's leading mobile telephone systems company is a nice and plausible story. Few would, however, expect that Ericsson owes a lot to military electronics for its success, and it is an embarrassing story that Ericsson top management for years tried to suppress development of radio telephony internally to free resources for its failed, but perhaps more logical, entrance into the business information systems market (Eliasson 1995, Ch. 12 & 13, 1996a:194ff). So the story is truly serendipitous and based on three positive circumstances; (1) a curious and innovative customer, the Swedish Telecommunications Agency (item 1 in Table 2C), that tried for years to push a reluctant Ericsson into Mobile Telephony, (2) the existence of a digital, modularized, switching technology within Ericsson (the Axe system) and (3) the lucky circumstance that Ericsson military electronics had developed several technologies (notably four out of 14 technologies needed to compose a mobile telephone system, Eliasson 1995, pp. 102 ff) that were in place at the critical moment when the market became ready. One of the three legs missing, perhaps only one of the part technologies, and Ericsson most probably would no longer be an autonomous player in the highly competitive telecom systems market. This property of failing "analytical foresight" and a top management that is neither curious nor attentive is a natural attribute of an experimentally organized market economy that carries strong implications for the organization and the management of a firm (Eliasson 2005b). Competence bloc theory (in Table 2C) brings the competent and active customer and two innovations (the AXE system and new military electronics technology) together with the internal commercialization competence of a large firm that clicked in once the top management of Ericsson understood that it had a winner inhouse . The entrepreneurial competence entered in the form of the stubborn manager of Ericsson Radio System (a subsidiary) that resisted top management pressure to terminate development work on radio telephony using a secret slush account provided from a military budget. When Ericsson top management finally realized they had a winner money was no problem (items 4 and 5) and industrial competence (item 6) to scale up was to some extent available internally. Ericsson, however, was not an experienced player in the consumer electronics markets and later merged its hand terminal business with Sony´s into a separate company, Sony Ericsson in 2001 (*Dagens Industri*, February 21, 2001, pp. 18f), which is currently the third or fourth largest player in the world.

6.8 *Secondary spillovers – Ericsson HP Telecom and telecom control systems*

Ericsson HP Telecommunications (EHPT) illustrates the importance of a mobile group of people that had learned to solve a particular type of problem.

A modern aircraft, and notably a fast, high performance jet fighter needs an on board control system that sounds an alarm when something malfunctions, and preferably also corrects the situation by turning on a back up system. Saab´s Viggen was one of the first third generation combat aircraft which combined extensive use of digital electronics with mechanical technology. Already at the end of the 1960s a digital control system had been developed for the fighter version of Saab's Viggen. Also telecom networks need similar control systems to reorient traffic when one link crashes. Ericsson understood that there was a potential demand for such a control system to monitor their large land based AXE switches and systems. They also understood that the experience from solving organizational programming problems for the Viggen control system would be useful here. Hence, engineers from the military software development project were assigned to this civilian project. Towards the end of the 1970s the AOM 101 was ready to be installed in the AXE switches for Saudi Arabia and Australia. The AOM system was proprietary to Ericsson's own telecom system. In 1990 an open Unix based TMOS control system was introduced. But the telecom control systems needed advanced computing technology that Ericsson did not have. Hence, a cooperation with HP was established and Ericsson HP Telecommunications (EHPT) was founded in 1992. There is no limit to the need for such systems in mobile and land-based telecom systems alone. Even though an even larger market may exist outside the telecom area, Ericsson HP Telecom decided to stay within their own business. The company employed 1200 people in 2001. In 2001 Ericsson acquired HP´s 40 percent share of EHPT and the company was internalized within Ericsson.

6.9 *The emergence and disappearance of a Swedish computer industry*[23]

Saab engineers could always use more computing capacity to solve their design problems than was available. They were thus very early users of computers and advanced customers of the early computing industry. To solve their computing problems they, in fact, started to develop their own computers in conjunction with developing similar computers for their products/aircraft. They designed a vacuum tube based computer in the 1950s to support the

[23] This section is presented in detail in Eliasson (2001b).

design of F32 Lansen and F35 Draken. For aircraft missiles to be carried by the Viggen jet fighter Saab engineers designed a fully transistorized control computer already during the second half of the 1950s. This control computer was redesigned for civilian use in 1960 as *Sank* or D2. Hence, Saab had a fully transistorized computer ready about a year after the launching of RCA's, Remington Rand's and IBM's transistorized computers. Saab was first in Europe with a transistorized computer, and had a minicomputer ready in 1962 which became the basis for *DataSaab*, the computer division within Saab that soon had some 3000 employees and was later spun off as a separate company. Technologically, hence, Sweden and Saab were occupying a joint leadership position in the global market for transistorized computers in 1959/60 together with seven US manufacturers. DataSaab was acquired by Ericsson in 1981 as part of Ericsson's failed venture into Business Information Systems. The budding Swedish computer industry died with that venture (more on this in Eliasson 1998).

7. Conclusions

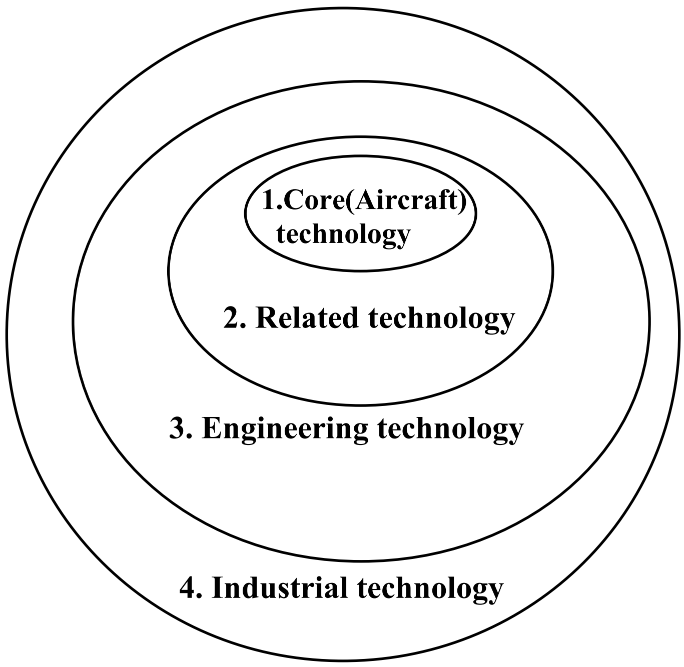
Swedish Aircraft industry was started as part of the Swedish defense effort in the 1930s in preparation for what was expected to come. At that time Sweden was an industrialized nation but not a leading industrial economy.

As a not intended positive side effect the Saab company has been an impressive technology generator that has helped significantly to catapult Swedish manufacturing industry to several leading positions in the postwar period. Part of the spillovers has been picked up and been successfully industrialized in other companies within Saab but the most important success stories have occurred outside the Saab Group. Several attempts to commercialize spillovers have failed, but surprisingly many have left a permanent positive signum on Swedish manufacturing performance, not least a positive brand of Swedish technological prowess.

When placed in the context of competence bloc theory these empirical facts can be systematically organized and presented in a consistent way to guide the policy maker. The competent customer not only contributes to product technology through an advanced procurement process. The customer is also a critical guiding party in the selection of winning ideas and projects to be carried to industrial scale production and distribution through the competence bloc. An important conclusion from this analysis has been the need to possess local receiver competence to make the local commercialization of spillovers possible. With joint production of the hardware product and associated spillovers and joint customer ship of the "dual character product", as is normally the situation with public purchasing of defense products, there exists a mutually beneficial, a win-win situation between the producer and the public customer to optimize the economic value of the spillovers. Rational marketing of the dual character product then involves helping to support local competence (receiver competence) to commercialize spillovers. Only when the public customer understands the value of the spillovers and needs local support to commercialize them can the producer charge for the spillovers.

The analysis carries a strong message on policy. One effective industrial policy role of Government is as a competent and demanding customer of public goods and services. As a customer the government knows what it wants. If the customer role is carried out competently there is little or no need to support inputs in the technology supply process. Government would then be involved in an economic choice process where it has little competence.

Figure 1. The four waves of spillovers



Source: Eliasson, Gunnar, 1999. *Undervattensteknologi i industriell tillämpning*. KTH, TRITA.IEO-R 1999:12.

Table 1. New Technology is diffused

1. When people with competence move (*labor market*)
2. Through new establishment by people who leave other firms (innovation and *entrepreneurship*)
3. When subcontractors learn from systems coordinating firm, and vice versa (competent purchasing)
4. Technology is acquired through strategic acquisitions of small R&D intensive firms (*strategic* acquisitions)
5. When competitors learn from technological leaders (*imitation*)
6. Through organic growth and learning in incumbent firms

Source: G. Eliasson, 1995 *Teknologigenerator eller nationellt prestigeprojekt? Exemplet svensk flygindustry* (A technology generator or a national prestige project? The Swedish aircraft industry). City University Press, Stockholm.

Table 2A. The dominant selection problem

Error Type 1: Losers kept too long

Error Type II: Winners rejected

Source: G. Eliasson - Å. Eliasson, 1996. The Biotechnological Competence Bloc, *Revue d'Economie Industrielle,* 78-4^0, Trimestre.

Table 2B. The four mechanisms of Schumpeterian creative destruction and economic growth

1. Innovative entry
   enforces (through competition)
2. Reorganization
3. Rationalization

   or

4. Exit (shut down)

Source: "Företagens, institutionernas och marknadernas roll i Sverige", Appendix 6 in A. Lindbeck (ed.), *Nya villkor för ekonomi och politik* (SOU 1993:16) and G. Eliasson (1996a, p. 45).

Table 2C. Actors in the competence bloc

1. Competent and active *customers*

   Technology Supply

2. *Innovators* who integrate technologies in new ways

   Commercialization process (Technology Demand)

3. *Entrepreneurs* who identify profitable innovations
4. *Competent venture capitalists* who recognize and finance the entrepreneurs
5. *Exit markets* that facilitate ownership change
6. *Industrialists* who take successful innovations to industrial scale production

Source: G. Eliasson - Å. Eliasson, 1996. The Biotechnological Competence Bloc, *Revue d'Economie Industrielle,* 78-4^{0}, Trimestre.

Table 3. Capturing the rents from spillovers

1. Joint production and customership
2. Establish in viable competence bloc
3. Establish joint ownership
4. Integrate vertically downstream
5. Engage in offset trade or industrial participation programs to support receiver competence. Create Win-Win situation.

Table 4. An advanced engineering product integrates:

(1) Advanced mechanical technology

(2) Computer and communications (C&C) technology

(3) Sensor technology and

(4) Hydraulics and

(5) New materials

Source: En teknologigenerator eller ett nationellt prestigeproject? – exemplet svensk flygindustri). Stockholm: City University Press.

Table 5. A military aircraft is

(1) an extremely complicated product with

(2) a very long life that is

(3) produced under very complex circumstances.

Source: En teknologigenerator eller ett nationellt prestigeproject? – exemplet svensk flygindustri). Stockholm: City University Press.

Table 6. Spillovers from Saab Military Aircraft Activities

(1) Saab civilian aircraft production

(2) The innovation market around Saab Scania

(3) Aircraft engines (Volvo Aero)

(4) The maintenance and modernization market for aircraft and aircraft engines (Volvo Aero Services)

(5) Hydraulic engines (Volvo Aero and VOAC)

(6) Integrated production

(7) Mobile telephony (Ericsson)

(8) Telecom Control Systems (Ericsson – Hewlett Packard Telecom AB, EHPT)

(9) Computers and information systems

(10) Etc.

Source: Eliasson (1995, pp. 68f).

Table 7. Integrated production allows the following advantages over regular production

1. A *holistic* view of production processes based on functional modules, exactly defined interfaces and competently organized design teams make delegation of work combined with central control of product performance characteristics possible.
2. Development and manufacturing can be distributed geographically and outsourced over many subcontractors.
3. The holistic view minimizes expensive mistakes (design errors, bulky devises and badly organized manufacturing flows).
4. Product development and manufacturing processes can be integrated.
5. Among many possible ways of organizing production, it becomes possible to choose one of the best.
6. Simulation techniques (*computational prototyping*) make efficient product solutions possible from the beginning. Large cost reductions can be achieved.
7. Maintenance and modernization problems can be anticipated and solved already at the design stage.
8. The manufacturing process can be organized for one-piece production, short production runs as well as volume production.
9. Quality control becomes more efficient and can be reduced. Costly after production adjustments can be avoided.

Source: Eliasson (1995), pp. 48 ff.

Bibliography

Arrow, Kenneth J., 1962a. Economic Welfare and the Allocation of Resources for Invention; in R. Nelson (ed.), *The rate and Direction of Inventive Activity: Economic and Social Factors.* Princeton: Princeton University Press, 609-626.

Arrow, Kenneth J., 1962b. ”The Economic Implications of Learning by Doing”. *Review of Economic Studies*, 29 (3) (June), 155-173.

Berndt, E.R. and T. Malone 1995. Information, Technology and the Productivity Paradox; Getting the Questions Right. *Economic Innovations and New Technology*, 3, 177-182.

Bernstein, Jeffery I. and P. Mohnen, 1994. ”International R&D Spillovers between U.S. and Japanese R&D Intensive Sectors”, Working Paper No. 4682 (March). Cambridge, MA: NBER.

Bernstein, Jeffery I. and Xiaoyi Yan, 1995, « International R&D spillovers between Canadian and Japanese industries », NBER Working Papers, Nr 5401 (December), Cambridge, MA :NBER

Burenstam-Linder, Staffan, 1961. *An Essay on Trade and Transformation*. Uppsala.

Carlsson, Bo (ed.), 1995. *Technological Systems and Economic Performance: The Case of Factory Automation*. Boston/Dordrecht/London: Kluwer Academic Publishers.

Cohen, W.M. – D.A. Levinthal, 1990. Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, 35, 128-152.

Day, Richard H., 1986b. "On Endogenous Preferences and Adaptive Economizing;" in R.H. Day and G. Eliasson, eds. (1986).

Day, Richard H., and G. Eliasson (eds.), 1986. *The Dynamics of Market Economies*. Stockholm:IUI, and Amsterdam: North-Holland.

Denison, Edward, F., 1961, *The Sources of Economic Growth in the United States,* New York: Committee for Economic Development

Denison, E.F., 1967. *Why Growth Rates Differ*, The Brookings Institution, Washington, D.C.

Denison, E.F., 1979. *Accounting for Slower Economic Growth: The United States in the 1970s*, pp. 48-89. New York: Basil Blackwell.

Eliasson, Gunnar, 1986. *Kunskap, information och tjänster – en studie av svenska industriföretag* (Knowledge, Information and Service Production – a study of Swedish manufacturing firms). Stockholm: IUI.

--------, 1990a. The Firm as a Competent Team, *Journal of Economic Behavior and Organization*, 13 (3), June.

--------, 1990b. The Knowledge-Based Information Economy; Chapter I in G. Eliasson, S.Fölster et al., 1990, *The Knowledge Based Information Economy*. Stockholm: IUI.

Eliasson, Gunnar, 1991a,. "The International Firm: A Vehicle for Overcoming Barriers to Trade and a Global Intelligence Organization Diffusing the Notion of a Nation;" in L.-G.

Mattson, and B. Stymne (eds.), *Corporate and Industry Strategies for Europe*. Amsterdam: North-Holland.

--------, 1991b. Modeling the Experimentally Organized Economy, *Journal of Economic Behavior and Organization*, 16 (1-2), 153-182.

--------, 1995. *En teknologigenerator eller ett nationellt prestigeprojekt? – svensk flygindustri* (A technology generator or a national prestige project? – Swedish aircraft industry). Stockholm: City University Press.

--------, 1996a. *The Firm, Its Objectives, Its Controls and Its Organization*. Boston/ Dordrecht/London: Kluwer Academic Publishers.

--------, 1996b. Spillovers, Integrated Production and the Theory of the Firm, *Journal of Evolutionary Economics*, 6, 125-140.

--------, 1997. General Purpose Technologies, Industrial Competence Blocs and Economic Growth; in B. Carlsson, ed., 1997. *Technological Systems; Cases, Analyses, Comparisons*. Boston/Dordrecht/London; Kluwer Academic Publishers.

--------, 1998. Svensk datorindustri – en kompetensblocksanalys av dess framväxt och försvinnande (Swedish Computer Industry – a competence bloc analysis of its emergence and disappearance); in P. Heum (ed.), *Kompetense og Verdiskapning*. SNFs Årsbok 1998. Bergen: Fagboksforlaget.

--------, 1999. *Undervattensteknologi i industriell tillämpning* (Underwater Technology Industrially Applied), KTH, TRITA-IEO-R 1999-12.

-------- (ed), 1999b. *Internet Economics and Internet Technology*. KTH, INDEK, TRITA-IEO-R 1999:06.

--------, 2000a. Industrial Policy, Competence Blocs and the Role of Science in the Economic Development, *Journal of Evolutionary Economics*, 2000, No. 1.

--------, 2000b. Technological spillovers from advanced defense production, *Militärteknisk Tidskrift* (Swedish Journal of Military Technology), No. 1.

--------, 2000c. *Advanced Firms as Technical Universities*. KTH, TRITA- IEO-R, 2000:04, Stockholm.

--------, 2001a. The Role of Knowledge in Economic Growth; in Helliwell, John (ed.), 2001.

--------, 2001b. The Emergence and Disappearance of a Swedish Computer Industry - a competence bloc analysis of the chance factor. KTH, TRITA (a Swedish version was published in Heum (1998). See Eliasson (1998).

Eliasson, Gunnar, 2005, (ed), *The Birth, the Life and the Death of Firms- the role of entreprenurship, creative destruction and conservative institutions in a growing and experimentally organized economy,* Stockholm: The Ratio Institute

---------, 2005b, " The Nature of Economic Change and Management in a New Knowledge Based Information Economy, *Information Economics and Policy, 17: 428-456*

Eliasson, Gunnar 2008a*, Företagen I en globaliserad ekonomi- full fart I huvudkontoret,* Stockholm:ISA, Eliasson, Gunnar and Åsa Eliasson, 1996. The Biotechnological Competence Bloc, *Revue d'Economie Industrielle*, 78-4^{0}, Trimestre.

Eliasson, Gunnar and Åsa Eliasson, 2005a " The Lake Mälar Competence Blocs- a Crisis and Opportunity Analysis of Regional Industrial Restructuring " Chapter VIII in Eliasson, Gunnar, 2005a, *The Birth, the Life and the Death of Firms-the role of entrepreneurship, creative destruction and conservative institutions in a growing and experimentally organized economy,* Stockholm:The Ratio Institute

Eliasson, Gunnar – Åsa Eliasson, 2005b. "The Theory of the Firm and the Markets for Strategic Acquisitions", in Cantner,U., Dinopoulos, E. and Lanzilotti, R.F. (eds), *Entrepreneurship, the New Economy and Public Policy* (Berlin, Heidelberg, New York:Springer)

Eliasson. Gunnar and Åsa Eliasson, 2008, "Competence and Learning in the Experimentally Organized Economy", KTH, TRITA and Working Paper, the Ratio Institute

Eliasson, Gunnar – Clas Wihlborg, 2003. On The Macroeconomic Effects of Establishing Tradability in Weak Property Rights. *Journal of Evolutionary Economics,* 13: 607-632.

Fredriksson, Billy, 1994. *Systems Engineering – A Holistic Approach to Product Development*. Griffin 94/95 (Nov.).

Fölster, Stefan, 1993. *De teknologiska spridningseffekterna av JAS: en ny empirisk metod* (stencil). Stockholm: IUI.

Griliches, Zwi, 1979, "Issues in Assessing the Contribution of R&D to Productivity Growth ", Bell Journal of Economics (Spring),10(1):92-116

Griliches, Zwi, 1984. *R&D Patents, and Productivity*. Chicago and London: University of Chicago Press.

Griliches, Zwi, 1986, " Productivity, R&D and Basic Research at the Firm Level in the 1970s", *American Economic Review*, Vol. 76, No.1:143-154

von Hayek, F. A., 1937." Economics and knowledge", *Economica*, 4: 33-54.

Helliwell, John (ed.), 2001, *The Contribution of Human and Social Capital to Sustained Economic Growth and Well*-being, HRDC. Canada.

Heum, P. (ed.), 1998. *Kompetense og Verdiskapning*. SNFs Årsbok 1998. Bergen: Fagboksforlaget.

Jaffe, Adam B., 1989. "Real Effects of Academic Researh." *The American Economic Review* (Dec.).

Johansson, Dan, 2005, " The Turnover of Firms and Industry Growth", *Small Business Economics*, 24(5):487-495

Johansson, Dan, 2007," The Theory of the Experimentally Organized Economy and Competence Blocs: an introduction" forthcoming *The Journal of Evolutinary Economics*

Jonason, Andreas, 1999. Pricing of, and Trading in Difficult to Define Commodities; in Eliasson (1999b).

--------, 2001. *Innovative Pricing*, doctorate thesis, Department of Industrial Economics and Management (INDEK), Royal Institute of Technology (KTH), Stockholm.

Jorgenson, Dale and Barbara M. Fraumeni, 1992, „ Investment in Education and US Economic Growth, *Scandinavian Journal of Economics,* 94, Supplement: 51-70

Jorgenson, D.W., and Z. Griliches, 1967. "The Explanation of Productivity Change." *Review of Economic Studies*, XXXIV (3) (July), 249-282.

Keller, Wolfgang, 2001, " International Technology Diffusion", NBER Working Paper No 8573 (October), Cambridge,MA:NBER

Lundberg, E., 1961. *Produktivitet och räntabilitet, Studier i kapitalets betydelse inom svenskt näringsliv*. Stockholm:SNS

Mamuneas, Theofanis,P. and M Ishaq Nadiri, 1995, " Public R&D Policies and Cost behavior of the US Manufacturing Industries," NBER Working Paper Nio 5059, Cambridge ,MA:NBER

Marshall, Alfred, 1890. *Principles of Economics*. London: Macmillan & Company

Marshall, A., 1919. *Industry and Trade*. London: Macmillan& Company

von Mises, Ludwig, 1949, *Human Action,* Contemporary Books: Chicago

Mun, Sung-Bae and M. Ishaq Nadiri, 2002, " Information Technology Externalities: Empirical evidence from 42 U.S Industries", NBER Working Paper No. 9272 (Oct.), Cambridge, MA:NBER

Nadiri, M. Ishaq – Theophanis, P. Mamuneas, 1994. Infrastructure and Public R&D Investments, and the Growth of Factor Productivity in US Manufacturing Industries. NBER Working Paper No. 4845 (Aug.), Cambridge, MA.

Nadiri, Ishaq, 1978. "A Dynamic Model of Research and Development Expenditure"; in B. Carlsson, G. Eliasson and I. Nadiri (eds.), 1978, *The Importance of Technology and the Permanence of Structure in Industrial Growth*, IUI Conference Reports, 1978:2, Stockholm.

Nadiri, Ishaq, 1993. "Innovations and Technological Spillovers," Working Paper No. 4423. Cambridge, MA; NBER.

Nadiri, Ishaq and Theophanis P. Mamuneas, 1991, " The Effects of Public Infrastructure and R&D Capital on the Cost Structure and Performance of US Manufacturing Industries" Cambridge, MA: NBER Working Paper No.3887

Nadiri, Ishaq and Theophanis P. Mamuneas, 1994, " Infrastructure and Public R&D Investments and the Growth of Factor Productivity in US Manufacturing Industries" , Cambridge,MA: NBER Working Paper No. 4845.

Nelson Richard., 1986. Institutions Supporting Technical Advance in Industry, *American Economic Review*, 76, 186-189.

Romer, P.M., 1986, Increasing Returns and Long-Run Growth, *Journal of Political Economy*, Vol. 94, No. 5 (Oct.), pp. 1002-1037.

Schumpeter, J.A., 1911, *Theorie der Wirtschaftlichen Entwicklung*, Dunker und Humblot, Jena. English ed., 1934, The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest and the Business Cycle, Vol. XLVI, Harvard University Press, Cambridge, MA.

Schumpeter, J.A., 1942, *Capitalism, Socialism and Democracy*, Harper & Row, New York.

Solow, R.M. 1957, Technical Change and the Aggregate Production Function, *Review of Economics and Statistics*, Vol. 39 (Aug.), pp. 312-320.

Solow, R.M., 1959, Investment and Technical Progress; in Arrow, K, Karlin, S. & Suppes, P. (eds.), 1960, *Mathematical Methods in the Social Sciences*, Stanford University Press, Stanford.

Stankiewicz, R., 1986. *Academia and Entrepreneurs. Developing University-Industry Relations*. London: Pinters Publishers, Ltd.

Suh, N.P., 1990. *The Principles of Design*; Oxford University Press.

Westerman, J., 1768, *Om Svenska Näringarnes Undervigt emot de Utländske, förmedelst en trögare Arbets-drift* (On the inferiority of the Swedish compared to foreign manufacturers because of a slower work organization), Stockholm.