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Parsing the Menagerie of Agglomeration and Network Externalities

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ABSTRACT

Externalities have for a long time been perceived as awkward cases that are alien to well-structured economic analyses. During recent decades ideas inherited from Marshall and others have regained interest in the analysis of specialisation and trade, urban formation and growth as well as innovation processes. A variety of contributions has brought about an equally varied set of externalities with labels such as localisation and urbanisation economies, industrial districts, innovative regions. This presentation attempts to bring order to the many ideas about externalities by classifying them with regard to the sources and consequences of the externalities, and to the externality mechanisms. A basic separation is made between those externalities that affect efficiency and those that generate development.

Keywords: Externalities, Networks, Agglomeration, Innovation

JEL Classification Numbers: O30, R30, L11

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1. INTRODUCTION

1.1 **Efficiency and Development Externalities**

The concept of external economies has entered the economic literature in waves. The original contribution is attributed to Marshall (1890/1920). There is a phase 70-80 years ago, represented by names such as Pigou (1920) and Knight (1924), with a focus on welfare economics and market failures. In the 1950s the issue returns with the help of Scitovsky (1954), now with a clear distinction between pecuniary and technological external economies. In the following decades the latter phenomenon dominated the thinking. During the last two decades of 20th century the externality concept returns again for two different reasons. First, it is used as an explanation of specialisation and trade (e.g. Krugman, 1979; Helpman, 1981; Porter, 1990). Second, it appears in models as a driving force that causes concentration in space of consumption and production, i.e., urban formation (Fujita, 1988; Krugman, 1991). Another strand of analysis has during the same period outlined models of spatial clusters (Baptista, 1998), with the focus on innovations and knowledge spillover. In the latter case the analysis is back to non-pecuniary externalities. Attached to this analysis is the idea that spatial clusters can have the form of regional innovation systems (Mytelka and Farinelli, 2000).

Although the title of this study may indicate an ambition to produce a catalogue of externalities, the intention is somewhat narrower. Specifically, the aim is to make precise three fundamental distinctions: (i) efficiency versus development externalities, (ii) proximity versus network externalities, and (iii) pecuniary and non-pecuniary externality. The first distinction concerns the consequence, the second concerns the source, and the third concerns the economic nature of the externality. Non-pecuniary knowledge flows are referred to as knowledge spillovers.

In a perfect market there is no direct contact between agents. The precondition of the perfect market is a price system and a complete provision of information about available options and associated prices. The existence of externalities can bring about imperfections or market failure. The existence of public goods and other collective phenomena, including clubs, generate such failures (Starrett, 1988). The most well known case is congestion in transport economics, which prohibits efficient use of resources if the market is not reorganised by means of road pricing (e.g. Johansson and Mattsson, 1995). The essential element here is interaction between road users outside the market. This interaction may be interpreted as a technological (non-pecuniary) externality. The most typical technological externality is the case where one firm's output generates residuals that affect the production of other producers.

Once introduced, the concept of technology externalities remained uncontroversial. In contradistinction, the externality phenomena that were introduced by Marshall have stimulated to more debate and criticism. In Marshall's analysis one finds pecuniary externalities, which operate via market prices, as well as information and knowledge spillovers, which occur outside the market and without economic compensation to the knowledge sources. Knowledge spillover from one firm to another can also be interpreted as a "residual" from the activities of one of the firms. Both Clapham (1922) and Robertson (1924) formulated critical remarks and referred to "empty economic boxes". And much later Bohm (1987) complains: "These cases are awkward to handle in traditional, well-structured economic analysis. So the main characteristic of these external economies, very much like most of those suggested by Marshall, is that we cannot yet say in any systematic way exactly what they represent."

The subsequent presentation starts where the quotation ends. There is a series of recent contributions that help to assess the Marshall-related externalities, which are essentially proximity externalities (Fujita, Krugman and Vennables, 1999; Fujita and Thisse, 2002). A major task in this assessment procedure is to single out efficiency externalities from development externalities. An efficiency externality may be classified as a static problem and refers to how externalities may cause one industry or several industries to be more efficient in one location than in another. Because of this, efficiency externalities can provide insights into why one location pattern of activities across regions is more efficient than another. Dynamic processes determine to what extent the allocation moves towards more efficient location patterns.

Although it may be considered as artificial, we suggest that a firm's activities can be divided into supply activities and development (innovation) activities. Certainly these activities may be intermingled, but they differ with regard to both inputs and outputs. The outputs of successful development activities are new products and new routines (techniques) of the firm. The inputs are R&D efforts of the firm and knowledge flows, and the latter are associated with both proximity and network externalities. In a sense this means that Schumpeter (1912) is brought into the picture, side by side with Marshall. The Schumpeter spirit is also present in a series of models where product differentiation, in the sense of Dixit-Stiglitz (1977), is extended in response to the size of demand. In these models product development takes place because new firms with new product variants enter the market (Krugman, 1979).

Recent contributions to the study of firms' development activities and the associated development externalities introduce the concept of links and networks between firms, which by their very nature are extra-market relations, encompassing extra-market transactions (Capello, 2001; Acs, 2001). Such links also play a role in firms' supply activities as a means to reduce transaction costs of various kinds. In this context one can conjecture that forming inter-firm links is a substitute for proximity externalities. Hence, the following presentation will illuminate the substitution between proximity and network externalities.

1.2 **Agglomeration and Network Externalities**

The spatial context in this contribution is a world that consists of small and large urban regions, referred to as functional urban regions (Cheshire and Gordon, 1998) or just regions and characterised by low contact or interaction costs for interaction that takes place inside each region. Large regions may contain separate and specialised districts, and small regions may be dominated by one single district, sometimes referred to as an industrial district. An economy is a multi-regional system, in which interaction takes place inside and between regions.

In the subsequent analyses the focus is on agglomeration of firms that can have two forms. In the first instance one observes a clustering or co-location of several firms that belong to the same industry. This form of agglomeration may cause localisation economies. In the second stance agglomeration refers to the clustering of many firms that belong to many different types of industries. This second form of agglomeration is expected to bring about urbanisation economies, where diversity and size of demand are essential features. This distinction between localisation and urbanisation economies was made early by Ohlin (1933) and was later studied by in particular Henderson (1988). An essential component of urbanisation economies is a concentration in space of diversified household demand.

Agglomeration means that firms can benefit from mutual proximity. Proximity has two consequences. It affects both how firms can interact via the market and how they can influence each other outside the market in the form of pecuniary and non-pecuniary information and knowledge flows. Proximity can affect transaction costs when firms buy distance sensitive inputs, e.g. complex information. If the supply of certain inputs is unevenly distributed between regions, this causes an efficiency externality, such that certain regions offer better conditions for firms using the specific inputs intensively. The same type of argument can be applied to the diversity of inputs (Rivera-Batiz,1988). But this is not where the story ends. For a supplier of distance-sensitive products, proximity to demand is also essential, both as regards household demand and demand arising from firms. This means that proximity plays a role both on the input and the output side, and this brings cumulative or self-reinforcing dynamic elements into the analysis of efficiency externalities as stressed in Fujita, Krugman and Vennables (1999).

According to the above arguments, distance sensitivity is of prime concern and means that transaction costs increase as the distance between seller (supplier) and buyer (customer) increases. These costs can under given conditions be reduced by forming transaction links between seller and buyer (Alchian and Demsetz, 1972; Williamson, 1979). When such links are suitable they reduce the importance of proximity. They may develop into networks with many participants, e.g. in the form of supply-chain networks, and hence influence the supply activities of a firm (Chandler, 1977; Pereira, 1997; Alderman, 2001; Polenske, 2003).

Links between firms may also be formed with the intention to influence development activities. In this case market purchase of knowledge is replaced by long-term contracts (links), according to which knowledge interaction and transmission is organised and controlled. Similar knowledge-links may be arranged as a means to reduce knowledge spillovers and replace them by knowledge transactions via links. When dealing with this issue we shall consider that the formation of interaction links may itself be a distance-sensitive activity and hence be more frequent inside a region than between regions (Aydalot and Keeble, 1988; Maillat, Crevoisier and Lecoq, 1994). This area of study includes various labels such as industrial districts, innovative milieux and learning regions.

A basic observation is that products and their distribution differ with regard to distance sensitivity. Hence, a firm's output may be distance sensitive and products that are inputs to the production process may also be distance sensitive. This means that transaction costs (including transport costs) increase as distance increases. In such cases, proximity matters. This conclusion is especially clear when transactions are interaction intensive. Less distance sensitive products are, to a larger extent, candidates for inter-regional sales.

Firms may also communicate outside the market. Communication of complex messages and tacit knowledge is normally considered to be distance sensitive. Also in this case proximity provides an advantage. These advantages are of special importance for a firm's development activities that generate product development and other forms of innovations.

The subsequent analysis will examine different forms of proximity externalities and assess their consequences. The literature contains a series of such externality phenomena, and it remains to investigate consistency and possible overlaps. It has been claimed that the very existence of agglomerations in space should tell us that proximity externalities exists (Krugman, 1991). On the other hand, firms may also invest in transaction and other interaction links to reduce transaction costs and improve communication. One may claim that the existence of inter-regional trade and a multi-regional economy indicate that also link externalities are in operation. However, the very existence of links does not in itself verify that externalities are involved. If it is costless to form links, Radner's result (1968) demonstrates that transaction links are consistent with a competitive market equilibrium, in which links have the form of contingency contracts.

1.3 Outline of the Menagerie

The introductory presentation emphasises three aspects of externalities labelled (i) source, (ii) consequence, and (iii) economic nature. These distinctions are illustrated in Figure 1.1. In this way one can avoid the contamination that obtains when sources and consequences of an externality are mixed. Proximity is an externality source by affecting both transaction costs and by facilitating uncharged spillovers. In a similar way a link affects both transactions and information spillover.

An efficiency externality appears in the form of static differences between regions with regard to the productivity and the cost per unit output of a firm. An innovation externality is a dynamic phenomenon and appears as a change of economic efficiency (new routines) but also as a change of new products, increased product diversity and similar novelties.

The economic nature of an externality manifests itself in two forms. In one form it operates via prices, and in the second it operates outside the market. In the first case we can identify both intra-market and quasi-market externalities, where the former arise in ordinary market transactions and the latter on transaction-links. In the case of extra-market externalities positive effects are free of charge and no compensation is given for negative effects.

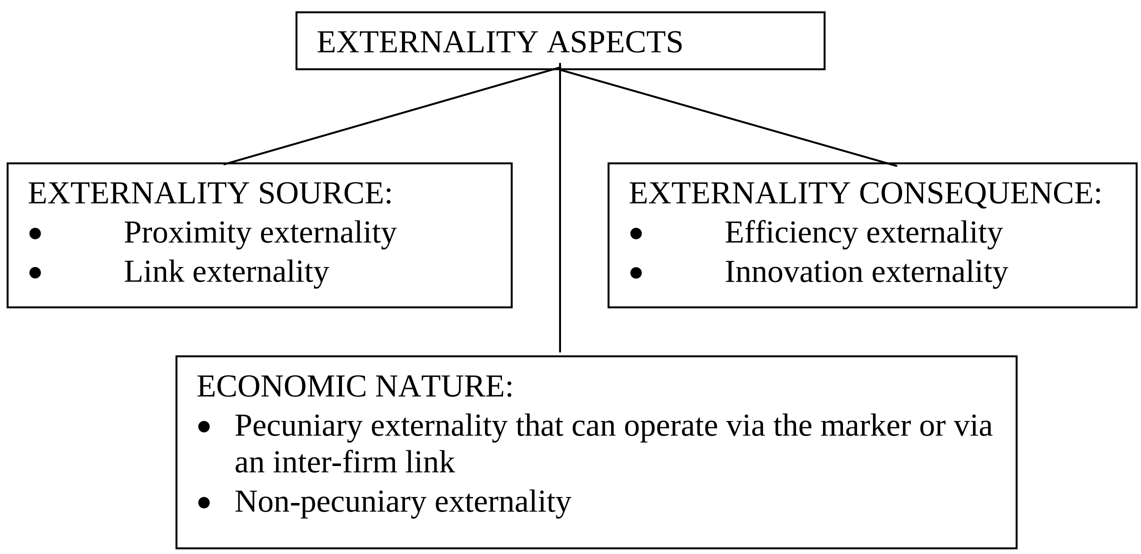

Figure 1.1 Sources, consequences, and economic nature of an externality

The three externality aspects in Figure 1.1 can be complemented by another dimension that separates horizontal from vertical externalities and divides vertical into upstream and downstream externalities. A downstream externality is a relation between a supplying firm and its customer(s). An upstream externality associates a firm with its input supplier(s). In addition to these considerations, the subsequent analysis will single out pure demand externalities as a special class of downstream externalities. Table 1.1 provides an exposition of the horizontal-vertical dimension and shows that for inter-firm relations upstream and downstream are dual concepts.

Table 1.1: Horizontal and vertical externalities classified against efficiency and innovation externalities

EFFICIENCY EXTERNALITIES	INNOVATION EXTERNALITIES
VERTICAL: • Downstream externality that affects the price a supplier can charge a customer • Upstream externality that affects the input cost of a firm	VERTICAL: • Downstream externality that affects knowledge flows between a supplier and a customer • Upstream externality that affects the knowledge flows between an input-buying and an input-selling firm
HORIZONTAL: Cooperation between two or several competitors, e.g. joint transport and marketing solutions of long-distance export	HORIZONTAL: Knowledge flows between competitors, e.g. joint R&D efforts based on a link or based on spillover phenomena
PURE DEMAND: The size of local demand facilitates the exploitation of scale economies for suppliers of distance-sensitive products	PURE DEMAND: Size and diversity of local demand facilitates experiments and communication with customers in the process of product development in the early phases of a product cycle

The subsequent analysis is organised as follows. Section 2 introduces a conceptual model of the firm by specifying two basic types of activities, called supply and development activities. Thereafter intra-market, quasi-market and extra-market externalities are considered as different forms of mediating externalities. The section ends with a set of classification schemes, examining proximity externalities, network (transaction links) externalities and spillover (extra-market) externalities. Section 3 presents efficiency externalities by means of standard microeconomic models and section 4 examines innovation externalities with a focus on knowledge flows. In sections 3 and 4 the focus is on making the externality mechanisms precise. Section 5 provides a brief summary and attempts to identify gaps and inconsistencies in existing models and research approaches in the externality menagerie.

2. A MODEL OF THE FIRM AND ITS EXTERNALITES

2.1 Two Categories of Activities

A firm is a potentially changing organisation. A model of the firm may focus on either its current operations or its processes of change. To make our arguments systematic, we introduce the following stylised model of a firm:

Supply activities: At each point in time a firm uses current and fixed inputs to produce an output by means of a given technique (routine).

Development activities: A firm may also use inputs to carry out a second type of activity that is here called development (R&D) or innovation activity. Such activities aim at changing routines and product attributes.

A failure to distinguish between these two activities has stimulated a lot of confusion in the analysis of spatial externalities. For example, scale economies may be present for each of the two categories of activities. However, the scale effects cannot be assumed to be identical for them.

Supply as well as development activities include associated interaction or transaction activities. These associated activities give rise to transaction or interaction costs. In the sequel we shall use the label transaction costs. We will consider the existence of distance-dependent transaction costs as a major source of spatial externalities. Transaction costs are costs of exclusion and costs of interaction between the buying and the selling parties, including transport or physical delivery costs.

Table 2.1 provides an enumeration of the supply activities that will be included in the analysis. A distinction is made between transaction costs and production costs other than transaction costs. Transaction costs appear both on the output and the input side and refer to both pure market transactions and transactions that are based on a set of buyer-seller links, where a link refers to investments that the buyer and seller have done in order to facilitate their transactions. It is assumed that a transaction link reduces transaction costs for both parties. In addition the table recognises that there may be adjustment costs associated with increasing and decreasing output levels, and that output expansion may require capacity investments.

Table 2.1 Supply activities and associated costs of a firm

Supply activities	Specific costs
(i) Buying inputs	Transaction costs
(ii) Selling and distributing	Transaction costs
(iii) Producing	Production costs other than transaction costs
(iv) Adjusting the output level	Start up, investment and adjustment costs

The first two activities in the table generate transaction costs. For inputs and outputs that are distance sensitive, these costs increase as the distance between supplier and customer increases. Hence, proximity brings about an advantage. Transaction costs may also reduce when a buying and a selling firm establish a joint transaction link. More complex forms apply when a seller has links to more than one customer or when a seller is a part of a supply chain (Polenske, 2003). In this way supplier-customer networks can develop. As will be shown subsequently, link formation involves investment and is limited to economic agreements or contracts between few participants. In such cases a supplier-customer link can be a substitute for transaction proximity, although co-located firms can also form links.

The third activity is production. It refers to processes inside the firm. As such it may comprise separate activities that interact. In view of Coase (1937) the associated transaction-like costs are considered to be internalised and hence absent by definition. This means that externalities that affect production operate outside the market. Subsequently we shall consider information and knowledge flows, including spillovers, which take place between localised firms and between firms that are coupled in networks.

Activity four has to do with changes in output. Adjusting the output level may bring about adjustments costs which arise when a firm needs to change its relations to both input suppliers and output customers. For example, transaction links may have to be altered. The associated adjustment costs will be distance sensitive when there are proximity advantages. In several recent models output level alterations are depicted as an industry phenomenon, where increased output takes the form of firm entry in a monopolistic-competition setting with product differentiation (Krugman, 1981)

The above comments refer to partial analysis and will have to be qualified in subsequent sections. In particular, it remains to make precise what should be meant by proximity externalities for each of these statements. Proximity externalities that make buying inputs and selling outputs less costly are assumed to work via the market, i.e., via market prices. A major observation is that this means that prices are not given but are affected by decisions by the agents in each region. Proximity externalities that relate to (iii) and (iv) may operate outside the market, and hence have the form of extra-market externalities.

In the discussion of supply activities we have already considered product differentiation, which may be realised as entry of new firms. Supply activities of firms may also imply that an industry adjusts towards the best-practice routine. Is this an efficiency problem or a development issue? It has the nature of an efficiency problem when equilibrium solutions are studied and compared.

Development activities of a firm have to do with resource consumption that aims to generate novelties in the Schumpeter sense. In table 2.2 development activities are classified into operations that are intended to (i) change product attributes, (ii) routines, (iii) output markets and (iv) input markets. All these operations require inputs in the form of persons employed, consultancy and research services, etc. Some or all of these inputs may be distance sensitive.

Table 2.2 Development activities and associated costs of a firm

Development activities	Specific costs
(i) Changing output attributes	Development and transaction costs
(ii) Changing routines as regards input flows, production and output distribution	Development and transaction costs
(iii) Searching for new customers and establishing customer links	Search costs and transaction investments
(iv) Searching for new input deliverers and establishing input links	Search costs and transaction investments

Analyses of development activities of a firm (or of an industry) imply an evolutionary perspective. Contrary to supply activities, the main focus is not equilibrium solutions but rather change processes (e.g. Nelson and Norman, 1977). The first activity consists of a firm's attempt to change output attributes. It is normally labelled product development. In monopolistic competition new products appear as the result of firm entry, where a new firm is associated with a new product variety. This is an industry perspective, and should be considered as a proper development activity only when it consumes resources.

Development activities can be internal to a firm but may also include the firm's purchase of development services. In this latter case one may expect distance-sensitive transactions to appear, and that represents one type of proximity externality. Moreover, product development is also the core area of knowledge spillovers (Echeverri-Carroll, 2001), which is a second type of a proximity externality.

Next, consider development activity (ii). A firm's attempt to change routines is usually referred to as process development. We should observe that routine here is used as a label for technique in the broad sense suggested in Nelson and Winter (1982). Hence, the routines of a firm comprise production technique as well as technical solutions with regard to input flows and output distribution. Routine development can also involve purchase of development services, causing transaction costs that may be distance sensitive.

The third development activity consists of searching for new customers and establishing pertinent links. It is not only a process of lining out new markets, but it is potentially associated also with product development and renewal of distribution/transaction techniques. A similar suggestion can be made for the fourth development activity, which comprises a firm's attempts to find new input suppliers. In addition, it can be related to improvements of a firm's routines in this regard.

The various development activities in table 2.2 can include purchase of services that support a firm's innovation efforts. Such services are often assumed to be distance sensitive (Noyelle, 1983; Malecki, 1980). They may also require elements of trust (Breschi and Lissoni, 2001). Moreover, this type of interaction can include the use and transmission of tacit knowledge. Again, proximity becomes an issue.

2.2 Intra-Market, Quasi-Market and Extra-Market Externalities

In the framework of Scitovsky (1954) externalities are classified as either pecuniary or technological. The first category comprises externality phenomena that operate either via the market (price formation) or via a quasi-market (transaction links). In both these cases prices are influenced by the externality. The non-pecuniary category includes external effects outside the market, which may be called extra-market externalities. This category includes information and knowledge spillovers, also termed communication externalities (Fujita and Thisse, 2002).

In order to understand the difference between externalities that occur inside and outside the market, we must provisionally agree upon what a market is. A perfect (competitive) market is an institution that satisfies two conditions. First, there is an established price system and all agents are price takers. Second, each agent is provided with information about all available options and the price related to each option. In this case the decisions by firms and households do not affect the price system. Other markets are imperfect. In this analysis we consider two cases. The first is the standard case when supply decisions by firms influence prices and where there may be search and transaction costs. This case can be thought of as a pure market in contradistinction to a market with transaction links, which can be thought of as a network market or quasi-market..

A special distinction has to be made with regard to links in a network market. First, we may note that if links are established without costs and have the form of complete contracts (including all contingencies), then we can define competitive equilibrium for a network market (Radner, 1968). One may add that Radner associates such a solution with the condition that agents have unlimited computational capacity. However, if a link decision is coupled with a set-up cost and if the pertinent contract is incomplete, we arrive at an imperfect market.

Consider now that the there is a temporal sequence of decision making in a network market. Then there will be a putty-clay dimension of links. Ex ante before a link has been established a firm may search for link partners in a market-like process. The establishment of a link requires mutual commitments and a contract that may be explicit or implicit. For an incomplete contract, this means that within the frames of such a contract, the link transactions take place outside the market. However, market phenomena may enter the relation by providing incentives to break and discontinue the link, including re-negotiations between contractual parties.

The distinctions between intra-market, quasi-market and extra-market externalities may involve ambiguities that should be removed. Essentially, the distinction is about how the externality is mediated. An intra-market externality is mediated through the formation of market prices. The same holds true for a quasi-market externality, but now with regard to link-specific prices. In contradistinction, communication externalities or spillovers are extra-market externalities, and when such spillovers are region specific they affect the relative costs and prices for the same commodity in a distinct way in each region. At the same time they may leave the intra-regional prices locally competitive (Fujita and Thisse, 2002). The same phenomenon may also hold for intra-market externalities but not for link or network externalities, because the latter are specific for the firms that belong to the same network, and this is economic-club phenomenon. Insiders and outsiders are separated.

Intra-market and quasi-market externalities can without limitations be associated with both efficiency and innovation externalities. With regard to spillovers the discussion later on will clarify that they are unambiguous only in the case of innovation externalities. They refer to dynamic or evolutionary processes.

Intra-market and extra-market externalities are both influenced by proximity. The former externality reduces transaction costs and may in that way also bring down the price of goods and services for the pertinent customer. Spillovers can in an analogous way be assumed to be more intense inside a region than between regions. Transaction links, however, are different. They represent a way to overcome distances. For an individual supplier, the existence of an attractive customer in a far-away region may provide an incentive to locate in the neighbourhood of the customer. An alternative, when relocation cost are high, is to establish a link to the customer and thereby reduce the transaction costs. The same reasoning can be applied with regard to an attractive input-supplier. Forming a link is an alternative to relocation or multi-location. In addition to these suggestions, one may observe that a link between two firms in the same region may result in reduced transaction costs, even when transactions take place inside a region. A specific example would be knowledge transactions. Since the establishment of links comprises search and negotiation cost, we also have to consider the possibility that link formation may be less costly when it takes place inside a region. Thus, proximity would then be essential also for the emergence of links and networks.

In order to treat proximity externalities we shall introduce the following three spatial concepts when analysing interaction:

- Intra district, where a district is an area inside a functional urban region
- Intra regional, referring to interactions inside a functional urban region
- Interregional, referring to interactions between regions

The prime concept is the functional urban region (city), within which transactions are assumed to take place at lower costs than when they occur between agents in two different regions. For particular purchasing activities, districts may provide even lower transaction costs, where districts may manifest themselves in specialised shopping areas, malls and the like. These are intra-market externalities.

The urban region is important also for communication externalities, because spillovers are assumed to be more intense inside than between regions. In this case one may also contemplate research districts and other concentrations (clusters) of creative interaction. These are basically quasi-market and extra-market externalities, and would as such primarily influence innovation processes, which in turn may improve efficiency.

Links between firms can be established both inside and between regions. In both cases we assume that the motivation is to reduce transaction costs. When links are formed between firms that are located in different regions, they constitute a substitute to proximity. As one aspect of this we may recognise foreign direct investments and multinational firms (Venables, 1996; Braunerhjelm and Ekholm, 1998).

2.3 A Further Classification

So far our classification has focussed on how an externality is mediated, with the three cases intra-market, quasi-market and extra-market externalities. In all three cases proximity remains an important feature, whereas link externalities may also be present over long distances. There are, however, more distinctions to be made. We shall start with intra-market externalities, classify transactions and examine the principle mechanisms in table 2.3. Observe that the inter-firm transactions in the table in principle cover inputs to both supply activities and development activities. However, the latter have not been considered very much in formal models. Because of this, there is a bias in the table towards efficiency issues.

For intra-market externalities in table 2.3, only vertical externalities between firms are considered. The first two cases focus on a firm buying inputs to be used in its supply and development activities. The first case is a Marshallian input-cost externality. If inputs are industry-specific this case will correspond to localisation economies rather than urbanisation economies. The second form of upstream externality can be associated with Rivera-Batiz (1988). Proximity to a rich variety of inputs improves the productivity of input buying firms.
The basic case is urbanisation economies (Eithier, 1982; Abdel-Rahman and Fujita, 1990).

Table 2.3 Intra-market externalities

Externality form	Type of transaction	Principle mechanism
Vertical	*Upstream or input-cost externality*. Covers both localisation and urbanisation economies.	Suppliers to a firm (or firms in an industry) provide inputs with lower transaction costs and potentially at a lower price due to proximity.
	Upstream or input-diversity externality. Diversity corresponds to urbanisation economies.	Diversity of input alternatives improves the productivity of a firm (or firms in an industry).
	Downstream or delivery cost externality. Covers both localisation and urbanisation economies.	A firm (or firms in an industry) can supply the products with lower transaction costs and potentially at a lower price due to proximity.
Demand	*Intra-regional demand externality*. This corresponds to Porter's "home market effect" and is a form of urbanisation economies.	A large local demand makes it possible for firms to exploit scale economies and hence supply commodities to households at a lower price and with a greater variety.

Consider that the upstream input-cost externality provides an incentive for firms with special input requirements to locate in a region with a large supply of industry-specific inputs. Then the downstream delivery-cost externality provides a supplier firm with an incentive to locate in a region where there is a large demand for the firm's output. It is evident that when upstream and downstream externalities prevail simultaneously, they combine into a self-reinforcing mechanism.

The demand externality is directly related to the size of an urban region. The main mechanism is consumers' taste for variety. When such products are (i) distance-sensitive and (ii) produced with fixed costs, they primarily have to find the demand inside the region of production. This amounts to urbanisation economies (Krugman, 1980; Rivera-Batiz, 1988). In addition, the demand externality may be considered also for knowledge providers to firms' development activities. The larger the demand in a region, the richer the variety of development services. The externality obtains if a rich variety improves the innovation processes of firms. This is often referred to as a Jacobs externality (Jacobs, 1969, 1984).

Table 2.4 presents an overview of transaction-link externalities. These represent idiosyncratic inter-firm relations that provide the participants with advantages that occur in a quasi-market setting, outside the ordinary market. In this way a network shares the extra-market properties of a club.

Table 2.4 Transaction-link externalities

Externality form	Transaction type	Principle mechanism
Vertical	*Upstream or input- cost link externality*. Outside market transactions as long as the link lasts.	A link between an input supplier and a customer firm reduces transaction costs, some of which may be distance sensitive. The advantage of the customer firm is focused.
	Downstream or delivery-cost link externality. Outside market transactions as long as the link lasts.	A link between an input supplier and a customer firm reduces transaction costs, some of which may be distance sensitive. The advantage of the supplier firm is focused.
Networks	*Supply-chain externalities* and *Complex network externalities*	Firms belonging to a network form a club, through which they have accessibility to joint assets that facilitate transactions.

Table 2.5 presents a second form of extra-market externalities. These concern information and knowledge spillovers that occur as by-products in the course of normal market activities and interactions between firms. The prime focus is on innovation and development activities that are assumed to be stimulated by the enumerated spillover externalities (Echeverri-Carroll, 2001; Karlsson and Manduchi, 2001; de Groot, Nijkamp and Acs, 2001). In this case, so-called knowledge providers are a particular type of input suppliers.

In a very important sense, upstream and downstream spillovers are much more easy to understand than horizontal spillovers. The reason for this is that a communication externality between a supplier and a customer firm involves complementary features. The two firms are not competitors, and the customer firm will indeed benefit from making the supplier a better supplier. The quality of the input may improve, and the supplier may be able to deliver the input at a lower cost. Analogously, the supplier will benefit if the customer firm becomes more competitive and is able to expand its production. This form of complementarity is not present in the case of horizontal communication externalities.

Table 2.5 Spillover externalities

Externality form	Form of spillover	Principle mechanism
Vertical	*Upstream or input spillover*. The spillover can be due to proximity and then it covers both localisation and urbanisation economies. Inter-firm links can also facilitate spillover. *Downstream or delivery spillover*. The spillover can be due to proximity and then it covers both localisation and urbanisation economies. Inter-firm links can also facilitate spillover.	As a by-product of the interaction between an input-buying firm and its suppliers, information and knowledge spill over and stimulate innovations of the buying firm. As a by-product of the interaction between an input-selling firm and its customer firms, information and knowledge spill over and stimulate innovations of the selling firm.
Horizontal	*Competition between similar firms in the proximity of each other*. This may be referred to as a Porter externality and corresponds to localisation economies (of a specialised cluster).	Due to proximity competing firms may imitate each other to move towards best-practice solutions and to improve these solutions.
Demand	*Diverse demand spillovers*. This may be compared with the Jacobs hypothesis and the product-cycle model assumptions. It is primarily a form of urbanisation economies.	Large local demand provides information about the variety of demand among diverse consumers/customers and hence stimulates the innovation process of firms.

Horizontal spillovers can be divided into current information and durable knowledge. With regard to current information, one may argue that horizontal spillovers provide the necessary information for a competitive market. Hence, it supports the market institution. Other horizontal spillovers can be related to the concept of localised knowledge spillovers, given the acronym LKS by Breschi and Lissoni (2001). They identify the following three LKS conditions: (1) Innovative firms and R&D organisations generate knowledge, which is transmitted to other firms. (2) The pertinent knowledge is a public good satisfying non-excludability and non-rivalry. (3) The knowledge is mainly tacit, and because of this face-to-face contacts are an essential part of the spillover process. This makes it localised. Evidently, in such a process firms benefit unambiguously from spillovers as long as they remain free riders. However, the knowledge-generating firms cannot privatise the knowledge that they create. This raises the question: why do they accept this loss, how do they trade-off losses against benefits?

The above question mark is stressed when the R&D-process in product cycle models is examined. In such a model, firms make innovation efforts because they foresee temporary monopoly profits when new successful (and firm-specific) knowledge is created. Another aspect of the product cycle model is that the innovative firm can benefit from accessibility to diversity of demand, partly as an element of a trial and error interaction between the product developer and pertinent customers (Johansson and Andersson, 1998). Obviously, diverse demand spillovers have a more consistent basis than do the horizontal externalities. Information of customer preferences are transmitted not only for existing but also for products under development.

3. EFFICIENCY EXTERNALITIES

The aim of this section is to make precise the externality mechanisms that improves the efficiency of firm's supply activities. Four types of externalities will here be discussed in a formal way: (i) upstream efficiency, (ii) downstream efficiency, (iii) horizontal, and (iv) demand externalities. In all four cases the difference between intraregional and interregional transaction costs plays an essential role. The externality mechanisms are examined with the help of well-known microeconomic formulations.

3.1 Upstream Efficiency Externalities

A firm's relations to suppliers of inputs have been referred to as upstream relations. The literature considers three main forms of externalities of efficiency type. The first is a proximity externality such that transaction costs are lower when the suppliers are located in the same region as the buying firm. The second is a transaction-link externality. The third is a diversity externality such that the firm produces at a lower cost

A firm's input demand depends on the output level, *x*, and can be subdivided into labour inputs, service inputs, and material inputs. To simplify, let *S*(*x*) denote the inputs of labour and services and let the input of goods be given by *G*(*x*).

The corresponding input prices in a given region are denoted by w_1 and w_2. Finally a fixed cost component, *F*, is introduced and this yields the following total cost expression:

$$C = F + w_1 S(x) + w_2 G(x) \tag{3.1}$$

Writing $s = S(x)/x$, and $g = G(x)/x$ yields the unit cost function

$$c = F/x + v \; ; \; v = w_1 s + w_2 g \, . \tag{3.2}$$

The two input prices are weighted averages of regional and external prices, such that

$$\begin{aligned} w_1 &= \alpha_S w_1^0 + (1-\alpha_S) w_1^* \\ w_2 &= \alpha_G w_2^0 + (1-\alpha_G) w_2^* \end{aligned} \tag{3.3}$$

where w^0 refers to regional prices and w^* refers to prices when the delivery comes from outside the region. Moreover, $\alpha_S \leq 1$ and $\alpha_G \leq 1$ denote the share of each input that is acquired inside the region. Let us assume that the *S*-input is sufficiently distance sensitive to imply that $w_1^* > w_1^0$. When this applies it is favourable to have a high value of α_S, and this share parameter can be assumed to be large if the supply inside the region is large with regard to the relevant type of labour and services. A similar argument certainly applies also to the *G*-input. However, a frequent assumption would be that $\alpha_S > \alpha_G$. From this we can define the essential upstream proximity-externality:

> *Upstream proximity externality*: With a large regional supply of inputs that are distance sensitive a regional firm can produce at a lower unit cost level and hence produce more. With a larger output the region may attract labour and suppliers of distance sensitive inputs and thus increase the relevant α -parameters. Since changes in the α -parameters affect the prices w_1 and w_2 , this constitutes an efficiency effect via the market. The equilibrium adjustments are such that the input-buying firms are attracted by localised supply of inputs, and input suppliers are attracted by localised demand for inputs.

Consider now the possibility of a link formation, based on an agreement between the input-buyer and an extra-regional supplier. To simplify, we assume that the link concerns the delivery of the *G*-input. Forming the link can have three consequences. First, a link-investment has to be made by the buyer implying that the fixed cost increases from *F* to $\hat{F}$. Second, the transaction/delivery cost reduces and this implies a new input price $\hat{w}_2^* < w_2^*$. Third, the share of external inputs increases from $(1-\alpha_G)$ to $(1-\hat{\alpha}_G) > (1-\alpha_G)$. Such a link is favourable if

$$w_2^o\alpha_G + w_2^*(1-\alpha_G) + F/x > w_2^o\hat{\alpha}_G + \hat{w}_2^*(1-\hat{\alpha}_G) + \hat{F}/x \qquad (3.4)$$

The rationale behind the inequality in formula (3.4) is that the link agreement allows the buying and the selling firm to select a routine that is not feasible without the agreement, for example due to stochastic demand or other market disturbances. The price for this is a higher fixed cost $\hat{F} > F$. This is illustrated in figure 3.1 by the fat curve describing technique options. The point (*v*, *F*) is above the iso-cost line that runs through the point $(\hat{v}, \hat{F})$.

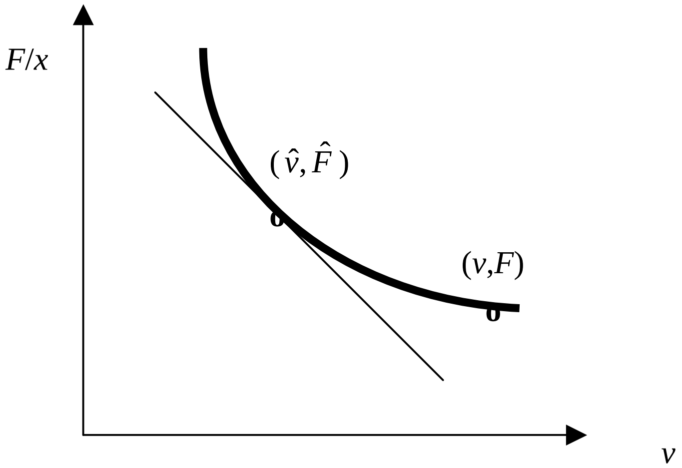

Figure 3.1 Effects of a link investment

A remaining issue, which is not treated here, is whether it would be more efficient for the input-buying firms to locate in the same region as the supplier in question, instead of using the link. However, once the link is formed it represents sunk costs and affects thereby the choice set of the input buyer. In models with transaction networks one may identify both inertia and path dependence (Johansson and Westin, 1994). For the link phenomenon we observe the following:

> *An input link as an alternative to proximity*: As modelled above, a link can replace a proximity relation due to technical superiority. One may conjecture that such technical options are scale dependent. Hence, the larger the input flow, the more technical alternatives are available. Moreover, there is a major aspect of link formation to be considered. Link formation requires search and other transaction activities. Thus, in the process of link formation there may be proximity advantages.

The third case of upstream externality focuses on how individual firms (or industries) can improve their productivity by using a richer composition of input varieties. The typical model to describe this is to employ a production function, which relates an output X to the input of labour resources, signified by *L*, and the input of producer services, *Q*, where the value of *Q* increases as the number, *n*, of input services increases. Letting S_i denote the amount of services of type *i*, this yields

$$X = L^a Q^{(1-a)} \ , \ Q = \left[\sum_{i=1}^{n} S_i^{\rho} \right]^{1/\rho} \tag{3.5}$$

where $0 < a < 1$, and $0 < \rho < 1$. The Cobb-Douglas production function in (3.5) implies that a given share of returns is spent on producer services, while *X* expands as *n* increases, implying increasing returns. We assume that the service supply is characterised by monopolistic competition. In a regional equilibrium setting this means that a region that has a large output will also have a large diversity of service supply. To see this, let *p* be a given price of the output (possibly exported) and observe that $\sum_i p_i S_i / pX = (1-a)$, i.e., the cost of input services is a constant share of returns, while p_i remains proportional to the price of the *L*-resource (Pettersson, 2002). We have already observed that the production function is Cobb-Douglas. Thus, with a constant cost share, output per service input increases as *n* increases. As a consequence, the input cost per unit output will decline.

The externality is based on the assumption that services can only be provided locally. Does the model related to (3.5) depict conditions of an industrial district such that localisation economies apply? Alternatively, does it depict urban diversity such that urbanisation economies apply? If the output, *X*, represents all kinds of distance-insensitive export production, then (3.5) would rather relate to urbanisation economies. These economies imply that the services, S_1, …, S_n can be used by many industries. On the other hand, if the services, S_1, …, S_n are specific to a given industry, the externality could be classified as localisation economies. Obviously, the more economy-wide the relation in (3.5) is, the stronger the input externality will be. This would then suggest that primarily formula (3.5) refers an urbanisation-economies phenomenon.

> *Proximity to input diversity*: The model components in formula (3.5) refer to a multi-regional setting. The possibility to export the output, *X*, (e.g. a composite export commodity) increases as the size of the input supply, *Q*, increases. At the same time there is an incentive to increase *Q* as *X* increases. In this sense, *X* remains an exogenous demand factor that stimulates the differentiation of distance-sensitive supply of inputs. This latter part of the circularity is a kind of downstream externality.

The above conclusion may of course be extended, given that the demand for *X* increases as the export price is decreased. In this case the self-reinforcing effects of the externality can be described by the sequence: (i) increased diversity, (ii) increased productivity and decreased costs, (iii) reduced price and increased export sales, followed by opportunities to further increase diversity.

3.2 Downstream Externalities

A downstream market externality is present if the size of customer demand determines whether a local supplier of inputs could be established in a region or not. The easiest way to formalise this problem is to employ at back-to-back diagram. In this way we can utilise arguments from the model of spatial-price equilibrium (Takayama and Judge, 1971) and make use of the notion unit delivery cost, which is the sum of unit production-cost and unit transaction-cost in view of the customer.

With this new setting, consider an input supplier offering his output to one or several other firms at the price p^0, determined as follows:

$$p^o = (c^o + t^o)(1+\pi) \tag{3.6}$$

where c^0 denotes the unit cost as introduced in (3.2), t^0 the transaction cost per unit delivery inside a region, and $\pi = (p^o - c^o - t^o)/(c^o + t^o) \geq 0$ denotes profit as a share of unit delivery cost. This price can be compared with the price, p^*, that obtains when the input is delivered from outside the region with the transaction cost $t^* > t^0$ as described in (3.7):

$$p^* = (c^* + t^*)(1+\pi) \qquad (3.7)$$

The proximity phenomenon is basically the same as in section 3.1, though viewed from the supplier's side. Figure 3.2 illustrates the essence of the problem. A unit cost curve is descried for region 1 and region 2. The output of firms in region 1 determines the demand for the input, denoted by *D*. At this level of demand $t^* - t^0$ is small enough to make region 2's supply cheaper. Hence, no input supplier will find it feasible to locate in region 1. However, increased production in region 1 can augment the demand for the input and will then move the demand point to the right from *D* to $\hat{D}$. The augmented demand can lead to an equilibrium such that $p^* = (c^* + t^*)(1+\pi) > p^o = (c^o + t^o)(1+\pi)$, which means that local supply can offer a lower price than external supply.

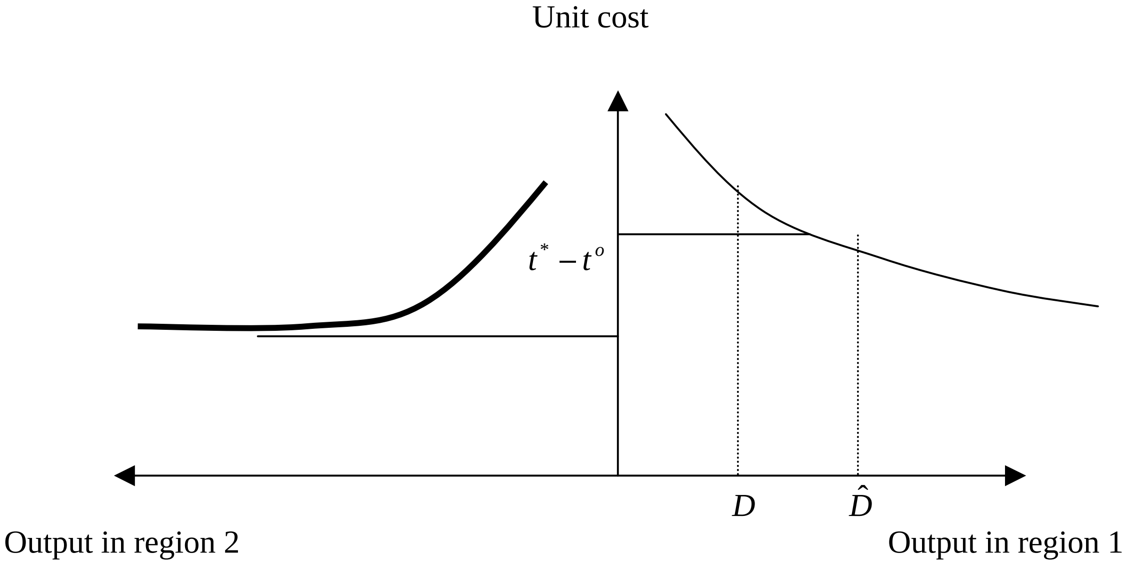

Figure 3.2 Competition between intra-regional and extra-regional input delivery

The argument applied here is that the local demand has to be large enough to motivate a local supplier to establish himself in region 1. The mechanism is as follows:

Downstream externality: At the input-demand level *D* the benefits from lower transaction costs are too small to compensate for the cost advantages of external deliverers. From (3.2) the unit price of a supplier in region 1 is $(c + t)(1 + \pi) = (F/x + w_1 s + w_2 g + t)(1 + \pi)$. As demand increases to $\hat{D}$, the output will expand to $\hat{x} > x$ and the price can be reduced below the level of external deliverers. Hence, scale economies of input suppliers play a vital role. If scale economies are negligible, input suppliers will always find it feasible to locate in region 1.

3.3 Horizontal Externalities

Porter (1990) has stressed the importance of horizontal externalities. An argument is that with competing firms that are localised in the same region can stimulate each other to improve efficiency and develop product attributes. Researchers who have adopted this idea have elaborated the reasons for this in various ways, and there is not really one specific model of how firms stimulate each other.

In the following analysis we shall assume that there is a proximity-based information externality, which implies that neighbouring firms get more precise information about each other than competitors that are located in different regions. One may then consider that each firm in a given region adjusts towards the best-practice solution that is present among the group of firms. To formalise this, let μ be an index that indicates how advanced the product attributes are, and let τ be a routine index, showing the level of technical efficiency. By $\mu*$ and $\tau*$ we denote the best index values among the competing firms in a region.

For each firm, the price, $p^i = p(\mu^i)$, and the output, $x^i = x(\mu^i)$, are assumed to be influenced by the attribute level μ^i. For the same firm the input coefficients, $(s^i, g^i) = (s(\tau^i), g(\tau^i))$, are assumed to be determined by the routine level τ^i. Consider now firm *i* and assume that $\mu^i < \mu*$ and that $\tau^i < \tau*$. We assume that more efficient routines should imply lower costs per unit output such that

$$\tau^i < \tau* \Rightarrow w_1 s^i + w_2 g^i > w_1 s* + w_2 g* \qquad (3.8)$$

where $s* = s(\tau*)$ and $g* = g(\tau*)$. In a similar way improved product attributes implies a growing market such that

$$\mu^i < \mu* \Rightarrow p^i x^i < p* x* \qquad (3.9a)$$

where $p* x* = p(\mu*)x(\mu*)$. Routine improvement as described in (3.8) is usually modelled as a change, where product attributes remain invariant. It has been studied in various putty-clay or vintage models (e.g. Johansen, 1972; Johansson and Marksjö, 1984). This approach is easy to grasp, because it focuses one-sidedly on cost savings. Analyses of product development is much more complex and even ambiguous, since it has to consider that new products also require new routines. Thus, the condition in (3.9a) has to be extended to have an explicit rate of return, $\bar{\pi}$, such that

$$p(\mu*)x(\mu*) - w_1 s* - w_2 g* > \bar{\pi} \qquad (3.9b)$$

The first mechanism in this model is that each firm *i* imitates the best practice and adjust its product attributes and its routines to approach the aspired level (μ^*, τ^*). Obviously, if this is the only mechanism, the adjustments will lead to a stalemate, where all firms are identical. To make the process progressive, it has to be assumed that the firm (or firms) that has achieved the best-practice level tries to keep the gaps $\mu^* - \mu^i$ and $\tau^* - \tau^i$ as large as possible over time for each follower *i*. In a sense this is a leader-follower setting, where the followers are chasing the leader. If a follower "by accident" becomes a leader the same argument would apply for the new leader. In essence, this whole discussion is about innovation externalities.

3.4 Demand Externality

Demand externality could be formalised with the help of the spatial price-equilibrium model associated with formulas (3.6) and (3.7). However, there is a more obvious alternative, which is offered by the approach labelled "new economic geography". The most influential contributions to spatial economics during the last two decades employ models that stress demand externalities. Many of these contributions combine scale economies and monopolistic competition in order to establish equilibrium solutions (e.g. Krugman, 1979; Fujita, 1988). In the following discussion the focus is entirely on the nature of the demand externality, and the equilibrium issue is suppressed.

To simplify arguments, consider that there is a market potential, *M*, in a region, where *M* plays the role of a demand budget to be used for consumer purchases. Consumers are assumed to have a preference function of Cobb-Douglas type, which is separable with regard to different product groups. To simplify assume also that consumers are identical and have the same share of the budget *M*. Let us focus on one product group for which the budget is *kM*, with 0 < *k* < 1. Then we can derive the following demand expression for product *i* that belongs to the selected product group: $x_i = \beta_i kM / p_i$, 0 < β_i < 1.

The price of a local supplier is signified by p_i^o, and the price of external suppliers is exogenously given as p_i^*. The unit cost of production is $c_i = v_i + F_i / x_i$, as specified earlier in (3.2). This unit cost structure applies both to the local and the external supply. The external supply is assumed come from regions with much larger local demand then our region, and this implies that our region cannot sell its output outside the own region. The crucial factor is the fixed-cost component, F_i.

With this setting the consumers spend the budget $\beta_i kM$ on product *i* irrespective of the price charged. This means that a local supplier has to satisfy the condition $p_i^o x_i^o = \beta_i kM$, and the supplier obtains non-negative profits as long as $\beta_i kM \geq v_i x_i^o + F$. The firm will satisfy the demand when $x_i^o = \bar{x}^o$ in figure 3.3.

For external supply the following condition holds: $p_i^* x_i^* = \beta_i kM$, and this determines the value of x_i^*, because p_i^* is treated as given. This implies that the local supplier will not start production of product *i* when the following condition applies:

$$p_i^o = \beta_i kM / x_i^o > p_i^* = \beta_i kM / x_i^* \qquad (3.10)$$

In figure 3.3 the local firm expands it sales along the ray $p_i x_i = F + v_i x_i$ and the external sales value will expand along the ray $p_i^* x_i^*$. The former ray crosses the budget line when the local output is $\bar{x}_i^o$. The latter ray crosses the budget line, $\beta_i kM$, to the right of $\bar{x}_i^o$, which implies that local buyers receive more goods when buying from the external supply. Hence, the local firm has no incentive to start production. Obviously, condition (3.10) applies when $x_i^* > \bar{x}_i^o$. We can also see that when $F_i > \beta_i kM$ local production will not be considered. It should also be observed that p_i^* is the sum of an external supplier's mill price and the interregional transaction cost. Hence, $p_i^* > v_i$.

Suppose now that the local market becomes larger. This is represented by a shift from M to $\hat{M}$. In this case the local and external supply become $\hat{x}_i^o$ and $\hat{x}_i^*$ as specified in (3.11):

$$\hat{x}_i^o = (\beta_i k\hat{M} - F_i)/v \text{ and } \hat{x}_i^* = \beta_i k\hat{M} / p_i^* \qquad (3.11)$$

It is clear from (3.11) that since $p_i^* > v_i$, $\hat{x}_i^o$ will get larger than $\hat{x}_i^*$ when $\hat{M}$ gets large enough. When this happens, local production can start.

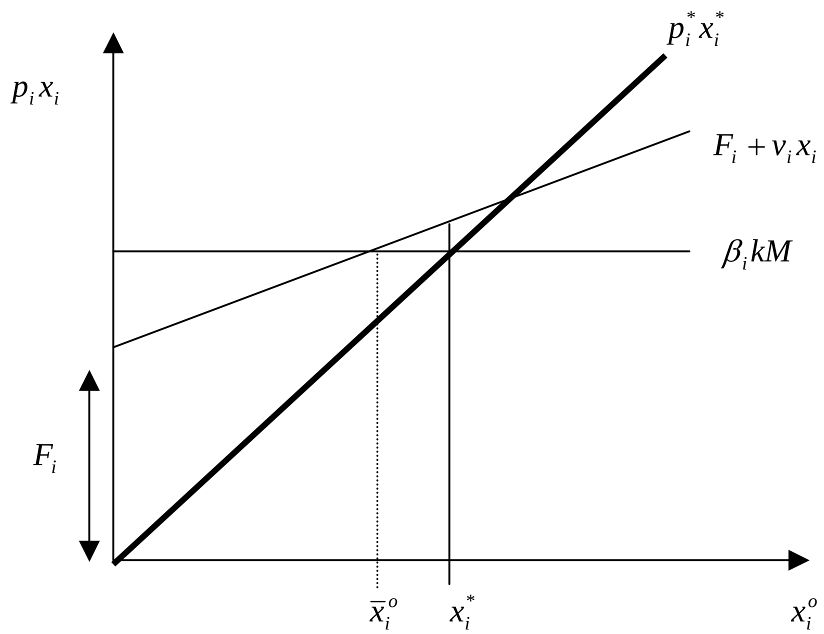

Figure 3.3: Local output and size of local demand

The result obtained above is derived for a restrictive type of demand. A similar result can be derived in the same way with a CES preference function, which yields a less restrictive demand structure. The demand externality is now obvious and can be summarised as follows:

Demand externality: Formulas (3.10) and (3.11) show that p_i^o can be reduced as *M* grows. This implies that production can start in the region when the size of the local market, *M*, has reached sufficient size. And when production starts income will increase and the size of *M* will be growing, which in turn can allow still further types of products in the region. In a static context, demand externalities provide large regions with an advantage. They can host many more types of production than smaller regions. Moreover, with large local demand the impact of fixed costs, F_i, will be small and this allows suppliers to charge low prices that make exports to other regions competitive.

Another demand externality aspect is related to the sub-market coefficient *k*. For a product group with novel products the information about and appreciation of the quality and usefulness of these products may be gradual process, and that would mean that the value of the coefficient *k* might increase over time. Such growth may of course imply that a region with a market potential, *M*, such that *kM* initially is too small, may later on be suitable for local production when *k* has increased to $\hat{k} > k$, which will make $\hat{k}M > kM$.

3.5 Conclusions about Efficiency Externalities

The formal description of efficiency externalities in section 3 stresses the importance of proximity. At the same time it is concluded that links between two firms can be an alternative to proximity. The formal descriptions focus on externalities that operate via the market (pecuniary externalities).

Downstream and upstream efficiency externalities are mirror pictures and apply with more or less identical arguments to localisation and urbanisation economies as regards price effects on inputs and outputs, caused by proximity to suppliers and customers, respectively. The additional aspect of urbanisation economies is that this label also includes effects that arise due to a larger variety of distance-sensitive input supplies and a larger (and perhaps more varied) demand that stimulate a greater variation of distance-sensitive outputs. In both cases a demand externality is present.

The cases described above emphasise proximity between suppliers and customers. The analytical formulations allow for consistence in the arguments. The same conclusion cannot be drawn with regard to horizontal efficiency externalities, however important some scholars may think that they are.

4. INNOVATION EXTERNALTIES

The development of economic models during the past 25 years includes quite remarkable progress in the understanding of processes associated with innovations – both with regard to process and product development. This observation is in particular true for growth models of "macro type" (e.g. Romer, 1986; Lucas, 1988; Barro and Sala-I-Martin, 1995). In these models technology development is an endogenous part of each model, and the endogeneity is related to externality assumptions. A remaining problem is a weak microeconomic underpinning. Micro arguments can be found in studies that have stronger empirical focus and that try to conceptualise regional innovation systems as well innovation milieux (e.g. Acs, 2002; Andersson and Karlsson, 2003). The following presentation provides a brief overview of micro considerations for all these models, with an ambition to illuminate some basic inconsistencies with regard to models depicting localised knowledge externalities and regional innovation systems. The assessment will in particular shed light on the difference between those knowledge flows that are based on contracts and transactions and those that have the form of spillover, where the knowledge receiver does not compensate actors from whom the knowledge originates.

Sub section 4.1 characterises the role of knowledge flows in an innovation process. In the following sub sections, the presentation is separated into two branches. The first investigates routine development, i.e., process innovation. It represents an extreme case, in which the output of a firm remains unchanged, i.e., the firm supplies products with already established product attributes. Routine development is motivated by the goal to reduce costs.

The second strand of discussion concerns product development. In this case a new product (or a developed product) is associated with specific routine features that determine operation costs. Just as with routine development, product development is associated with development costs – and the outcome of the development activity is uncertain.

4.1 Knowledge Flows and Innovation Externalities

Firms that carry out development activities compete with each other in an innovation game. The nature of such a game is different for routine improvements and product development. However, there are general features of knowledge flow systems that influence innovation activities. To make the problem tractable it is fruitful to separate R&D efforts inside the firm from knowledge flows that influence the innovation process and which originate from outside the firm.

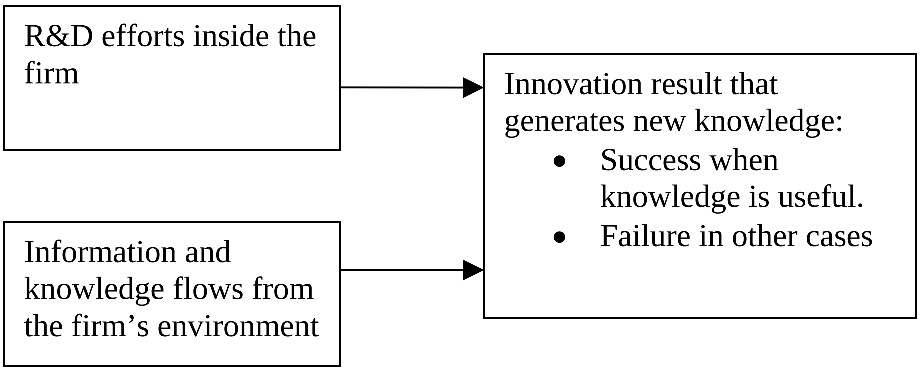

Figure 4.1: The two components of innovation activities

As stressed in previous sections, knowledge flows should be separated into two categories. The first category contains flows that are based on transactions, which means that there is deliberate agreement between the supplier and the receiver of the knowledge. Such agreements are not present in the second category, i.e., knowledge spillovers. Figure 4.2 also shows how the pertinent externalities are mediated.

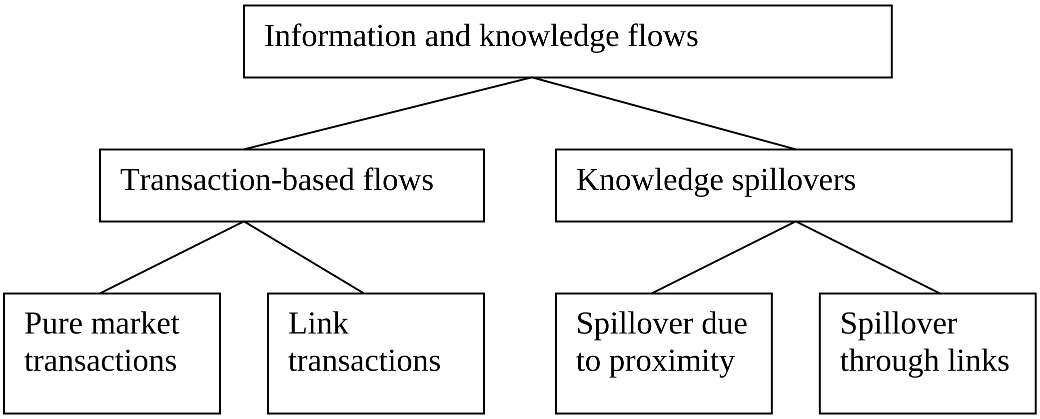

Figure 4.2: Classification of knowledge flows

When knowledge flows are transaction based, there is a reciprocity between sender and receiver of the knowledge. With pure market transactions a firm explicitly pays for knowledge services that it receives. Link transactions refer to various forms of agreements and contracts, including situations where two or several actors cooperate in the R&D process on the basis of an understanding of how profits and losses should be distributed among the participants. These considerations are further elaborated in Table 4.1.

Table 4.1: Transaction-based knowledge flows and knowledge spillovers

TRANSACTION-BASED FLOWS	SPILLOVERS
Cooperation between firms inside an industry, where there are explicit or implicit contracts	Firms in the same industry observe and imitate each other and get inspired by each other. When the knowledge is complex, proximity may be essential. In this case knowledge is difficult to privatise.
A firm cooperates with an input supplier. In this case there may not be any rivalry but explicit or implicit agreements regulate how costs and benefits should be distributed.	In the course of normal transactions with a supplier the firm acquires knowledge as a by-product. In this case there may not be any rivalry, although there is no agreement.
A firm and a customer of the firm cooperate in development of product attributes and delivery features. Explicit or implicit agreements regulate how costs and benefits should be distributed.	In the course of normal transactions with a customer the firm acquires knowledge as a by-product. In this case there may not be any rivalry, although there is no agreement.
A firm buys knowledge services from a professional knowledge supplier. When knowledge is complex, the transaction may be link-based rather than a pure market transaction.	In the course of normal transactions with a knowledge provider the firm acquires knowledge as a by-product. In this case there may not be any rivalry, although there is no agreement.
In the internal network of a multi-establishment corporation individual units cooperate in development activities.	In the normal interaction inside a multi-establishment cooperation an individual unit acquires knowledge as a by-product. In this case potential rivalry may be regulated by the head office.

The observations in Table 4.1 show that spillovers between firms in the same industry represent a problematic case in comparison with all the others. Moreover, transaction-based cooperation between firms in the same industry may violate written law. Thus, horizontal externalities constitute a problem area of itself.

4.2 Routine Development

Classic product cycle models employ the assumption that products develop over time from non-standardised attributes in the early phases to standardised attributes in later and more mature phases. When products have become standardised routine improvements represent the major form of innovation and production is frequently located in non-metropolitan regions, whereas production of non-standardised products has the opposite location pattern (Hirsch, 1967; Norton and Rees, 1979; Johansson and Andersson, 1998; Karlsson and Klaesson, 2002). This suggests that routine development has other requirements as regards knowledge flows.

In order to discuss routine development we can return to the cost expression in (3.2), which reads $c = F/x + v$, where $v = w_1 s + w_2 g$ Routine improvement of the production process implies that $dc/dt < 0$, which requires that at least one of the components, F, s or g is being reduced. However, routine improvements can also concern inflow of inputs. In formula (3.2) this will be reflected by reduced levels for the input price variables w_1 and w_2 .

A routine change from $c = F/x + v$ to $c^* = F^*/x^* + v^*$ should satisfy that $c > c^*$. In view of (3.8) this corresponds to a shift in routine vintage from τ to τ^*, where $c(\tau) > c(\tau^*)$. The development cost associated with the shift in routine is $R(\tau^*,\tau)$. Let ρ denote the annuity of the development cost. Then the development can be considered successful if

$$\pi(\tau^*) = p - c(\tau^*) - \rho R(\tau^*,\tau) > 0, \text{ and } \pi(\tau^*) > \pi(\tau) \qquad (4.1)$$

where $\pi(\tau)$ denotes the original profit level. It should be observed that (4.1) is an ex post condition. Ex ante the firm has to consider the probability of achieving this positive result, balanced against the probability of failure.

The central question here is: How do changes of the type described in (4,1) come about? Where and how is the necessary knowledge created and how does it reach the innovating firm? Moreover, how does the probability of success vary across regions? These considerations imply that a stochastic framework applies, with models that show how the probability of success is influenced by regional characteristics such as (i) the supply of knowledge services, (ii) the opportunities to interact with input suppliers, and (iii) the existence of other knowledge flows.

A currently dispersed literature provides a variety of answers to the above questions. In spite of the diversity of models and model fragments that can be found in empirical and theoretical contributions, there is one profound communality. Almost without exceptions the literature contains the assumption that the development activity requires inputs of complex and contextual information/knowledge. An even stronger version of this assumption obtains when tacit knowledge is assumed to be the basic fuel. In both cases the assumption is that knowledge is created and transmitted by means of face-to-face contacts (FTF-contacts) and direct observations of technical improvements. This type of assumptions leads to the conclusion that proximity externality is a fundamental aspect of innovation. The nature of the proximity externalities is that the cost of direct observations and FTF-contacts is lower when made in the proximity (e.g. Feldman and Audretsch, 1999).

How can the various assumptions and theoretical suggestions in models of routine development be organised into a more transparent structure? The following list of innovation mechanisms provides an attempt to span the territory of different suggestions (Baptista, 1999, 2000):

(i) Routine development takes place as a learning-by-doing process in the individual establishment. This is an extreme model, for which spatial aspects disappear. At the same time, in this case the probability of spillover of achievements to neighbouring competitors can be minimised.

(ii) The firm imitates routine development of other firms in its proximity. Imitation opportunities increase as the number of similar firms (in the same industry) increases. As an extension of this idea, each individual firm is stimulated by its neighbours to further improve its routines. A consequence of the described spillover mechanism is that the individual firm gains from neighbours but cannot keep its own routine improvements private. The spillover mechanism works in both directions.

(iii) The firm develops new routines in interaction with input suppliers that are located in the proximity. This form of development activity may be classified as learning by interaction. To the extent that this is a side effect of normal interaction it functions as spillover in an established network with links to input suppliers. Proximity is assumed to facilitate interaction with input suppliers

(iv) Routine-development activities of a firm may involve buying R&D results from knowledge providers (universities, consultants etc). Proximity is assumed to facilitate the purchase of knowledge inputs.

(v) Obviously, with our without explicit R&D-interaction, changes in the supply of inputs may improve the routines of a buying firm. Input quality can improve at non-increasing input prices, and the price of inputs may reduce at non-decreasing quality. Proximity can facilitate such changes to the extent that the changes are induced by FTF-interaction.

Empirical studies of the processes outlined above can focus on individual firms or on industries located in different regions. Studying the individual firms one can examine if the frequency of firm location is higher in regions where the likelihood of knowledge flows is comparatively large. Fischer and Johansson (1994) presents a set of studies indicating that networks play an important role for routine development.

Empirical studies of cost levels in entire industries have to handle a specific complication, since an industry’s performance is affected by exit of less and entry of more efficient establishments, and this process has consequences for the average cost level of the industry. However, this latter process does not necessarily reflect any innovation activity.

The spillover phenomenon described in (ii) raises a major consistency problem, which complicates model formulations. Proximity diffusion to an innovating firm is counteracted by diffusion from the firm to its neighbouring competitors. In order to motivate the existence of a clustering process and maintenance of an industrial district, it is necessary to clarify that the positive consequences of spillovers outweighs the negative. In which settings is it more likely that this balance between positive and negative effects obtains? Such environments would have to bring about benefits from spillovers to each firm that are larger than the losses that each firm makes when its own knowledge diffuses to its neighbouring competitors.

Indeed, the mechanisms in (iii) and (iv) are by their very nature consistent with profit maximisation behaviour. There is no generic rivalry that makes spillovers from and R&D interaction with input suppliers and with establishments belonging to the same firm. Moreover, case (iv) represents a standard transaction between a supplier and a customer firm. The proximity externality is self-evident, because links between a firm and its suppliers are easier to establish if suppliers are located in the proximity. This form of spatial externality does not exclude that competitors in the same industry still may show a tendency to agglomerate in the same region. On the contrary, the competitors will cluster together as they are attracted by the location of input suppliers.

With regard to efficiency externalities it has been demonstrated in section 3 that clustering of input suppliers and input-buying firms may bring about mutual benefits to both types of firms. In the context of routine-development externalities, one may consider to formulate an innovation-game model and examine under which conditions such a game has Nash equilibrium properties that are consistent with the pattern of knowledge flows between different types of participants in the game. Such an approach would relate to the early contribution by Kamien and Schwartz (1982).

4.3 Product Development

In general product innovation is more complex than routine development. The reason for this is that product development comprises a development of both product attributes and production techniques. This coupling of the two types of development activities is specifically stressed in product cycle models (e.g. Johansson and Andersson, 1998). These models also emphasise that product innovations depend on knowledge flows that can be found in metropolitan regions.

The main question here is: how important are proximity externalities for product-development activities? Are these activities triggered by regional externalities and does the probability of success depend on such externalities? And which are the externalities? These considerations imply that a stochastic framework applies, with models that show how the probability of success is influenced by regional characteristics such as (i) the supply of knowledge services, (ii) the opportunities to interact with input suppliers and customers, and (iii) the existence of other knowledge flows.

Formally, the problem may be modelled in a stochastic context, where the outcome of an innovation effort in region *r* is (i) a successful product innovation, with probability P_r and (ii) a failure with probability (1-P_r). Let π_r^* denote the present value of profits when the innovation effort is successful and let $\pi_r^o < \pi_r^*$ denote the present value or profits when the effort is a failure. The present values of profit include the R&D costs. Moreover, the potential knowledge flows in region are denoted by I_r.

Let *R* denote a typical R&D effort. For a firm that spends *R* on R&D, the expected profits can be described as

$$\pi_r^* = \pi(R, I_r) \tag{4.2}$$

In this formulation the level of π_r^* depends on I_r. The probability of success for a given value of *R* can be written as $P_r = P(\pi = \pi_r^* : I_r)$, where the probability depends on the value of I_r. We may assume that a firm is willing to carry out product development activities if

$$P_r \pi_r^* + (1 - P_r)\pi_r^o \geq \overline{\pi} \tag{4.3}$$

which means that the expected profit value exceeds a minimum level $\overline{\pi}$. The condition expressed in (4.3) has to be supplemented by an assumption that the financial conditions of the innovators are such that the expected outcome is a meaningful criterion.

With the formulations in (4.2)-(4.3), and with *R* taken as given, we may assume that (i) the size of π_r^* increases as I_r expands, and (ii) P_r increases as I_r expands. Given this, the following hypotheses could be formulated for empirical comparisons of regions:

- The value of π_r^* is larger for regions with a high I_r-value, which could reveal itself in a higher frequency of new products and patents
- The value of P_r is higher for regions with a high I_r-value, which should reveal itself as a higher frequency of successful R&D efforts.
- The frequency of R&D efforts is higher for regions with a high I_r-value

In empirical studies of the indicated type, potential knowledge flows could be represented by a vector, distinguishing knowledge flows of different types and separating transaction-based flows from spillovers.

In a recent review article Breschi and Lisson (2001) examine the literature on localised knowledge spillovers (LKS). They identify a series of logical gaps and inconsistencies that are present in LKS-studies such as Jaffe (1989), Feldman and Florida (1994) and Keeble and Wilkinson (1999). A major inconsistency in LKS analyses is that many scholars consider knowledge resources and R&D results in a region as both (i) a local public good and (ii) tacit knowledge. However, when knowledge is tacit it cannot be public. If knowledge were tacit, contextual and complex, the exchange of knowledge would rather take place in links between firms, i.e., in the type of durable networks that has been discussed in preceding sections. LKS-studies also tend to argue that all local knowledge flows are spillovers, i.e., pure (non-pecuniary) externalities.

Consider now a firm involved in product development activities, a developer. Information and knowledge that facilitate product development may be exchanged (unintended or commercially) between the developer and other economic agents. Potentially this type of exchange could take place between the following categories of agents (von Hippel, 1988; Johansson and Larsson, 1986):

(i) The developer and other firms in the same industry

(ii) The developer and firms that are input suppliers

(iii) The developer and firms and other agents who are customers

(iv) The developer and commercial knowledge suppliers (including universities and R&D organisations)

(v) The developer and other firms belonging to the same concern (multi-firm corporation)

Orthodox economic analysis tells us that a firm can more easily exploit R&D results if other competitors are excluded from using the result. The firm needs to cover the R&D costs by the returns to the R&D effort. In the spirit of Schumpeter an innovator's incentive is the possibility to obtain temporary monopoly profits. Hence, knowledge spillover to other competitors is an unwarranted thing. This observation suggests that any spatial cluster of competitors must have another motivation.

Two competitors can form an R&D alliance, where the cooperation is regulated according to a contract. In this case we observe a development link that facilitates mutual knowledge provision. Obviously, this is a commercial relation, not a spillover phenomenon. At the same time, the interaction will most likely bring about unintended spillovers as a side effect.

A firm's contact with a commercial knowledge provider in case (iv) is an ordinary transaction that may or may not have the form of a durable transaction link. In any case, proximity to such knowledge providers will facilitate the interaction.

In case (ii)-(v) the individual firm may have ordinary links to a supplier, a customer, and to a sister firm or a subsidiary firm. Spillover would then be a side effect of the ordinary use of the links. I all these cases one can also conceive that R&D links can be established on a commercial basis. The agents cooperate making use of implicit and explicit contracts that specify how costs of and returns to the R&D efforts are intended to be shared between the parties – both when the cooperation fails and succeeds. With this background, two major observations should be made:

- Sections 1-3 analyse under which conditions a firm decides to form a link with customers as well as input suppliers. It is conceivable that knowledge spillovers will occur in the course of normal link-interaction. Thus, spillover is an additional consequence of the externalities already analysed in preceding sections.

- Consider next the formation of R&D links. The decision to form such links is of a similar nature as decisions about the transaction links described in table 2.4. Thus, most of the analysis in preceding sections is relevant also in this case. The novel element here is that the outcome of an R&D link is uncertain in a fundamental sense.

Which are the conclusions? First, it has been suggested that a firm acquires knowledge and support in its development activities by purchasing inputs from knowledge suppliers. Second, a firm can form R&D links with other agents for cooperation on commercial basis. Third, knowledge is acquired as a spillover effect of ordinary interaction on its established transaction links. In all these cases we may argue that spatial externalities can play a role, because transactions and link formation are less costly in an agglomeration, where proximity reduces transaction and interaction costs. In other words, our previous analysis indicates that intra-market knowledge transactions as well as the formation of R&D links are more efficient and less costly in an agglomeration.

The conclusions made above can be related to the discussion of the two types of externalities that are represented by (i) localisation economies and (ii) urbanisation economies. With regard to innovation externalities the first is referred to as the Marshall-Arrow-Romer externality between firms in the same industry. The second has been called the Jacobs externality, which assumes that transfer of knowledge among sectors is the major form of innovation externality (e.g. Capello, 2001). The discussion in this paper does not exclude any of these. However, in a large agglomeration there are greater opportunities of finding knowledge providers, of forming R&D links, and of establishing links in general. If this is true we end up with the conclusion that innovation externalities are more prevalent in large urban regions than in small districts. The story about successful industrial districts would then be the exception – not the rule. This latter story applies to the limited cases with social networks and strong ties between entrepreneurs that allow them to exchange tacit and contextual knowledge.

The conclusion above can be modified by making the observation that a metropolitan region can be described as a set of districts. In a recent contribution Capello (2002) claims that there are positive localisation economies in such metropolitan districts.

5. CONCLUDING REMARKS

The assessment of spatial externalities in the preceding four sections has invariantly employed a distinct reference setting – the pure market institution. The latter has two components that may be conceived of as infrastructure. The first component is a system of prices and the second component is a system of information dissemination about available options and the price associated with each option.

The information system of the market institution is not run without costs and active market operators participate in the diffusion of information. There are local and global aspects of the market institution. It is quite clear that spatial size externalities are present in local markets. Information supply is disseminated by sellers who announce their sales offers and by customers who inform about their willingness to buy. However, in a large agglomeration information specialists and information traders can find market niches, where they function as middlemen, brokers and the like. From a distance, these market activities may appear as spillover phenomena, referred to as “thick” or “dense” markets. In another perspective they are specialised markets, which help the whole set of markets in a region to function efficiently. They are a vital part of the information system of the market institution. And the information system can be assumed to increase its efficiency as an agglomeration grows in size. Paradoxically, this is an externality that makes the market institution more workable.

The first overall conclusion concerns the efficiency of supply activities. In the preceding sections the analysis shows that static efficiency externalities (related to supply activities) can be generated by both proximity and links (networks), given that transactions are distance sensitive. From the classification and model exercises it should be clear that these externalities are primarily mediated via markets and quasi-markets, where basic economic mechanisms play a major role. It is also suggested that the pertinent externalities generically are vertical, including pure demand externalities. Empirical research has not yet come to a state where we can have any research-based opinion about the relative frequency of the various cases in tables 2.3 and 2.4.

Tables 2.5 and 4.1 indicate that knowledge spillover can be a by-product of ordinary transactions between firms. Knowledge spillover would then be an additional consequence of inter-firm interaction in their supply activities. In the discussion it is conjectured that such by-product spillovers are more likely to occur when firms interact via transaction links. Also in this case vertical interaction is considered to be the most important case, whereas horizontal spillovers remain problematic.

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The second overall conclusion concerns externalities related to a firm’s innovation (or development) activities. The first observation is that economic theory can be applied in a straightforward way when knowledge flows are transaction based. Secondly, economic modelling is unproblematic also in the cases where knowledge spills over in the course of normal interaction on transaction links between firms (von Hippel, 1988). Future empirical research in this area should preferably combine detailed case-study information with frequency information.

In this context we may refer toe Breschi and Lissoni (2001) who ends their assessment with two major conclusions. First, empirical studies of knowledge-spillover externalities may in fact primarily reflect pecuniary (or rent) externalities. Second, what is claimed in empirical studies to be unintended knowledge spillovers may actually be economically regulated knowledge flows between firms, including transaction-based and link-based flows.

With regard to externalities that are based on spillovers between competing firms, the current state of the art is obviously still in a state of confusion. One cannot seriously claim that such spillovers are unlikely to occur. However, there is a lack of models that make the microeconomic behaviour consistent for this type of phenomenon. This is indeed a challenge for future model building (Fujita and Thisse, 2002). To make further progress, empirical research would have to rely on much more explicit formulations of the micro foundations for the processes examined. This paper has been written as a small contribution to foster such a development.

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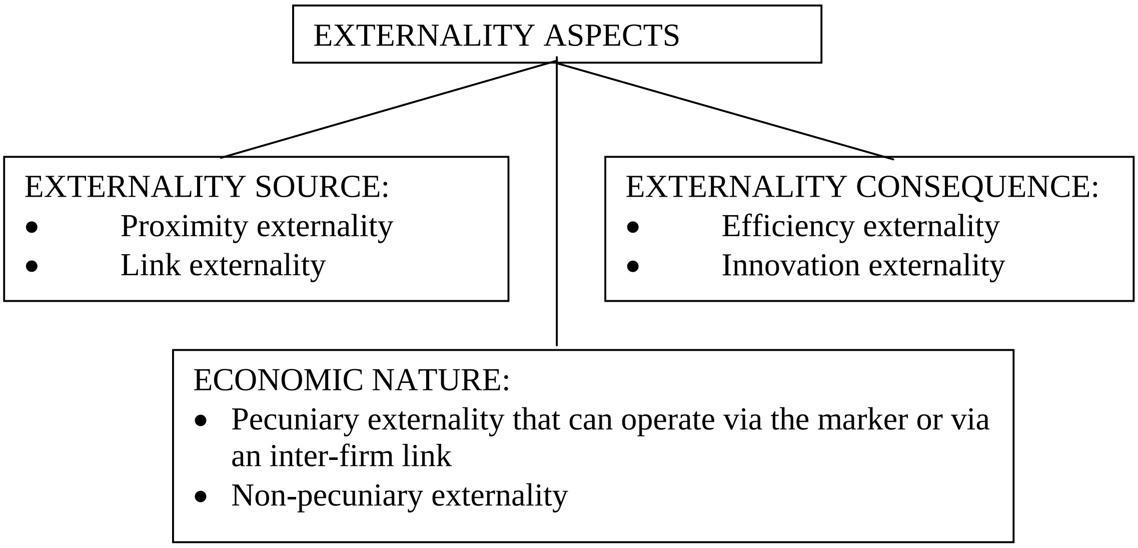

Figure 1.1 Sources, consequences, and economic nature of an externality

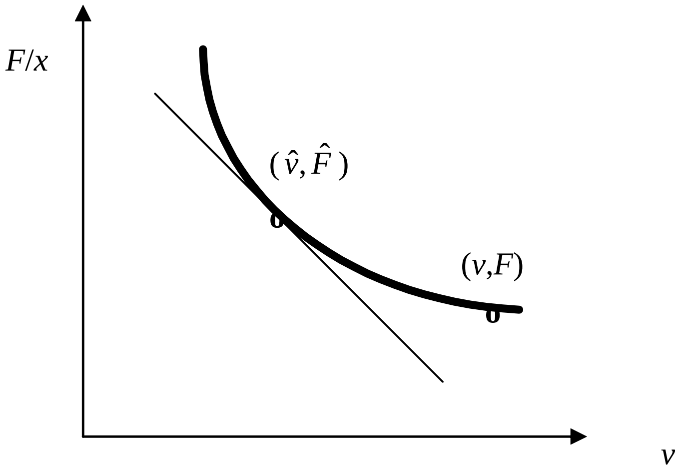

Figure 3.1 Effects of a link investment

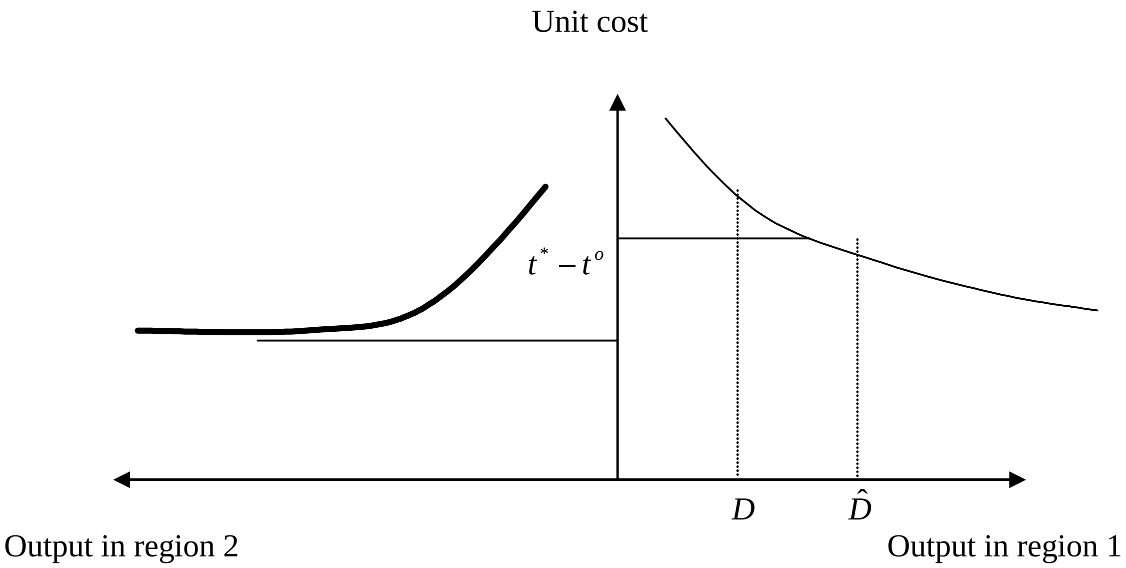

Figure 3.2 Competition between intra-regional and extra-regional input delivery

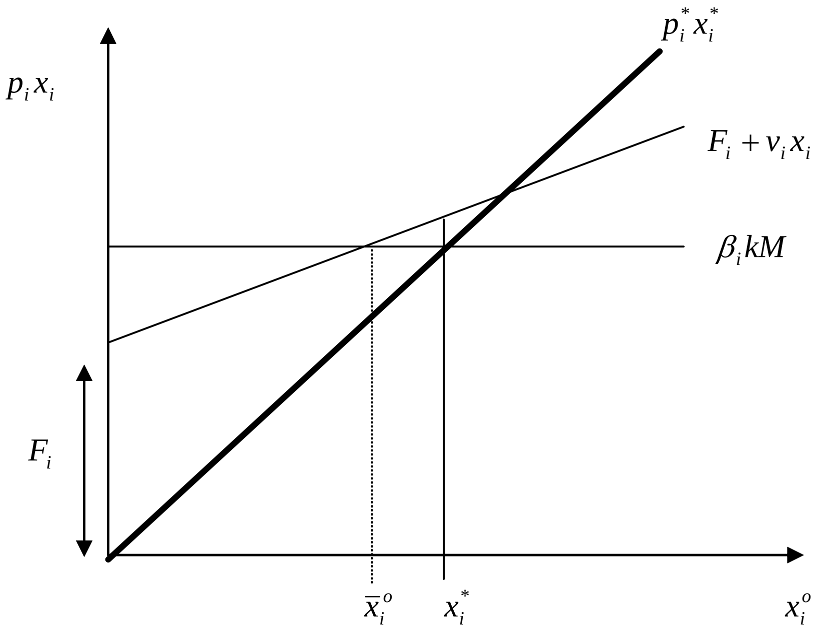

Figure 3.3: Local output and size of local demand

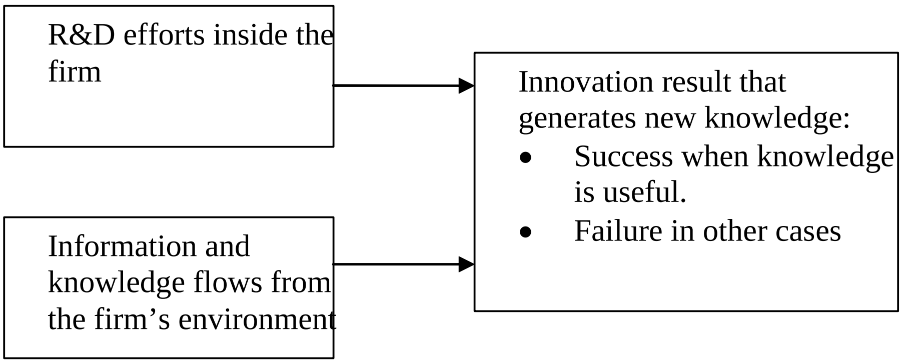

Figure 4.1: The two components of innovation activities

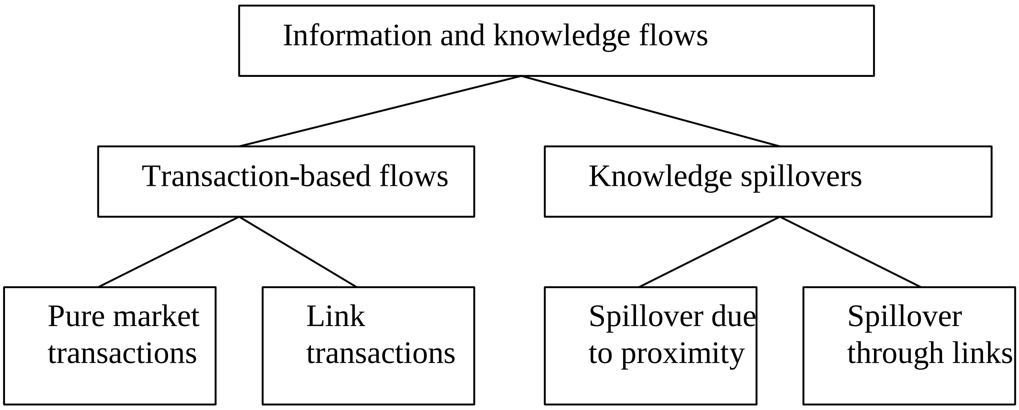

Figure 4.2: Classification of knowledge flows