CPB Memorandum

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Clusters: Determinants and Effects

This memorandum surveys the empirical literature about the effects and determinants of clusters. It finds that clusters generally lead to more innovations, knowledge spillovers, faster diffusion of technologies and knowledge, and competitive advantages. The presence of a skilled labour force is the most important determinant for clusters. Other important factors for the existence of clusters are economies of scale and scope, knowledge spillovers, and competition from foreign competitors.

Clusters appear to be especially important for small firms. Surprisingly, there is relatively little cooperation between these firms. Even though clusters are generally located near a knowledge institution, there is also relatively little cooperation between the cluster and the knowledge institution.

Since clusters need skilled labour and competition, a good cluster policy may be no cluster policy at all. Instead, the government should look after an education system that produces a highly educated and skilled workforce, and stimulate competition by (further) opening markets to foreign competitors.

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1 Introduction

Clusters are expected to have many positive economic effects. These expectations have caused the Dutch Ministry of Economic Affairs to actively perform cluster policy. However, cluster policy only has these effects if, first, the theoretical expectations of clusters hold true empirically and, second, if the policy indeed enhances the existence and appearance of clusters. To analyse whether both are the case, this study takes stock of the results of empirical cluster analyses. It compares the theoretical effects and determinants of clusters with the empirical effects and determinants. From this analysis, it becomes clear that although clusters have many of the expected effects, cluster policy does not. The results of empirical analyses show that instead of performing cluster policy, the government should support the system of universities and other knowledge institutions, to provide for an educated and skilled labour market, and stimulate competition, for example by further opening markets to foreign competitors.

Section 2 briefly describes the theoretically expected effects and determinants of clusters. After this, Section 3 analyses which clusters are identified in the Netherlands. The central question of Section 4 is 'what are the effects of clusters?', while Section 5 searches for the factors that cause clusters to emerge, *i.e.* it answers the question 'what are the cluster determinants?'. Although these sections build upon existing analyses rather than new research, the consistent results found in the literature allow for stronger conclusions than each analysis separately. Furthermore, by taking stock of the outcomes of earlier empirical analyses that each highlight one or a few aspects of clusters, this study obtains a more complete picture of the role of clusters in an economic system. The consequences of the findings for government policy are discussed in Section 6, after which Section 7 concludes.

2 Clusters in theory: determinants and effects

A wealth of economic literature explains the emergence of clusters. Even if these analyses are classified in types of approaches, many different theories exist.[1] The most well-known approaches for explaining clusters are the new economics of geography and the new economics of knowledge, which can be roughly identified with respectively Krugman (1991) and Porter (1990).

Krugman states that Marshall is the original source of theories about the emergence of clusters. The three reasons given by Marshall (1920) for localization are, in the words of Krugman (1991, pp. 36-37), that an industrial centre:

- allows a pooled market for workers with specialized skills;
- allows provision of non-traded inputs specific to an industry in greater variety and at lower costs;
- generates technological spillovers.

Krugman stresses the role of interactions between factors that cause localization. He formalizes his theory in a model that explains the emergence of clusters from the existence of economies of scale and scope, transportation costs, and mobile production factors. In another model, he shows how pooled labour indeed causes all workers and firms to end up at the same location. Based on these simple models, many other more sophisticated models have been developed that underline the findings of Krugman (see, for example, Fujita, Krugman, and Venables, 1999).

Porter (1998) stresses the positive effects of 'agglomeration economies' which may explain the existence of clusters. He refers to several positive effects of agglomerations, such as sharing infrastructure, communication technologies, availability of inputs, and access to output markets. Porter also mentions the role of transportation costs in the existence of clusters, but these transportation costs differ from the transportation costs mentioned by Krugman: Porter assumes that firms choose the same location in order to minimise transportation costs of inputs needed by these firms to produce their own product, whereas Krugman assumes that firms cluster in order to decrease transportation costs of their products to consumers.

[1] For example, Muizer and Hospers (2000) mention the location theory (classical, neo-classical and modern), the industrial organisation theory, the transaction cost theory, the industrial districts theory and the systems of innovation approach.

The different transportation costs in the analyses of Porter and Krugman point to a difference between supply and demand factors that cause clusters. Although there are exceptions, many factors that Krugman uses to explain clusters can be associated with the demand for the products of a firm, whereas the factors that Porter names mainly refer to the supply side, since they refer to the production process of a firm. Therefore, there is no need to 'choose' between the theories of Porter and Krugman because both types of effects may occur simultaneously.

Baptista and Swann (1998) explicitly distinguish between factors on the demand side and factors on the supply side (Baptista and Swann, 1998, p. 527). They survey which factors that enhance or cause clusters are mentioned in theoretical analyses. At the demand side, they distinguish four factors. Firstly, clusters may arise at places with strong demand. Secondly, firms may gain market share by moving close to a competitor. Thirdly, the existence of a cluster decreases search costs for consumers. Fourthly, firms located near customer markets can easily exploit information flows of important customers, for example by providing additional customer services. At the supply side, Baptista and Swann name the three factors that were originally introduced by Marshall: pooled labour, the availability of (specialized) inputs, and knowledge spillovers. The self-reinforcing effect of clusters is limited by congestion and competition effects.

Although there are differences between the theories about clusters, there are many factors that appear in several theories. Since this study analyses which factors also appear empirically, it begins with a list of the factors that appear often in theoretical studies. The factors found empirically can then be compared to these theoretical factors. If we define cluster determinants as factors that lead to the emergence or existence of clusters, the following list of cluster determinants may be obtained from most theories (see, Porter, 1990, Krugman, 1991, Baptista and Swann, 1998, and Muizer and Hospers, 2000):

- Economies of scale and scope
- Transportation costs to the consumer market
- Transportation costs of inputs
- Search and transaction costs
- Availability of production factors or (intermediate) inputs at a specific location
- Knowledge, information and technological spillovers
- Developing and using innovations
- Cooperation between firms, for example for developing innovations or between suppliers and buyers
- Decreasing uncertainty.

Besides the cluster determinants, this study also analyses the effects of clusters. Most of the effects follow directly from the cluster determinants. Since firms in clusters have lower costs, they may enhance their profits. Furthermore, since production becomes easier, the country as a whole may experience increased economic growth. For firms in a cluster it is easier to cooperate, which supports the process of obtaining inputs of the right quality and selling outputs with the right specifications. Hence, Porter (1990, 1998) argues that clusters increase the competitive advantages of a country. Firms are better able to compete in international markets, which may increase exports. Spillovers in clusters increase the rate of diffusion of technologies and knowledge and lead to more innovations.

Except for Porter, most authors focus on the determinants of clusters and do not explicitly mention the effects of clusters. However, the effects of cluster can be derived from the cluster determinants. These findings combined with the analyses of Porter lead to the following list of possible cluster effects:

- Increased profits
- Increased exports
- Faster economic growth
- Stronger competitive advantages
- More innovations
- Faster diffusion of knowledge
- Faster technological growth.
- Increased productivity growth

Besides these positive effects of clusters, some authors also mention negative effects that may arise due to clusters (see,*e.g.* Porter, 1998, or Schmutzler, 1999). The negative effects are

- Negative externalities due to pollution or congestion
- Decreased competition due the forming of cartels
- Increased prices for *e.g.* housing, wages, or land rents
- 'Groupthink', which may lead to rigid ideas and a failure to adapt new technologies or ideas

The positive and negative effects described above are the possible effects that can be expected on the basis of theoretical analyses. This does not mean that these expected effects occur in practice as well; theoretical expectations do not necessarily correspond to empirical observations. To analyse whether the results of the theories also appear empirically, the next sections compare expectations with empirical results.

A final remark concerns the definition of a cluster. Since the aim of this study is to compare the empirical effects of clusters with the theoretically expected effects, it is important to stay close to the clusters used in theoretical analyses. Since the effects are compared by surveying the results of earlier analyses, the definition of cluster depends on the analyses discussed. This implies that the definition of a cluster is not always the same. For this reason, the definition of a cluster in this analysis is kept broad; a cluster is defined as a group of related firms located at the same spot. However, this definition only reflects clusters of firms, whereas many empirical analyses focus at clusters of sectors. Since these clusters are based on sectors rather than firms, the definition above does not apply to them. Hence, these so-called meso-clusters are defined as a group of related sectors. As a consequence, clusters based on firms are sometimes called micro-cluster. Since theoretical analyses generally refer to micro-clusters, the word ‘clusters’ is used to refer to ‘micro-clusters’. Meso-clusters are referred to by their full name.

The definition of a (micro)-cluster states that firms in a cluster are located at the same spot. One might argue, however, that firms in a cluster do not necessarily share the same location. After all, cooperation in developing innovations can also take place between firms at great distances. Still, most theoretical analyses try to explain localization; they answer questions like: why are firms located close together? Furthermore, the empirical analyses discussed below show that most cooperation takes place between firms on different locations, whereas firms in clusters cooperate relatively little. If a system of cooperating firms that are not located at the same spot is labelled as a network, it is possible to compare clusters and networks. The empirical analyses show that networks generally consist of different firms and have different effects and determinants than clusters (see, *e.g.*, Nooteboom, 1998). For example, the type of innovations produced by clusters and networks differs considerably: whereas clusters produce radical innovations, networks generally develop incremental innovations. Policy aimed at clusters therefore leads to different economic effects than policy aimed at networks. Since the distinction between clusters and networks is important, the geographical aspect is an important and necessary part of the definition of a cluster

3 Which clusters are found in the Netherlands?

Before analysing the effects and determinants of clusters, this section summarises which clusters are identified in the Netherlands. This answers the question whether clusters exist at all and it shows which firms or sectors would be eligible for support. Since no two clusters are the same, each cluster will have a different mix of the cluster determinants and effects found in the analyses. If a government wants to support certain cluster effects, it is necessary to know which clusters are present, because in that case the government is able to select the clusters for which the desired effects are most prominent.

Empirical analyses that identify clusters can be divided into two groups. The first group identifies micro-clusters and the second group identifies meso-clusters. The difference between these two groups reflects the level of aggregation: whereas micro-clusters refer to clusters of firms, meso-clusters refer to clusters of sectors (see, *e.g.,* Hoen and Arnoldus, 2000).

Meso-clusters can be analysed with quantitative methods, whereas the identification of micro-clusters generally involves qualitative methods. Further, meso-clusters already provide much information about which clusters are probably present in a country, how these clusters will look like, and where these clusters can be found. Many authors therefore choose to analyse meso-clusters rather than micro-clusters. In order to show which clusters exist in the Netherlands, this section uses both the results of meso-clusters and of micro-clusters. It begins with clusters at the meso-level. From there, the focus will be shifted to less aggregated levels, until the results of analyses about micro-clusters are discussed.

The pictures emerging from different studies about meso-clusters in the Netherlands are rather similar to each other. As an illustration, Table 3.1 summarises the findings of two representative studies[2].

Table 3.1 Empirically found meso-clusters

Roelandt and Van der Gaag (1995)	Roelandt, Den Hertog and Jacobs (1997)
Energy	Energy
Construction	Construction
Agriculture and food	Agro-food
Multi-media	Media
Manufacturing	Manufacturing
Chemicals	Chemicals
Services	Commercial services
Harbour and transportation	Transportation, harbour and communication
	Non-commercial services
Health	Health

[2] Table 3.1 shows the results of two analyses, because the results of only one analysis would not show the similarity between the identified clusters, whereas the outcomes of three or more analyses do not change the picture. A comparison of more studies can be found in Hoen and Arnoldus (2000), p. 25, Table 5.

Since the results in Table 3.1 refer to meso-clusters, they are very broad and together they contain almost the entire economic system. Especially some of the larger meso-clusters such as 'Manufacturing' and 'Commercial services' are not specified very well. Other analyses sometimes narrow down these meso-clusters. Witteveen (1997) and Roelandt, Den Hertog, Van Sinderen and Vollaard (1997) distinguish three smaller meso-clusters in the manufacturing cluster: 'metal-electronics', 'paper' and 'other'. Likewise, Hoen and Arnoldus (2000) distinguish 'Cars', whereas Verbeek (1999) finds the meso-clusters 'Textiles' and 'Paper'. Although these meso-clusters are already significantly smaller than one cluster 'Manufacturing', they remain rather broad.

Another drawback of the broad meso-clusters is their geographical size. Although clusters are in theory located at a specific location, meso-clusters are defined for a country as a whole. Hence, they generally cannot be attributed to a specific location smaller than a country. Eding, Oosterhaven and Stelder (1999) partly solve this problem by identifying meso-cluster that can be assigned to regions smaller than a country. They use input-output tables of Dutch regions that are smaller than the country as a whole, but in some cases these regions are still rather large, such as the three northern provinces. First, however, they identify meso-clusters for the nation as a whole. Then, they identify meso-clusters in three specific Dutch regions: the region around Amsterdam, the region around the Rhine estuary, and the northern part of the Netherlands. The meso-clusters found in each case are shown in Table 3.2.

Table 3.2 Regional clusters found by Eding, Oosterhaven and Stelder (1999)

The Netherlands	Amsterdam	Rhine Estuary	Northern-Netherlands
Construction	Construction	Petrochemicals	Agro-industry
Business services	Wholesale and retail trade	Construction	Construction
Agro-industry	Business services incl. printing	Agro-industry	
Sea and air transport		Wholesale and retail trade	
Insurances		Business services	

These regional meso-clusters are defined at the sectoral level. To find clusters that are more compatible with the clusters used in theoretical studies, it is necessary to lower the level of analysis, preferably to the level of firms. Therefore, the remainder of this section discusses the outcomes of empirical analyses concerning micro-clusters. They can be found by analysing micro data, by using case studies, or by a methodology developed by Porter (1990) that uses export data to list characteristics of sectors in a so-called 'cluster chart'. Since theoretical analyses also analyse micro-clusters, the term 'cluster' is used to indicate a micro-cluster.

Kusters and Minne (1992) focus on clusters in manufacturing and they include a geographical dimension in their cluster definition. Following the methodology of Porter (1990), they use export data to derive one most important cluster, three other important clusters, and three potential clusters. The seven clusters are denoted in this order in the first column of Table 3.3. Also following Porter's cluster charts, Jacobs, Boekholt and Zegveld (1990) use export data to compute which Dutch sectors are successful. They select eleven of the most successful sectors, which are supposed to be the centre of a cluster. These clusters are denoted in the second column of Table 3.3. Later, using the same methodology, Jacobs, Vethman and De Vos (1992) find the clusters denoted in the last column of Table 3.3.

Table 3.3 Clusters based on the methodology of Porter (1990)

Kusters and Minne (1992)	Jacobs, Boekholt and Zegveld (1990)	Jacobs, Vethman and De Vos (1992)
the international cluster	Dairy products	Cut flowers
the agro-industrial cluster	Machines for dairy products	Plants, bulbs
the deep sea harbour	Cocoa butter and cocoa powder	Eggs (in shell)
the international airport	Cut flowers	Pigs (live)
the high tech cluster	Plastics and polymers	Tomatoes
Aken/Luik/Maastricht	Industrial textiles	Cocoa powder
Bio-technology	Pre-recorded sound mediums	Milk (sweetened)
	Photocopiers	Cocoa butter
	Road transport	Potatoes
	Trucks	Pigmeat
	Yachts	

The 'clusters' in Table 3.3 are based on export data about products. Hence, they concern manufacturing. Services can be analysed by the same methodology applied on data from a different source. In this way, Jacob, Vethman and De Vos (1992) find many wholesale and retail trade and two transport sectors with relatively large export. All in all, they conclude that the Netherlands have a strong position in the clusters:

- Agriculture / food
- Petroleum / chemicals
- Transport
- Materials / metal

As the results in Tables 3.2 and 3.3 show, the broad meso-clusters in Table 3.1 can be narrowed down to more specific products. However, it is not sure whether the products in Table 3.3 are indeed the main products of a cluster. Furthermore, the clusters specified in Table 3.3 are only some examples of existing clusters, they do not list all clusters in the Netherlands. These drawbacks can be circumvented by using micro-data, an approach taken by, among others, Rats (2001). Rats defines five cluster characteristics that should appear in the data of a region that contains a cluster. Based on a literature survey he concludes that a cluster has five dimension: it consists of *agents* that are related through *linkages*, who use *resources* to develop *activities*, and who are all located in the same*region*. Since each cluster is centred around a specific sector, the five characteristics are identified for firms in a specific sector. Rats uses the number of firms as indicator of the number of actors, the production value of a sector as indicator of the activities of firms, the inputs of a sector as indicator of the linkages, the number sub-sectors present in the region as indicator of the presence of resources, and the share of value added to production value as indicator of the quality of a region. Each region for which at least three of these characteristics exceed certain exogenously specified critical values is supposed to contain a cluster. Rats finds an agro-food and a textile cluster in the region Brabant, a media cluster near Amsterdam, chemical clusters in Rotterdam and at several other locations, manufacturing metal-electro clusters in the southern and eastern parts of the Netherlands, and a cluster called "Manufacturing paper" that cannot be appointed to a specific location. These results are already much more detailed than the meso-clusters found before, although the names of the clusters and the sectors at the hearts of the clusters indicate that the types of clusters found are still remarkably similar to the meso-clusters.

Schmitz and Heijs (2001) also use micro data. They analyse the location of innovations by mapping the labour costs of R&D workers in a database with 52000 firms that applied for an R&D subsidy. Clearly, the location of R&D workers is strongly localized. It is very similar to the pattern of the location of production; many R&D takes place in the region around Den Haag and Rotterdam (Rijnmond), near Eindhoven, in Twente and in Limburg. If the labour costs of R&D are divided by the total number of jobs, the localization remains, but the pattern changes. Now, most relatively high R&D intensity occurs in Twente, Arnhem/Nijmegen, Eindhoven, Limburg, Flevoland and parts of Zeeland. Brabant and Limburg contain regions that are specialised in processing industry (base metal, chemicals, food, biotechnology) and metal-electro (other metal, electro technology, ICT, transport equipment). The region Arnhem/Wageningen is relatively specialised in processing industry, and Twente in metal-electro. The regions in the Randstad (Amsterdam, Den Haag, Rotterdam) are not specialised, they contain R&D workers in all four distinguished sectors (processing industry, metal-electro, modern services and other services). The division in sectors as well as a division in technologies shows that specialisation is generally low. Again, many of these clusters are of a type that was already found as a meso-cluster.

From the clusters found in the analyses discussed above, some interesting conclusions can be drawn. One of these conclusions refers to the type of technology used in the clusters found:

especially the analyses that identify meso-clusters almost never find a high-tech cluster in the Netherlands; most clusters are centred around traditional agricultural or industrial products. A similar results was already found by Van Hulst and Soete (1989), who analyse the relation between technology and international trade. They find a strong relation between the export position of a sector and it's technological position. According to Van Hulst and Soete, the Netherlands have a strong position in chemicals, oil refinery, food, and electro technology. None of these sectors have a high R&D intensity or are considered high-tech sectors.

Wever and Stam (1999) explicitly search for high-tech clusters in The Netherlands. After comparing the location of Dutch high-tech firms, their sizes, and their most important partners, they conclude that high-tech clusters in the Netherlands do not exist. This agrees with the results of Swann (1999) who analyses the presence of high-tech clusters in Europe. Swann concludes that the Netherlands are simply too small for containing a high-tech cluster; the critical mass needed for the existence of a high-tech cluster cannot be reached in small countries such as Belgium, Denmark, or the Netherlands. However, the absence of high-tech clusters does not mean that there are no clusters in the Netherlands. Wever and Stam (1999) do not extensively analyse or identify which clusters do exist, but they give a few examples of Dutch clusters (see page 393):

- the oil and petrochemical clusters near the port of Rotterdam
- horticultural clusters such as the glass houses between Rotterdam and The Hague
- flower growing in the region around Aalsmeer
- fishing in the region around Urk
- a multimedia cluster in and near Amsterdam

The results of the empirical analyses discussed above clearly show that clusters exist in the Netherlands. It is, however, hard to identify these clusters. Still, it is not impossible and careful analyses of meso data, export data, micro-data, and case studies may show particular clusters and their location. Most Dutch clusters appear to be rooted in agriculture (such as cut flowers), chemicals (such as plastics), transportation (road transport), business services (insurances), manufactured products (pre-recorded sound mediums), and wholesale and retail trade. It is even possible to associate most of these clusters with a specific location, for example, the flower auction in Aalsmeer, the multi national group of chemicals companies DSM in Limburg, the Dutch main ports such as the harbour in Rotterdam and Schiphol airport, and the electronics company Philips in Eindhoven. Now that it is clear that the Netherlands contain clusters, the question that pops up next is 'what are the economic effects of these clusters?'

4 Cluster Effects

Theoretically, clusters lead to technological and knowledge spillovers and exploitation of economies of scale and scope, which influence the degree of innovativeness and the rate of economic growth and improve the export position of a country. This section surveys the empirical literature that analyses whether these effects were also found in practise. The first two sections focus on the effects of clusters on innovations and competitive advantages. The last section discusses other effects of clusters.

4.1 Clusters and Innovations

According to the theoretical analyses, clusters should increase the number of innovations, lead to more knowledge spillovers and a larger knowledge stock, and they should enhance the speed of the diffusion of knowledge among firms. Since firms are located close together, they can relatively easy cooperate in developing innovations, communicate changes in the desired specifications of inputs, point out new products, signal changes in technologies or market demands, *etc.* However, cooperation and spillovers may also take place at larger distances. Nooteboom (1998) argues that geographical proximity matters especially for radical technological changes. In these cases, new technologies are not yet documented; instead, they are available as tacit knowledge. Contact between persons is important for exchanging this knowledge and therefore industrial districts are important for this type of technological changes. Geographical proximity matters less for incremental technological changes, since these innovations require more codified knowledge that can be communicated over a distance (Nooteboom, 1998, p. 75). Networks of firms (not necessarily geographically close firms) or large firms are important for incremental technological changes. Therefore, clusters are more important for firms that use or develop new technologies than for firms that use or develop incremental innovations.

This section uses a literature search to analyse whether the expected relation between clusters and innovations also holds empirically. It analyses whether clusters lead to more innovations, whether clusters especially support small firms, and whether clusters support the development of radically new technologies or products.

Just as in Section 2, the analysis begins with meso-clusters. Broersma (2000) identifies meso-clusters based on regular input-output linkages and on innovation linkages between sectors. These latter linkages are derived by combining input-output tables with several innovation indicators. Even with different types of innovation linkages, four clusters consistently show up as innovative clusters. These four clusters are also identified with the use of normal input-output-linkages. Hence, there is a correspondence between innovative meso-clusters and production meso-clusters, which implies that production clusters are also innovative. However, the relation does not necessarily hold for all clusters.

The findings of Broersma imply a confirmation of the positive relation between clusters and innovations. However, the theoretical analyses all mention this relation at the level of micro-clusters. The remainder of this section therefore concentrates on empirical findings of the relation between innovations and micro-clusters. Baptista and Swan (1998) analyse the relation between micro-clusters and innovations directly. They use micro data to estimate a model that relates the number of innovations to the number of employees in the industry in which the firm is located. Since the last variable shows whether an industry is over- or under-represented in a certain region, it is an indicator of the presence of a cluster of firms in this industry in a certain region. Further, they include variables indicating concentration and market share in their model. They find that if an industry is relatively strong in a region, a firm belonging to that industry is more likely to innovate than the same firm in a region in which the industry is relatively weak (Baptista and Swann, 1998, p. 535). Hence, they conclude that clusters generate more innovations. They also find a positive contribution of market share to innovativeness, which implies a feedback between innovative success and market power. Since concentration has a (not significant) negative effect on the number of innovations, they argue that more competition leads to more innovations as well. Finally, they include the number of employees in other industries in the model, to analyse whether the presence of unrelated clusters also stimulates the level of innovation. Since this variable has no effect, they conclude that this factor does not play a role.

The analysis of Baptista and Swann confirms the theoretical expectations: clusters enhance the number of innovations. Other empirical analyses generally confirm this finding as well, although most of them use a more indirect approach. By implication, a more indirect approach highlights different aspects than a direct approach. In some cases this may enhance the analysis by showing the nature of the relation between innovations and clusters, or by showing the factors that contribute to the relation. Knowledge, innovation and technological spillovers are expected to be important factors that enhance the innovativeness of firms in clusters. If these spillovers are local, firms in a cluster can exploit the benefits of the spillovers. Jaffe, Trajtenberg and Henderson (1993) analyse the localization effect of innovation spillovers by comparing the geographical location of patent citations with the geographical location of cited patents. To correct for other agglomeration effects, they compare the data with a control group of patents that are not cited but that have the same temporal and technological distributions of the cited patents. Even after correcting for self-citations, they find that innovation spillovers tend to be localized. The localization fades over time. This result suggest that clusters generate more innovations due to the existence of local innovations spillovers.

Although Jaffe, Trajtenberg and Henderson showed that clusters profit from innovation spillovers, they did not analyse the role of knowledge spillovers. The existence of innovation spillovers implies that firms in a cluster profit from innovations developed by other firms in the same cluster. In the same way, firms in a cluster may profit from knowledge that is present or developed by other firms in the same cluster. If knowledge spillovers occur and are local, firms in a cluster have access to a larger knowledge stock that can be used to develop innovations. Hence, knowledge spillovers will also lead to more innovations. To analyse the role of knowledge spillovers, Audretsch and Feldman (1994) construct a model that explains the geographical distribution of innovations in each sector by the geographical distribution of production, industrial R&D, skilled workers, and university research. Simultaneously, the geographical distribution of production of each sector is explained by transport costs, the presence of natural resources, the size of the sector, capital intensity, industry R&D intensity, and skilled workers. The empirical results show that industrial R&D and skilled workers positively influence the geographical concentration of production; the geographical distribution of innovations is positively related to industrial R&D, skilled workers, and university research. These results show that knowledge spillovers are more important for the spatially clustering of innovations than the geographical concentration of production. Sectors in which knowledge spillovers are more prevalent have a stronger tendency to cluster spatially. In a later study, Audretsch and Feldman (1995) add that the clustering takes place especially in the early part of the product life cycle, when tacit knowledge is most important.

These results of the empirical analyses discussed so far are all in line with the theoretical expectations: due to knowledge spillovers and innovation spillovers, clusters generate innovations; the existence of clusters is particularly important for generating totally new products and technologies instead of incremental changes.

Further evidence of the relation between innovations and clusters is obtained by Arcs, Audretsch, and Feldman (1993). Moreover, they shed light on the processes at work in a cluster by analysing the nature of the firms in clusters, which is done by distinguishing between the effects of knowledge spillovers on large firms and on small firms. They start their analysis by observing that innovative clusters must be present, since innovations are largely concentrated: 11% of the states in the United States accounted for 81% of all innovations (p. 4). To analyse the processes at work in these clusters, they estimate a production function of innovations and conclude that innovations are positively influenced by spillovers from industrial R&D expenditures and university research combined with geographical coincidence. The distinction between small and large firms shows that both factors stimulate innovations of all firms, although spillovers from university research affect small firms more than large firms whereas corporate R&D stimulates innovations in large firms more than in small firms. The same conclusion was drawn with data from Italian firms by Audretsch and Vivarelli (1994). Again, the results confirm the original hypotheses about the positive relation between clusters and innovations, particularly for small firms.

The empirical analyses about micro-clusters discussed above are all based on micro data. They show that micro-clusters lead to more innovations, due to innovation spillovers and knowledge spillovers in clusters. These spillovers in clusters are especially important to small firms, which makes them likely to support the development of radically new products and technologies. Are these conclusions also reached by empirical analyses that use different approaches than micro-data? Hagedoorn, Link and Vonortas (2000) note that the empirical literature is divided into two approaches; either they analyse data sets or specialized surveys, or they apply case studies. Hence, after having surveyed the results of analyses based on data sets, we continue with an analysis that uses case studies.

Baptista (2000) uses case studies to analyse the diffusion process of technologies in clusters. He examines the number of firms in regions of the United Kingdom that adopted two specific technologies (computer numerically controlled machine tools and microprocessors). The data show that adoption rates are faster when more firms in the region already adopted the new technology. Hence, geographical location matters for the diffusion speed of new technologies. This effect is stronger in the early stages of the diffusion process. As Baptista himself puts it: “Regional differences in diffusion rates result from the geographical clustering of innovators and early adopters of new technology. Geographical proximity stimulates networking between firms, thereby facilitating imitation and improvement. It is at the diffusion stage that the greatest impact of technological change upon economic growth is seen to occur. If a region lags behind in the invention or adoption of new technology, it may face industrial decline” (p. 516). This observation not only confirms the theoretical expectation about the positive relation between clusters and the diffusion of knowledge and technologies, it also shows a positive relation between clusters and economic growth.

The discussion above shows that the results of the empirical analyses are almost unanimous. The existence of clusters has a positive effect on the number of innovations. Since clusters are especially important to small firms, they are likely to support the development of radically new products and technologies. Innovation, knowledge and technological spillovers are an important factor for the innovations developed by firms in a cluster. Further, clusters enhance the diffusion of new technologies in a country and they contribute positively to economic growth. Clusters especially support small firms. Hence, the empirical findings confirm the theoretical expectations about the positive relation between innovations and clusters, and about the nature of firms and innovations in a cluster.

4.2 Clusters and Competitive Advantages

An increase in the number of innovations is not the only expected effect of clusters. Porter (1990, 1998) argues that clusters will also lead to an increased competitive position in the international market. Since firms in a cluster exploit economies of scale and scope, they reduce their costs, which increases their profits and strengthens their competitive positions. The increased innovativeness of firms in a cluster also allows the firm to introduce innovations that may lead to an increased international market share, since other firms still produce the old product or use the old technology. Furthermore, if a cluster consists of suppliers and buyers, cooperation between these firms allows for a smoothing of the production process. The desired specification for inputs can be easily communicated and changed, while the inputs can be delivered at the right time and in the right quantity. If the cluster also involves related companies, changes in the demand for the goods produced by these firms are easily seen by all producers. At the same time, competition between the firms in the cluster leads to more efficient production that is also more competitive in the international market. Hence, Porter expects clusters to lead to increased competitive advantages.

This section discusses whether the expected positive effect of clusters on competitive advantages is also found empirically. The methodology of Porter cannot be used for this analysis. Porter uses a cluster chart to identify clusters. The chart appoints international successful sectors of a country to certain pre-defined type of clusters, which makes clear which clusters are successful and how they are connected. However, Porter uses international trade data to analyse which sectors are successful, and he assumes that these sectors will be included in a cluster. This means that Porter's methodology uses competitive advantages to identify clusters, by which the relation between clusters and competitive advantages becomes tautological. Further, Jacobs, Vethman and De Jong (1992) note that such clusters are mainly based on end products and they conclude that clusters identified by Porter's method are not necessarily the same as the production clusters that exist within a country. As an implication of both disadvantages mentioned above, the empirical relation between competitive advantages has to be analysed differently.

Since the former sections showed that conclusions based on meso-clusters generally agree with those based on micro-clusters, we start again with meso-clusters. However, no empirical analyses relating competitive advantages to meso-clusters were found. Therefore, some own calculations are used to highlight this relation. A former analysis identified meso-clusters in ten OECD-countries (Hoen, 2001). These meso-clusters are based on the intermediate deliveries in OECD input-output tables. The input-output tables also contain export data, which enables the computation of competitive advantages. Since the export data and the intermediate deliveries are expressed in the same sector classification, the results of both exercises can be confronted with each other.

First, a specific cluster and a specific country are selected. Then, the export share of this cluster in total exports of the country is computed, by adding the exports of every sector in the selected cluster in the selected country, and dividing this number by total exports of the selected country. Finally, the export share of the same aggregation of sectors in total exports of all other countries is subtracted from the first export share. If the index is positive, the country has a competitive advantage in this cluster; if it is negative the country has a competitive disadvantage in the cluster. The height of the index shows how large the competitive (dis)advantage is. With this procedure, the competitive advantages of each cluster in each country is computed. Table 4.1 displays the results.

Table 4.1 Competitive advantages of meso-clusters in ten OECD countries, percentages

	Australia	Canada	Denmark	France	Germany[a]	Italy	Japan[b]	Netherlands[a]	United Kingdom[a]	United States[a]
Agro-food	14.5	4.4	18.6	4.6	– 2.7	– 2.9	– 8.5	10.9	– 1.2	0.4
Mining	30.8	12.7	– 1.1		– 2.4			13.3	3.5	– 1.0
Energy										
Construction	– 0.9	– 1.9	– 2.1		0.9	1.7	2.0	0.1	0.2	0.1
Metal				-3.2	0.2	6.7			– 5.7	
Business Services		– 1.4				2		2.0	– 3.5	5.6
Chemical							– 3.5			– 2.7
Paper and transportation		4.6								
Vehicles				– 0.9						
Social					– 0.8					
Electronics							14.9			

[a] Mining and Energy are aggregated in one cluster
[b] Construction and Metal are aggregated in one cluster

Table 4.1 shows that certainly not all meso-clusters have a competitive advantage. From the total of 41 meso-clusters in Table 4.2, 23 have a competitive advantage whereas 18 have a competitive disadvantage. Although the majority of the clusters has a competitive advantage, the difference is far from significant. There is, however, a striking difference between the clusters with a competitive advantage and the clusters with a competitive disadvantage: the average competitive advantage is 6.7%, whereas the average competitive disadvantage is -2.6%. This difference can also be seen by looking at the clusters with an index larger than 5% in absolute value. In that case, there are 9 clusters with a competitive advantage and only 2 with a competitive disadvantage. Hence, although the number of clusters with a competitive advantage is almost equal to the number of clusters with a competitive disadvantage, the competitive advantages are much stronger. These results may not be very convincing, but at least they do not contradict the theoretical expectations. The relation between competitive advantages and meso-clusters appears to be positive, but it is not as strong as one would have expected.

For a better comparison of theoretical expectations and empirical results, the remainder of this section will shift the focus to micro-clusters. Just as in the former sections, the word cluster is used to indicate a micro-cluster.

Although only few analyses analyse the relation between competitive advantages and micro-clusters directly, a more indirect method may also shed light on this relation. Since clusters exist partly because of economies of scale, the relation between economies of scale and trade may be used as a proxy for the relation between clusters and competitive advantages. The former relation is the focus of Davis and Weinstein (1998), who analyse whether increasing returns to scale induce the trade pattern of a country. They start their analysis by mentioning that the new economic geography presents models that explain trade as a consequence of, among other things, increasing return to scale. With increasing returns and trade costs, a strong domestic demand for a good in a country may lead that country to export this good, the so-called 'home market effect'. Since this home market effect does not arise from comparative advantages, Davis and Weinstein use this concept to analyse whether trade arises because of comparative advantages or because of increasing returns to trade. They find that if the analysis incorporates the effects of distance on demand, increasing returns indeed partially explain the trade pattern.

The results of Davis and Weinstein are an indirect confirmation of the theoretical expectations. Still, the evidence so far is certainly not overwhelming. In order to analyse the relation between competitive advantages and clusters further, more empirical studies are discussed. Similar to the analysis of the relation between innovations and clusters, an author may use large data sets or case studies to analyse the relation between competitive advantages and clusters. Whereas Davis and Weinstein used the former approach, De Man (1995) discusses the outcomes of case studies. Although he uses another methodology, his results confirm the conclusions of Davis and Weinstein. De Man (1995) begins by noting that in explanations of international success innovation increases in importance, whereas comparative advantages in the traditional sense, *i.e.* the endowments of production factors in a country, decrease in importance. Cluster policy tries to use the relation between innovations and economic performance to make a country more competitive. According to De Man, cluster policy makes three assumptions:

- innovations are more important than production costs
- innovation leads to competitive advantages
- clusters enhance innovations.

De Man mentions that several case studies affirmed the last assumption. However, other characteristics also matter, such as the nature of the demand, the structure of the market and the characteristics of the process of innovation. He further argues that innovations spread faster within a country than over borders, which enhances the competitive advantages of a country. Hence, clusters indeed strengthen the competitive advantages of a country, but this is only part of the story.

The results found so far do not contradict the expected positive relation between clusters and competitive advantages. However, the evidence is not very strong and the analyses suggest that there may be other important factors that influence the relation between competitive advantages and clusters. Other empirical analyses sometimes show more certainty about the influence of clusters on competitive advantages. For example, Nelson (1993) summarizes the main findings of several country studies about national innovation systems, a concept that is broader than a cluster but which certainly includes clusters: clusters as well as national innovation systems refer to a complex of firms, (including suppliers and customers). Linkages between these actors influence the development of innovations in both concepts. Hence, the two concepts are related and analyses of national innovation systems may be used as an indirect method to study clusters, if carefully interpreted. Nelson concludes that innovations are necessary for firms in all countries to stay competitive (p. 509). Furthermore, he finds that firms need to do most of the research themselves. Only by learning the technological specifications and by working with new technologies, firms can successfully implement innovations. Hence, external sources are not enough for innovations (p. 510); strong competition usually is a necessary factor for a firm to become strong. Although large countries may have enough domestic competitors, for small countries foreign competitors are needed. In this way, competitive advantages may support the innovativeness of domestic firms as well.

The analysis of Nelson implies in an indirect way that clusters and competitive advantages enhance each other. In a later analysis, this observation is made even stronger. Nelson (1999) studies the historical development of seven major high-tech industries (machine tools, organic chemical products, pharmaceuticals, medical diagnostic equipment, computers, semiconductors, and software) in the USA, Japan and Western Europe. In this study, he concludes that firms first became strong on the home market before they became dominant on the world market. The firms were stimulated by strong sectoral support systems. Although these systems are not exactly clusters, they resemble the actors in a cluster and the way these actors work together in developing innovations. Furthermore, research conducted at universities often lead to innovations that could be used by firms to gain a dominant position on the world market or even take over this position from a leading firm in a different country. These case studies show a process in which innovations in a cluster-like environment create competitive advantages. Hence, the results of Nelson show that clusters are likely to lead to competitive advantages.

Although it is hard to study the relation between clusters and competitive advantages directly, the empirical analyses show that it is highly plausible that clusters indeed lead to competitive advantages. This is especially true if clusters lead to innovations, a relation that was affirmed by the analyses discussed in the former section. Just as in the former section, the results in this section confirm the theoretical expectations about clusters. However, the evidence is mostly indirect and not very strong.

4.3 Other Effects of Clusters

The last two sections analysed the effects of clusters on respectively innovativeness and competitive advantages, but clusters can have more effects. Most authors that focus on other effects than innovativeness or competitive advantages analyse whether clusters lead to higher profits. This relation may be hard to analyse directly, but because clusters lead to more innovations, it may also be analysed indirectly by computing the effects of innovations on profits. Furthermore, it may be assumed that more innovations imply that more R&D is performed. Then, it follows that the relation between profits and R&D may also be used as an indicator of the effects of clusters on profits.

Hospers (1998) quotes Mansfield et. al. (1977) and Nadiri (1993). Both authors compute that the private returns to R&D lie between 20% and 30%, whereas the social returns may even be as large as 56%. Donselaar, Nieuwenhuijsen, Van Sinderen and Verbruggen (2000) also survey several studies and derive similar conclusions: the direct rates of return of R&D generally lie between 20% and 30 %, whereas the social rates of return lie between 20% and 100%, with an average of 50%. With a simulation based on an applied general equilibrium model they compute the macro-economic effects of an increase in R&D. They conclude that a 10% raise in R&D expenses would raise total exports by 2.86% and gross value added by 1.2%. Expressed in values, these percentages result in 8.5 guilders extra value added due to an increase in R&D with 1 guilder.

It was shown before that a firm in a cluster innovates more than the same firm outside the cluster. This implies that the firm in the cluster also spent more on R&D. Since the studies above show that R&D is profitable for a firm as well as for the society as a whole, it may be concluded that participating in a cluster increases the profit of a firm, whereas clusters also generate large social benefits that result in higher economic growth.

Although the conclusion above confirms the theoretical expectation, it is based on R&D instead of innovations. There is an important difference between the two: whereas R&D measures the input in the process of developing innovations, the number of innovations refers to the output of this process. Section 4.1 showed that clusters enhance the number of innovations, but it did not analyse the effects of clusters on R&D. Therefore, the conclusions about the effects of clusters on profits can be strengthened by examining the relation between innovations and profits rather than R&D and profits. Such an analysis is performed by Geroski et al. (1993). By analysing a data base with firm data of the United Kingdom, they show that innovators have larger profit margins than non-innovators. Each innovation yields the innovating firm on average 2.1 million ponds, on an average total sales of 139 million pounds. Besides this direct effect of the product innovation, there are also indirect effect of the innovations, which can be associated with the process of innovation which transforms a firm's internal capabilities; innovators benefit more from spillovers and are less sensitive to macroeconomic shocks. The indirect effects may be as large as three times the direct effect.

The findings discussed above confirm the positive relation between participation in a cluster and a firm's profit and they confirm the positive relation between social returns and clusters. In each case, the social returns are considerably higher than the private returns. The positive relation between innovativeness and profits is found by input indicators such as R&D as well as by output indicators such as the number of innovations. A final analysis can be used to tie up two loose ends. First, although we assume that R&D and the number of innovations are related, this relation was not yet analysed empirically in the analyses discussed above. Second, we used the number of innovations as output indicators. It is not sure whether the results also hold if we use another output indicator. The number of innovations may not give a good picture of the innovativeness of firms, because it is not exactly clear what is meant by an innovation. Some firms may count small incremental changes of a product or production process as an innovation, whereas other firms may only count really new products or technologies. The number of patents is a more objective indicator for innovativeness, since it only counts the innovations that were worth patenting.

Both loose ends are analysed by Griliches (1990), who presents a survey about the use of patent statistics in economic analysis. First, he concludes that the input measure "R&D expenditures" has a strong positive relation with the output measure "patent numbers" (p. 1701) in cross-section analyses. Then, he concludes that a large fraction of the patents is used for commercial purposes. The economic gain of these patents is considerable (on average $473.000 in 1988 prices), but they show high dispersion. In order to sustain a patent, the owner has to pay a renewal fee. Since this fee is payed in many cases, the expected benefits of the patent must be positive. In the section about spillovers, Griliches (p. 1688) concludes that in technological clusters R&D spillovers increase a firm's R&D investments ratio, its number of patents received, and its output growth. The effect of spillovers in a cluster on profits depends on the R&D intensity of a firm; the net effect is positive for firms with high R & D and negative for firms with R&D more than one standard deviation below average. These findings again confirm the hypotheses about the positive effect of clusters on profits and economic growth.

Although most analyses estimate the relation between clusters and profits only indirectly, the results confirm the expected positive relation. Since clusters lead to more innovations, and innovations lead to increased profitability, clusters enhance the profit rates of the participating firms. Because the social returns of innovations are even higher than the private returns, cluster contribute positively to economic growth and welfare.

5 Cluster determinants

Section 3 made clear that clusters exist in the Netherlands, and Section 4 discussed the effects of these clusters. Of course, different clusters will have different effects, since the nature of the cluster processes will be different. Likewise, different clusters will appear for different reasons. Roelandt, Den Hertog, Jacobs (1997) underline that the Dutch clusters are really different and that different clusters have different characteristics. They elucidate these differences by describing in a qualitative way the role of technology and innovations in each identified cluster.

In spite of the differences, there may be some factors that keep appearing as reasons for firms to participate in a cluster. Even the different reasons for different clusters may be just another mix of these factors, instead of totally different reasons. Such factors can be labelled as cluster determinants. This section analyses which cluster determinants are found in empirical analyses. However, only few empirical analyses study cluster determinants directly. This means that the analysis again has to use indirect methods. Since many analyses describe processes that resemble the working of a cluster or of firms in a cluster, the results of these analyses will be used as a proxy for the results of clusters. Of course, the interpretation in terms of clusters has to be done carefully, since it only applies for the factors that are found in clusters as well as in the object under analysis.

Nelson (1999, p. 4-6), analyses which factors are important for industrial leadership. He distinguishes four 'critical factors':

- resources, comparable to the comparative advantages of Ricardo and Heckscher Ohlin;
- institutions, for example universities that guarantee the supply of skilled labour;
- market demand, either from consumers or from the government;
- superior technology, and management, or scale.

Since these four factors are related, it may be difficult to classify certain specific events. Nelson uses the term 'sectoral innovation system' to denote a complex of firms, suppliers, customers and institutions. In many cases, these systems turned out to be a key factor for industrial leadership. Especially the availability of skilled labour and a large home demand are important for a firm. Hence, interactions between the firm and a broader (mostly national) institutional environment are important factors of industrial leadership. By stimulating demand for certain goods (*e.g.* the defence market) or by maintaining or building the proper infrastructure (*e.g.* universities), governments may play a role in obtaining industrial leadership.

Although the determinants found by Nelson may be important for the emergence of clusters, his list is certainly not complete. In order to find all possible cluster determinants, Muizer and Hospers (2000) analyse the existing cluster theories extensively. They survey the location theory (classical, neo-classical and modern), the industrial organisation theory, the transaction cost theory, the industrial districts theory and the systems of innovation approach. From a summary of the motives for establishing clusters according to all theories, they select the following set of relevant cluster determinants (p. 30):

- Transport costs
- Labour (availability, mobility, importance of human capital)
- Locational interdependence
- Locational externalities
- Scale and scope effects
- Knowledge spillovers
- Asset specificity
- Frequency of transaction
- Relevance of innovation

Then, they evaluate the determinants by interviewing ten firms. The outcomes show that the determinants in these ten cases differ substantially. All determinants are mentioned at least three times. Muizers and Hospers conclude that locational factors, such as labour, locational interdependence and locational externalities, are important cluster determinants. However, relevance of innovation and asset specificity also appear relatively often as cluster determinants (Table 4, p. 47). Since a survey of ten firms is rather limited, they conclude that further empirical analyses are necessary for deriving more robust results.

The outcomes of Muizer and Hospers show a large list of cluster determinants, but they do not show which determinants are most important. Their list of cluster determinants is too long and their survey is too limited for deriving such conclusions. An analysis of micro-data would solve these disadvantages and lead to more objective results. Feldman (1994) surveys the theoretical determinants of clusters from the economic and geographic theory, after which she uses a large innovation data base to analyse whether these determinants also apply empirically. Both theoretically and empirically she finds that product innovations are clustered geographically. The location of these clusters are related to the level of university R&D and industry R&D expenditures. Besides, she finds that the location of clusters also depends on the presence of related industries and specialized business services. (p. 8 and 9). In short, she concludes that geographical clustering occurs “because new product commercialization relies on knowledge that is cumulative and place-specific.” (p. 29). Universities contribute to innovations by providing scientific knowledge and skilled workers (p. 104). Clearly, knowledge and skilled labour are the most important cluster determinants in this case.

The empirical analyses discussed above suggest that knowledge spillovers and the presence of skilled labour are the most important cluster determinants. Surprisingly, none of the analyses found that cooperation between firms in a cluster matters, even though in theory this may lead to considerable gains for firms in clusters. Schmitz and Heijs (2001) confirm this finding explicitly. They find that cities with knowledge institutions also have high R&D activity, even after correcting for R&D worker in the knowledge institutions. However, most cooperation with respect to R&D takes place with firms in other regions. They conclude that the most important factor that leads to clustering of innovations is the existence of a skilled work force. Again, the skilled work force pops up as the most important cluster determinant, whereas cooperation between firms is not important for the emergence of clusters.

The surprising conclusion that cooperation is not a cluster determinant is worth further investigation. Since the analyses show that clusters especially emerge near a knowledge institution, we might expect these firms to cooperate with the knowledge institution. Two empirical studies use micro-data to analyse the cooperation partners of firms. According to CBS (1999), other companies are the most important external source of innovations and information to a firm. Hence, research companies, universities and innovation centres are less important as external sources of information and innovations than related firms, suppliers and buyers. Hulshoff and Snel (1997) derive a similar conclusion. They conclude from a survey that most cooperation agreements are between firms and not between firms and research or educational organisation. Hence, these analyses confirm the absence of cooperation with a knowledge institution as cluster determinant. This does not mean, however, that institutions such as universities do not play a role in the existence of knowledge spillovers, since they still publish results of their research, provide services, and provide for an educated work force. Education may therefore still be a cluster determinant, whereas cooperation does not seem to play a role in the emergence of clusters. The knowledge institution still enhances clusters since it leads to a skilled labour force and to knowledge spillovers, two factors that are important cluster determinants.

The absence of cooperation as cluster determinant may be an indicator of a low degree of specialisation of clusters. After all, if the firms in a cluster cooperate, the cluster is likely to be centred around the production of a particular good, which implies specialisation. If firms in a cluster do not cooperate, this means they may sell unrelated products. Even though the goods produced in a cluster may share a common knowledge base or technology, each firm makes its own products. Hence, no cooperation implies that clusters do not need to be specialised; instead, they may exist of all kinds of firms related by buyer-supplier relations or by firms that share the same knowledge base or technologies, but each of which produces its own good without cooperating with the other firms.

The absence of specialisation in a cluster is confirmed empirically by Schmitz and Heijs (2001), who find relatively little specialisation in the geographically concentrated R&D in the

Netherlands, and by Feldman and Audretsch (1998). The latter authors analyse which industry mix offers the largest propensity to innovate. In their empirical model they analyse how much specialisation and diversity in a region influence the number of innovations. They conclude that most innovations occur when the industry is relatively diverse. Within a firm or a sector, diversity of innovations across complementary economic activities sharing a common science base positively influences the number of innovations: " (...) an organizational structure of economic activities that are diverse, but still complementary, apparently yields a greater innovative output than a specialization of economic activity." (p. 4). Another result of their analysis is that the degree of competition positively influences the number of innovations. Both studies show that specialisation is not a cluster determinant. Hence, clusters will generally not be centred around the production of one specific product. Rather, they consist of related firms that supply inputs, buy outputs, or produce similar products.

The study of Feldman and Audretsch mentions an important determinant for innovativeness. Besides the availability of skilled labour, a high degree of competition also influences the innovativeness of firms. Although determinants for innovativeness are not necessarily cluster determinants, clusters may emerge if innovativeness has to be enhanced, *e.g.* to remain competitive or as a response to increased foreign competition. Hence, factors that increase the need for innovations, may also increase the emergence of clusters. The literature about determinants of innovativeness therefore indirectly indicates factors that may also be determinants of clusters. Brouwer (1997) analyses the determinants of innovativeness, and confirms some of the conclusions derived above about cluster determinants. By estimating innovation models with micro data, he finds that the following factors play a role in the number of innovations developed in a firm:

- firm size, demand growth, and R&D intensity both positively influence the probability that a firm develops an innovation as well as the number of innovations developed by a firm;
- the level of competition and the presence of small firms enhance the diffusion of innovations, but not the number of innovations that are new to the sector;
- R&D collaboration, acquisition of technological transfer, and innovation centres have little impact on innovations, although the first factor positively influences the number of patent applications;
- the location of a firm matters for developing innovations. Firms in central regions have a higher probability to innovate and a higher number of innovations.

Although these factors do not include the availability of skilled labour, the last factor suggest that there would be a positive relation between clusters and the availability of skilled labour.

Furthermore, the findings of Brouwer confirm the importance of competition and the relative unimportance of cooperation. Although the conclusions of Brouwer do not contradict the cluster determinants found before, the factors analysed by Brouwer differ from the factors that were suggested as possible cluster determinants. De Jong and Brouwer (1999) analyse determinants of innovations that are very similar to the cluster determinants mentioned before. Hence, their outcomes are more comparable to the theoretically expected cluster determinants. With their literature overview, De Jong and Brouwer "(...) pretend to give an exhaustive overview of the determinants mentioned in these traditions" (p. 7). They conclude there are seven factors that are internal to the firm (people characteristics, strategy, culture, structure, availability of means, network activities and company characteristics). Furthermore, there are two factors that are external to the firm: innovation infrastructure and market characteristics. With respect to innovation infrastructure, the scientific infrastructure is a crucial factor for developing innovations, because of available services and educated people. The existence of patents, tax reductions and R&D subsidies may also play a role. With respect to market characteristics, an open economy and a high or a mid degree of competition tends to favour the innovativeness of firms. High demand, heterogeneous demand, uncertain demand, and low price elasticity of demand also stimulate innovations. Both factors have also been found in analyses described above. Therefore, competition and education are the most important determinants found so far.

So far, the empirical analyses show a clear picture. Although there are many cluster determinants that each play a role, there are three determinants that are especially important: the availability of skilled labour, the existence of knowledge spillovers, for example due to the nearness of a knowledge institution, and the degree of competition. However, these conclusions are derived from indirect evidence. The analyses from which the determinants were derived are not based on clusters, but the systems in the analyses do reflect the way firms in a cluster operate. Hence, the determinants found are likely to be cluster determinants, but there is no certainty.

The empirical analyses used to derive the conclusions above are mainly based on analyses of micro data. As before, the cluster determinants may also be analysed with case studies. Since other sections showed that analyses based on case studies generally lead to the same conclusions as analyses based on micro data, it is expected that the picture will also be the same for cluster determinants. Still, the analyses based on case studies sometimes lead to a better understanding of the processes underlying the conclusions. Therefore, the remainder of this section analyses whether empirical research based on case studies lead to the same conclusion as found above.

Nelson (1993) summarizes the main findings of several country studies about national innovation systems. He concludes that the economic size and the income of countries matter for the technological innovations developed in a country. Large countries have enough domestic demand for technological innovations in production of goods that require large scale, such as aerospace, electronics, and chemical products. Countries with low incomes generally differ from countries with high incomes in the economic activities in which they can have a comparative advantage, which influences the nature of the technological innovations (p. 507). In all cases, Nelson finds that strong competition is a necessary factor for a firm to become strong. Therefore, the trade policy affects the innovativeness of firms, since free trade enhances competition with foreign rivals. Further, Nelson finds that many firms in industries that are strong in a country have strong interactive linkages with suppliers (p. 510), and many of these firms also had a strong home market. Another factor identified by Nelson for sustaining competitive and innovative firms is the presence of well-trained and educated labour. However, the presence of universities does not suffice, since they should also "(...) consciously train their students with an eye to industry needs." (p. 511). Besides these university trained labourers, the industry needs privately trained people in a range of functions out of R&D. All in all, education and macro-economic policy are two important political instruments for generating innovative firms (p. 512).

The analysis of Nelson based on case studies confirms the results found before. If these conclusions are interpreted in terms of clusters, there is indirect evidence that clusters arise especially because of the presence of an educated work force. The presence of competition and the nearness of a knowledge institution may also be important factors for enhancing clusters. These results are underlined by a later analysis of Nelson(1999), who also concludes that research conducted at universities often leads to innovations that could be used by firms to gain a dominant position on the world market or even take over this position from a leading firm in a different country. Furthermore, Nelson and Rosenberg (1993) slightly change the picture by noting that the relation is twofold: new science creates new technology, but new technologies create new science as well (p. 7).

Although the evidence is indirect, the empirical analyses discussed in this section show two factors keep appearing and that can be interpreted as cluster determinants. First, it is crucial to have a well-educated work force. Knowledge institutions such as universities guarantee the supply of labour with the right skills. Furthermore, these knowledge institutions generate knowledge spillovers that can be used by firms to develop innovations. Second, competition is necessary for generating innovations. Besides a good competition policy, it is important to have open markets since they enhance competition with firms abroad. If these two factors are present, firms form clusters at places where skilled labour is available. The clusters then allow for exploiting economies of scale and spillovers, which increases the competitiveness and profitability of firms. Interestingly, cooperation is not a cluster determinant. Although firms prefer a location near a knowledge institution, they hardly work together with this institution. Instead, they cooperate with suppliers and buyers, and cooperation partners may just as likely be located at a different place. Spillovers, economies of scale and available labour are more important cluster determinants than cooperation.

6 Consequences for policy

6.1 The best cluster policy

If a government wants to enhance certain effects caused by clusters, such as the innovativeness of firms or of the nation as a whole, it can develop policy that supports clusters in general or certain specific clusters. This is possible by stimulating the cluster determinants that create these clusters, or it can be done by directly supporting or even creating the desired clusters. Nelson (1999) argues that in many cases government policy was crucial in gaining industrial leadership. However, in many other cases government policy failed to reach its goal. Although his analyses were not based on clusters, the concept of national innovation systems used by Nelson are close enough to be extrapolated to the concept of clusters. Hence, his conclusion imply that there appear to be no general rules for successful cluster policy. Although policy that does not support specific sectors or firms seems to offer the best opportunities, Nelson stresses that it is almost impossible to think of such policy. For example, most industries have their own regulatory problems, which requires a specific competition policy. Even supporting universities comes down to stimulating certain fields that are related to certain sectors. This finding is supported by Feldman (1994), who concludes that “(...) university research expenditures at the departmental level reflect the presence of related industry presence R&D activities.” (p. 105). Hence, Nelson (1999) argues that supporting universities almost unavoidably comes down to sector policy.

However, Nelson (1993) shows that direct stimulation of university research in specific fields does not always yield results. Although it seems to help in some fields, such as chemicals, agriculture, and, to a less extent, electronics, it does not seem an important factor for innovations in other fields, such as automobiles or aerospace. The effect of directly stimulating R&D appears to be highly uncertain. Sometimes it may have helped firms to become strong and innovative, but other times the money was spent on projects that failed totally (pp. 514-515).

Since direct support does not seem to be a very useful choice, Nelson (1999) concludes that "effective policies are basically focussed on providing the appropriate infrastructure and regulatory regime for the sector in question. In general (there are exceptions) effective industrial policies have avoided supporting particular firms and particular narrow-defined technologies" (p.15). The government should not try to 'pick the winner'; historical evidence shows that the important developments of each sector could not have been predicted. Nelson states that "Policies that presume that technology and industry will follow a particular track are highly to bet on the wrong one. Good industrial policies give industry room to make bets and hedge them, and shift direction if new developments occur" (p. 16). The result of Nelson concerning the positive effect of university research on innovations is supported by many other authors. For example, Audretsch and Feldman (1994) state that "(...) policy-makers concerned with attracting and creating innovative firms would be wise to concentrate efforts at enhancing university research, which clearly serves as an important input in the innovative activity of private firms." (page 2 of the non-technical summary).

The analyses discussed above show that government policy for supporting clusters is very hard. Especially supporting specific clusters, technologies or firms is likely to lead to a failure. General policy is also difficult to develop, since different clusters need different approaches. Furthermore, sometimes the national or local government is not the best level for developing policy. De Man (1995) argues that some clusters are better off with international policy instead of national policy, which complicates developing good policy even further.

Although developing good government policy is not an easy task, Feldman (1994, p. 98) argues that it is often needed since the market mechanism would lead to a too low level of R&D. Due to spillovers, innovations have a public good character which means that the social benefits of R&D are much larger than the benefits to the firms (see also Section 4.3). Feldman suggest that "What state arguments may do is act as umbrella organizations in supporting the knowledge-based innovative inputs which lower the cost of innovation to private firms." (p. 98) She suggests that government policy should be aimed at providing an innovative infrastructure (p. 97), while at the same time guaranteeing the presence of related industries and specialized business services (p. 108 - 109).

Most authors who argue for government policy use the same arguments as Feldman. However, their reasons are merely theoretical reasons; it is not clear whether these reasons also apply in practice. Weder and Grubel (1993) analyse empirically whether the reasons for government policy are justified in practice. Their results clearly contradict the statement of Feldman (1994) about the need for government policy. Weder and Grubel argue that although R&D spillovers clearly exist, this does not automatically imply the existence of under-investment in R&D. The market failures inherent to spillovers may be (partly) solved by the emergence of private institutions, such as industrial associations, company structures, industry clusters and other contractual agreements. In that case, there is no need for active government policy to stimulate R&D. In two case studies, concerning Switzerland and Japan, Weder and Grubel indeed find many such institutions. Although Switzerland and Japan are very different with respect to size, political systems, cultures, and histories of international relations, both countries have high levels of GDP per capita and both countries experienced a long period of economic stability. Further, both countries are the home countries for some multinationals that produce high quality goods which require innovative technologies. Switzerland and Japan have relatively large shares of R&D investments in total GDP, whereas in both countries the percentages of R&D financed by the government are relatively low. Weder and Grubel note that many successful innovative firms in Switzerland and Japan are located in industrial clusters and participate in other private institutions that internalise externalities from private R&D. Therefore, the government should facilitate the emergence of these institutions rather than finance private R&D. Furthermore, the level of competition needs to be sustained and specific interest groups should not be able to influence policy. One of the ways to derive these features is by stimulating open markets, which was also found as an important cluster determinant.

The results above indicate that it is almost impossible to develop good cluster policy. Moreover, they show that cluster policy is unnecessary; the theoretical reasons for policy do not appear in empirical analyses. The best cluster policy thus is no cluster policy. Instead, the government should take care of a well-working system of universities and a high level of competition. Still, if the government insists on developing cluster policy, another factor needs to be taken account of. This factor is the difference between small and large firms and will be discussed in the next section.

6.2 Cluster policy for small and for large firms

Many empirical cluster analyses find an important difference between small and large firms. Both types of firms develop different kind of innovations, have different cluster determinants and effects, and are affected by different policies. Hence, cluster policy should apply to the type of firms that leads to the effects that the government desires. Nooteboom (1998) notes that large firms are better suited for large scientific research projects. Whereas large firms use relatively much codified knowledge, small firms use relatively much tacit knowledge. Instead of large research projects, small firms generally combine several new technologies developed by third parties, which leads to radical technological changes. This agrees with the findings of Nelson

(1999), who notes that shifts in the locus of industrial leadership often take place by the introduction of a radically new technology. Since existing established firms often continue to use the old technologies, new smaller firms may take over leadership in these cases.

The difference between innovations of small and large companies is one of the reasons why clusters are especially beneficial for small firms. The radically new innovations developed by small firms use relatively much tacit knowledge, whereas the incremental innovations developed by large firms uses mainly codified knowledge. As a result, large firms do not have to be located near knowledge institutions, other innovators, or cooperation partners, whereas geographical proximity is important for small firms. This implies that small firms also benefit most from knowledge spillovers, which is confirmed empirically by Feldman (1994). She finds that small firms rely more heavily on the knowledge and research of external sources, whereas large firms are able to conduct research themselves[3] (pp. 70-73). Hence, locating near external sources of knowledge, such as universities, is especially important for small firms. This finding is also confirmed by Audretsch and Vivarelli (1994), who conclude that spillovers of universities to small firms are larger than to large firms. Similar observations are made by Arcs, Audretsch, and Feldman (1993) and by Audretsch and Vivarelli (1994). Bernardt, Borger and Braaksma (2001) find that small firms participate less in R&D activities than larger firms. However, the yields of R&D (*e.g.* patents) are larger for small firms than for large firms. Clearly, these analyses confirm the expectations about the differences between innovations of small and large firms. They show that clusters are especially beneficial for small firms, and that most benefits derived from clusters stem from small firms.

As a consequence of the above findings, government policy that affects small firms will work out differently than policy that influences large firms. Since large firms conduct relatively much R&D themselves whereas small firms make relatively much use of external knowledge and knowledge spillovers, funds for supporting R&D mainly influence large firms, which causes slow, incremental innovations. If a government wants a country to become leading in a specific field, radical innovations are useful. Such innovations are generally developed by relatively new, small firms. Small firms gain relatively much from spillovers of knowledge institutions. Therefore, supporting these institutions may indirectly support the development of radically new innovations.

[3] This may seem inconsistent with the notion of codified knowledge, since conducting R&D leads to new knowledge which has not been codified yet. However, codified knowledge is needed in order to start conducting own R&D. Hence, tacit knowledge may be viewed as an output of the R&D whereas codified knowledge is an input.

A final remark concerns government policy supporting cooperation between firms or between firms and knowledge institutions. Although cooperation may lead to more innovations, the empirical analyses show that it does not lead to more clusters. This surprising conclusion is a consequence of the analyses discussed in Section 4, which show that cooperation is not a cluster determinant. The empirical analyses show that the main reasons for the emergence of clusters are spillovers (of knowledge, technology and innovations) and the supply of skilled labour. Even though firms prefer to locate near a knowledge institution, firms do usually not cooperate with this institution. Instead they cooperate with suppliers and buyers at other locations. Hence, supporting cooperation does not support the emergence of clusters. This agrees with the finding that clusters are especially important for small firms, who do not cooperate much and use tacit knowledge to develop totally new products and technologies. Compared to small firms, large firms are relatively more involved in networks of firms that cooperate in developing incremental changes to existing products and technologies. In this case, codified knowledge is used relatively much and location is not an important factor anymore. Supporting cooperation therefore supports large firms and incremental innovations rather than clusters.

7 Conclusions

The empirical analyses discussed in this study show a lot of consensus about which clusters are present in the Netherlands. The exact clusters found depend largely on the definition of a cluster, the criteria and the data used to analyse clusters, and the level of analysis. An important distinction to be made is the difference between meso-clusters and micro-clusters. Whereas the former type of clusters refers to clusters of sectors, the second refers to clusters of firms. Theoretical analyses usually concern micro-clusters.

The identification of Dutch clusters in various empirical analyses shows that most meso-clusters as well as most micro-clusters are classified in the sectors agriculture, chemicals, transportation, business services, manufactured products, and wholesale and retail trade. In most of these sectors, (micro-)clusters can be identified that can be connected to a specific location. Instead of being centred around the production of one specific product, a cluster exists of many related firms, such as suppliers, buyers, competitors, and firms from the same sector that produce different goods. Most clusters show only little specialisation.

There is much consensus about the effects of clusters. Most analyses find that clusters lead to more innovations, knowledge spillovers, and faster diffusion of technologies and knowledge. Furthermore, clusters generate competitive advantages. Since innovations generally lead to higher profits, firms in clusters have higher profits than similar firms not located in clusters.

Empirical analyses show that the presence of a skilled labour force is the most important determinant for clusters. This is one of the reasons that clusters are supported by the presence of knowledge institutions such as universities. Furthermore, economies of scale and knowledge spillovers are important factors that lead to clusters. Competition is a necessary factor for a cluster to be successful, since it enhances the competitiveness and innovativeness of firms. Especially strong competition from foreign rivals can be very fruitful, although many successful firms first became large at the home market.

Although firms prefer a location near a knowledge institution, they do not cooperate much with these institutions. Instead, clusters are founded because of a skilled labour force, knowledge spillovers, and economies of scale. Cooperation generally takes place between suppliers and buyers. Hence, supporting cooperation does not enhance clusters.

The findings above are in line with the expectation that clusters are especially important for small firms. Whereas large firms have enough means to conduct R&D, small firms need knowledge spillovers to develop innovations. Moreover, radical innovations are often developed and introduced by small firms. These kind of innovations are based on tacit knowledge, which requires geographical proximity. Compared to small firms, large firms develop relatively much incremental innovations. Since incremental innovations depend relatively more on codified knowledge, cooperation can also take place between firms at different locations.

For government policy, clusters may be useful if the government wants to increase the number of innovations, the diffusion of technologies and knowledge, or if the government wants to enhance the competitive advantages or even take over a new market. Developing good policy, however, is not an easy task. Although there are some examples in which government policy succeeded in creating successful firms or in taking over the lead in a specific market, there are also many examples in which these attempts failed. Hence, it seems impossible to predict the consequences of policy. From the empirical evidence, however, it is clear that it is almost impossible to pick the winners. Furthermore, clusters are generally not highly specialised and clusters are mainly important for small firms. For these reasons, it seems unwise to support certain specific products or technologies, or clusters that are centred around a specific large firm. Another policy option is supporting cooperation between firms in order to stimulate the emergence of clusters. However, this will not enhance clusters since relatively little cooperation takes place between firms in clusters. Instead, cooperation occurs relatively much between large firms.

Most authors argue that the government should provide for the infrastructure which makes the emergence of clusters possible. Since clusters need skilled labour and competition, a good cluster policy may be no cluster policy at all. Instead, the government should look after a system of universities that produces a highly educated and skilled workforce, and stimulate competition by opening markets for foreign competitors. These policy options support the most important cluster determinants and will therefore support the emergence of clusters.

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