### 3.2.3 Strategic Location Decisions: Spatial Distribution, Network Formation and Knowledge Flows

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In previous years the analysis of global effects of local interaction structures has attracted a lot of attention of economists, where 'local' might either be interpreted in terms of spatial proximity, as in the literature on 'New Economic Geography', in terms of product characteristics or in terms of closeness with respect to some network structure generated for example by linkages between firms or social relationships. Whereas in a spatial framework moving to a certain region implies that an economic

agent becomes neighbor of all other agents in that region, in non-spatial networks connections can be established bilaterally. In many relevant economic applications the interaction between economic agents is governed by a combination of different types of neighborhood structures where some are of spatial nature and others are due to networks. This project aims to analyze the strategic decisions of firms concerning their position in spatial respectively non-spatial frameworks. In particular, we focus on the effects of location decisions on (local) knowledge flows between firms, the impact of the distribution of consumers across regions on firms' location decisions and the interplay of location decisions with market competition and innovative activities. The project consists of three parts, the first concentrating on location decisions in a spatial setting, the second on strategic network formation. The two parts are closely connected with respect to the research questions considered and the methodological approach. Furthermore, it is planned to combine the two aspects of the project by considering location decisions in scenarios where knowledge flows are fostered both by spatial proximity and by links in a firm network. The third part of the project also deals with network formation, but takes a different view by trying to formalize with the concept of relational capability the aim of individuals to maximize quality and quantity of their relationships.

## A: Location Decisions of Firms under Consideration of Knowledge Spillovers and the Distribution of Consumers

### Topic

The recent decrease in communication and transportation costs has lead to a strong increase in the mobility of capital within and across borders. Decisions where to locate production facilities, R&D departments or subsidiaries nowadays arise not only for global companies but also for small and medium size enterprises. Relevant arguments for the location decision are factor costs, entry into new markets, availability of skilled labor, the local institutional environment, the size or economic importance of a region in relation to the expected intensity of competition or the possibility to improve production due to technological spillovers from other firms or research institutions in the local proximity[3].

Whether (horizontal) technological spillovers improve or jeopardize the competitive stand of a firm on the market depends on its technological position relative to its competitors and the obstacles to knowledge flowing through the different spillover channels. The costs workers face when moving to a competitor in the same industry become small and therefore firms face increased risk of loosing know-how to competitors through movement of labor. In how far this affects incentives to invest in knowledge generation depends on the type of knowledge (firm- or industry-specific) and on which party has to make the investment (see Matouschek and Robert-Nicoud (2005), Almazan et al. (2007)). Local knowledge flows within a region might not only lead to a loss of cost-advantages compared to competitors but also to a reduction of the heterogeneity with respect to product and process design within the industry. This affects the degree of diversification of products offered on the market which has implications for the intensity of competition and consumer surplus. Whether competitors are able to acquire and usefully employ knowledge from a firm depends on their absorptive capacity which is determined by their previous innovative activities and the skills of their workforce (Cohen and Levinthal (1989)).

Hence, when making location decisions a firm faces potential intertemporal tradeoffs between short, medium and long term gains and losses. A tradeoff between short term and long term profits also arises when firms face the threat of future entry when making their location decisions: From a short-term perspective, the most attractive regions tend be those where the closest competitors are "far away" or which are densely populated. However, these are also the locations that are prone to attract additional entry in the future.

The aim of this project is to combine dynamic analytical and industry simulation methods in order to gain a sound understanding of the optimal location and dynamic investment policies of firms who face the tradeoff described above. Optimal policies will be described with respect to key parameters like factor price and skill differences between regions, distribution of consumers across regions, intensity of knowledge flows within a region, relative technological competence of firms and

[3]Recent empirical evidence suggests that cost considerations have gained importance relative to market entry and are now in many cases the main factor influencing firms location decisions (see Kinkel and Lay (2004)).

intensity of competition. Key questions to be addressed are:

- How does the decision of a firm to locate production facilities in the region depend on the relative technological position, the intensity of knowledge flows and the far-sightedness of the firm? Does myopic firm behavior lead to over-investment in regions with low current levels of factor costs and technology?
- What is the impact of the underlying distribution of consumers on the number of active firms in a market, their locations and the resulting product variety available to consumers?
- How does the intensity of spillovers within an industry agglomeration region influence the long run market prospects of the firms located there? How strong are selection effects resulting from strategic location decisions compared to positive knowledge externalities?

Complementary to the work focusing on strategic effects of location decisions attempts will be made to analyze location decisions under local externalities in a general equilibrium context. This work, to be headed by researchers in Paris, faces as a first challenge the proof of existence of an equilibrium in this context. Recent work by Cornet and Medecin (2006, 2008) has established the existence of a general equilibrium in spatial private ownership economies with a continuum of consumers, where endowments are location dependent, but no externalities exist. Once existence has been established a characterization of spatial equilibrium patterns for different types of externalities will be attempted and the general theory will be applied to gain insights on the effect of local knowledge flows on location patterns in a general equilibrium context.

**State of the Art and Own Prior Work**

The majority of recent work on spatial economic issues follows the 'New Economic Geography' (NEG) approach launched by Krugman (1991) or the more traditional framework of Hotelling (1929). Whereas the first approach has allowed for several very useful insights concerning the mechanisms working in favor and against spatial agglomeration of economic activity (see e.g. Fujita et al. (1999), Neary (2001) or Ottaviano (2003)), these insights are based on comparative statics and local stability properties of the steady states. The only dynamic aspect considered is the myopic[4] movement of labor between regions, where for each distribution of labor between regions a static equilibrium is assumed. Due to the focus of attention on the stable steady states little can be learned about the dynamic properties of agglomeration processes. Furthermore, strategic behavior of firms in a static or inter-temporal sense is not considered in the NEG approach.

Analyses of the strategic effects associated with locational choices of firms have been provided in Gersbach and Schmutzler (1999, 2000). They study agglomeration effects in a static scenario with local spillovers between firms within a region as well as knowledge flow between production facilities of the same firm in different regions. Matouschek and Robert-Nicoud (2005) also consider strategic location decisions in a static setting and derive predictions about the relationship between the specifity of human capital investments and the spatial firm distribution. Theoretical studies analyzing the tradeoff between cost reductions and the dynamic loss of technological advantages due to spillovers have been carried out in the literature on foreign direct investments, however to a large degree with quite different focus (e.g. Walz (1997), Petit et al. (2000), Mattoo et al. (2004)).

Simulation studies of industry dynamics which incorporate technological spillover effects and study issues of locational choice and local interaction structure have been carried out among others by Verspagen (1993), Keilbach (2000), Meagher and Rogers (2004), see Dawid (2006) for a survey.

Relevant own prior work includes Bischi, Dawid and Kopel (2003a,b) where advanced methods of analysis of non-linear dynamic systems are applied to study the evolution of the size of competing firm agglomerations in the presence of intra- and inter-cluster spillovers. The tradeoff between spillover and competition effects is a crucial point in this study. However, firm's behavior is determined by simple imitation-type market exit and entry rules rather than by forward looking elaborate decision procedures. Colombo and Dawid (2008) and Colombo, Dawid and Kabus (2007) analyze the interplay between the incentives for firms to invest in knowledge generation and the generation of new (spinoff) firms in a region induced by workers leaving incumbent firms. In a recent paper Dawid and Wersching (2006) consider the interplay between a firm's decision whether to locate in an industrial agglomeration

[4]The only exception in this respect is Baldwin (2001) where forward looking behavior of workers is considered in the framework of Krugman's 'Core-Periphery' model.

and its strategy concerning its technological position relative to the firms in the agglomeration. In the framework of a dynamic industry simulation model it is shown that increasing spillover effects in the agglomeration can lead to technological uniformity of firms and accordingly to negative effects on firm profits. Dawid, Greiner and Zhou (2008) analyze the incentives of a firm to move (parts of its) production to a region with factor cost advantages if such investments generate knowledge flows from the investor to competitors located in that region. In a general equilibrium context Cornet and Medecin have established the existence of a general equilibrium in spatial private ownership economies with a continuum of consumers for a finite (Cornet and Medecin (2006)) and infinite (Cornet and Medecin (2008)) number of available locations.

Previous work on spatial competition building on the canonical framework of Hotelling (1929), including the seminal contribution on entry deterrence Prescott and Visscher (1977), has almost exclusively considered the (somewhat unrealistic) case where consumers are uniformly distributed. Notable, exceptions include Anderson et al. (1997) and Loertscher and Muehlheusser (2008a) where the number of firms is exogenous and Palfrey (1984) and Callander (2005) who confine attention to special classes of symmetric distributions. Loertscher and Muehlheusser (2008b) generalize the dynamic framework of Prescott and Visscher (1977) to allow non-uniform distributions of consumers. It is shown that for large classes of densities, the equilibrium locations can be determined independently of the sequence in which they are occupied which makes the equilibrium analysis analytically tractable.

**Expected Line of Progress**

In order to start to analyze the issues raised above we will consider a basic stylized setup with one industrial agglomeration region with a number of competitive fringe firms and one or several technologically distinct firms currently situated outside the agglomeration. These firms have to decide whether and how much to invest for production facilities in the region under consideration. There are technological spillovers through the labor market between all firms in the region meliorating over time the differences in the employed technology.

Two different approaches will be employed. First, we will develop and analyze highly stylized analytically tractable models of competing firms who face the decision how much to invest inside and outside the industrial agglomeration in the face of potential labor poaching. The problem will be analyzed for different assumptions about the specificity of knowledge using a differential game approach. In case analytical characterizations of the transient equilibrium behavior is not feasible we will employ numerical methods to study the properties of equilibrium investment. To complement the dynamic analysis we will also consider further simplified two-stage games and decision problems which capture the basic tradeoff under consideration. Studying scenarios where more than two heterogeneous firms make locational investment decisions by analytical means seems infeasible. Hence we will employ as a second approach dynamic industry simulations to study the interaction in dynamic oligopolistic scenarios. The structure of the decision rules assigned to individual firms in these simulations will be based on our insights from the analytical models. Results obtained within the simulation framework will be statistically tested with respect to robustness across parameter constellations.

A second line of future work is concerned with further analyzing the impact of the underlying distribution of consumer preferences on equilibrium configurations, using and extending the tools developed in Loertscher and Muehlheusser (2008b). Thereby, two issues will be tackled. First, for many relevant classes of distributions, firms' equilibrium locations and the sequence in which these locations are occupied can, generally, only be simultaneously determined. This hinders an analytical approach and therefore, a simulation approach shall be developed to analyze such distributions. Second, the basic model shall be extended to a multi-period setting, where market entry occurs every period and where also payoffs accrue to every active firm in every period. This gives rise to an interesting trade-off between short-term and long-term profits: From a short-term perspective, the most attractive locations are those where the closest neighbors are far away or where the density of consumers is large. However, these are also the locations that are prone to attract additional entry in the future.

### B: Strategic Formation of Inter-firm Networks

#### Topic

There is a flourishing literature on how networks of bilateral relationships matter for economic outcomes, as well as on how networks emerge (the recent book by Jackson (2008) provides an overview of this lively field). Applications are not restricted to personal relationships but also consider networks between firms - be it based on strategic alliances, joint investments or joint R&D activities. The realization of product and process innovations are shaped by and shaping the knowledge in the collaboration network, analogous to the geographic neighborhood.[5] We want to focus on a firm's strategic decision to choose R&D collaborators and to define the efforts for the different R&D projects. Note that the choice of R&D partners is a choice of location, in the non-spatial sense of a network.

#### State of the Art

Since the seminal contributions of Jackson and Wolinsky (1996) and Bala and Goyal (2000) there has been a sequence of insightful papers on the formation of social and economic networks. Tools of both, cooperative and non-cooperative game theory were developed to study how individual linking decisions affect the structure of networks.
The first theoretical issue is the choice of an appropriate equilibrium notion. The two early papers above propose myopic notions for one-sided and two-sided link formation. Those have been refined and discussed.[6] Bloch and Jackson (2006) show that introducing the possibility of transfers is neither a refinement nor a proper enlargement of the equilibria. Dutta et al. (2005) and Page et al. (2005) relax the assumption of myopia by considering a concept of farsighted stability. And finally, by the idea of stochastic stability it is possible to sharpen the predictions (see e.g. Jackson and Watts (2003).
The second theoretical issue is the observation that individual linking incentives do not necessarily lead to efficient outcomes. A general statement of the tension between stability and efficiency and a list of examples can be found in Jackson (2001) and Jackson (2003).
Besides these theoretical issues, more applied models shed light no network formation decisions of firms. Goyal and Joshi (2003) present a micro-founded model of competing firms that have to decide about their inter-firm R&D efforts. They find that the stable network structures depend on the nature of competition and that the stable networks tend to be highly unequal: some few firms are heavily collaborating with many others. This point is further elaborated in Goyal and Joshi (2006) and Westbrock (2008). In a rather independent line of research Cowan et al. (2004) and Cowan et al. (2006) model R&D cooperations as the recombination of knowledge. In their model firms face a trade-off between collaborating with known partners which leads to predictable results and collaborating with new partners which might foster higher benefits, but is also more risky. They employ agent-based simulations as well as matching theory to study which networks emerge in such a setting.

#### Own Prior Work and Expected Line of Progress

Within this project we plan to work on the theoretical problems and to apply the findings to inter-firm networks. The theoretical part has multiple aspects to address.
First of all, while the number of specific examples for network formation models is constantly growing, there is a lack of consolidation of the results. In order to fully understand how individual incentives determine the network structure, it is necessary to compare similar models and find underlying characteristics that drive the results. The example of Buechel (2007) is certainly a step in this direction by showing under which conditions two specific models lead to the same network structures. Also Buechel and Buskens (2008) consider a utility function that is supposed to be a reduced form for two types of linking incentives. Moreover, they address the interaction effects between those two types of incentives.
Secondly, despite a multitude of examples discussing the tension of stability and efficiency, it has not been generally assessed *how* and *why* stable networks differ from efficient networks. Buechel et al. (2008) show generally that link formation with positive externalities[7] tends to induce underconnected

[5] The term "clusters of innovation" can also be interpreted in both ways.

[6] See e.g. Calvo-Armengol and Ilkilic (2007), Buskens and Van de Rijt (2008) for the refinement of pairwise stability and e.g. Goyal and Vega-Redondo (2008) use a refinement of Nash Networks.

[7] That is: agents not involved in a link do not loose utility when it is formed.

networks, in the sense that the welfare of the stable networks can be improved by the addition of links. And a similar result can be shown for negative externalities and overconnected networks. Those results can be illustrated using well-known examples from the network formation literature.
The literature on different stability notions has not generally answered under which conditions an equilibrium exists.[8] This issue can be addressed by the idea of hypercubes (also called "meta-networks"), those are networks where each node represents another network and directed ties indicate which deviations are possible. Studying hypercubes not only serves to show existence, but also provides insights into basins of attraction and the issue of uniqueness.
The combination of geographic location and network location is novel to the literature. Two models are promising approaches. First, there is a model of Caulier et al. (2007) on the simultaneous formation of groups and networks. They define a stability concept for situations in which agents have to decide with whom to form a bilateral relation and in which group to participate. Second Hellmann (2008) studies multiple networks on the same agents. Again there is a simultaneous decision with whom to collaborate on two levels that are not independent.

On the basis of those theoretical considerations and results, the second part of the expected line of progress is the application to inter-firm networks. There we want to address the following specific questions:

- Are the stable networks underconnected or efficient?
- Are the stable networks highly centralized or rather egalitarian?
- Which institutions can induce socially efficient outcomes?
- What are the effects of technological spillovers in the R&D network? How do they differ from geographical spillovers?
- How do locational choice and choice of R&D partners differ? And how do they interact?
- Who is more likely to generate radical innovations, firms that are central in the network or firms that are on peripheral positions?
- If efforts of R&D do not only increase the innovations, but also the absorptive capacity for knowledge spillovers, how does this affect the results?

### C: Relational Capability in Networks – a condition for human development.

#### Topic

The theoretical part of this research project belongs quite to the same area as the previous project on networks. However, it takes a different road since the purpose is quite different. The main idea is to defend a relational anthropology, defining a relational capability – according to Amartya Sen's capability approach, cf. Comim et al. (2008) – and a corresponding formalization of markets in network societies. Instead of assuming that each economic agent seeks to maximize a utility function based on consumption commodities — as is usually done in neo-classical micro-economics—, I suggest to assume that he aims at maximizing the quality and the quantity of the relationships he may entertain with people belonging to his neighborhood. Since, however, I want to stay in the spirit of the theory of "capabilities", the function to be maximized should not concern one's effective "functionings" (in the parlance of Sen) but rather one's *possible functionings*. Hence, we need to deal with *stochastic* networks. Another advantage of the probabilistic approach, in view of empirical applications, is that it provides statistical properties that may be indeed tested in "real networks", since what is known about the structure of large networks is usually limited to aggregate statistics. Probabilistic models are able to capture statistical properties of the network while its detailed structure depends on realizations. Working with probabilistic models ensures that results do not depend on details of the network structure, which would be impossible to verify empirically. Finally, our concept of relational capability applies to individuals and to social groups as well.

[8] For the notion of pairwise stability a partial answer is provided by Jackson and Watts (2001).

**State of the Art and Own Prior Work**

So far, the unique paper written along this research programme (Giraud and Renouard (2008)) focuses on a specific issue. Indeed, the main empirical observations on social networks seem to indicate that they generally fulfill the following properties (known as the "Small World property"):

> $\alpha$ – The distance between individuals (i.e., the minimal length of the path connecting two nodes in the graph) in order is short and much smaller than the number of nodes in the network;
>
> $\beta$ – Clustering, as measured by the presence of triangles or transitivity among nodes is high ;
>
> $\gamma$ – The average degree (i.e., the average number of immediate neighbors of an individual) is much smaller than the size of the network ;
>
> $\delta$ – Presence of community structure (i.e., of connected components that share poor relationships with the "rest of the world");
>
> $\varepsilon$ – Assortativity of degrees in social networks (i.e., people with a high degree tend to meet similar people), the contrary for technolo- gical networks;
>
> $\eta$ – Scale free degree distributions in many technological networks and in some social networks.

Let us provide some explanation about property $\eta$. In the internet, there can be very high variations in degree (i.e., the number of links starting from a node) between nodes (cf. Barabasi et al. (1999)). The probability of high degree nodes does not drop off exponentially but decreases as a power law (also referred to as a scale free distribution), for which the probability of very high degree nodes is much greater than with an exponential distribution. This feature has received much attention since it has dramatic consequences for a number of dynamics including the spread of infectious disease, examined for example by Pastor-Sartoras et al. Many different types of networks have been studied in the literature, and have been shown to exhibit scale free distributions, or at least distributions with non exponentially decrea- sing tails. This includes some social networks, such as the sexual contacts network studied by Lijedahl et al. (2001). Amaral et al. (2000) study the degree distribution in data from a number of different networks was analyzed. This study found gaussian tails of the degree distribution of the social networks that were included, meaning that the probability of very high degree nodes in these networks decreased rapidly. On the contrary, many of the technological networks were scale free. The authors suggested that these differences could be explained by differences in the costs for maintaining links or by limitations in capacity. Higher costs for maintaining social relationships could thus be an explanation for the differences between degree distributions in many social networks and in technological networks such as the internet. As for the stu- dies of general acquaintance networks, they seem to suggest only a moderate variation in degree, with the maximal degree being three or four times higher than the average one. While scale free degree distributions seem to be well documented in internet networks, I do not see compelling evidence that the degree distributions are generally scale-free in social net- works. Other properties related to the degree distribution also seem to vary between different kinds of networks (this is the content of property $\varepsilon$). In social networks, degrees tend to be positively correlated, see for example Newman (2002), meaning that individuals with many acquaintances tend to be linked to other individuals with many acquaintances. In the Internet, on the other hand, adjacent node degrees have been shown to be negatively correlated : high degree nodes link to a number of nodes with lower degree (think, e.g., of a webmaster).

**Expected Line of Progress**

Giraud and Renouard (2008) deals with the simple following issue: Consider a network society where every individual seeks to maximize his expected relational capability. Is it true that, on average, the resulting network will satisfy the Small world properties ? We construct a model where the answer turns out to be positive. More precisely, we show that, starting from a community-based initial network, every pairwise stable network (Jackson & Rogers) verifies the Small World property.

The next purpose is to replace the concept of pairwise stability by that of evolutionary stability: in economics, the literature on network formation games (see the references already previously cited) seeks to characterize the networks that are stable in a certain sense when individuals form links in order

to maximize the utility they derive from their network. An underlying assumption in such models is that agents are highly strategic and have an in depth knowledge of their network environment. In small networks, this may be reasonable but in a large network it is not always a natural assumption that agents have detailed information about the structure of the network as a whole. As a consequence, we shall deal with the evolutionary stability of network formation (in the sense of de Michelis and Ritzberger (2003)).

The second next purpose consists in rewriting General Equilibrium Theory after having replaced the individual utility-maximization programme by that of relational capability-maximization, and after having made the assumption that an agent consumes a commodity only inasmuch it enables him to increase his relational capability. In other words, I shall make the assumption that every market commodity exhibits "Club effects" (and not just internet or mobile phones). For instance, most people don't watch TV because they really "like" it, but because it provides a way to discuss (hence entertain relationships) with people watching the same programmes. Needless to say, the induced externality will make it impossible to recover the first-best efficiency of competitive equilibria (if any).

**Dissertation Projects**

- Strategic location choice under oligopolistic competition and local knowledge flows.
- Existence and characterization of general equilibria in spatial economies with local externalities.
- Characterization of equilibrium firm location patterns under different types of distributions of consumer preferences.
- Characterization of efficiency properties and connectedness of stable networks.
- Network formation in the presence of geographic proximity.
- Effects of interregional R&D network formation on firm's location decisions.

**Postdoc Project: Formation of R&D networks under consideration of knowledge complementarities**

The main purpose of this project is to apply recently deveoped theoretical concepts regarding network formation and stability to adress questions concerning the homogeneity respectively heterogeneity of firms in R&D networks. Such questions have been actively debated by scholars and policy makers concerned with fostering innovations. Much of the literature discussing spillovers and knowledge flows between firms stresses the importance of the relationship between the structure of the knowledge stock the different partners have, i.e. whether their know-how complements each other, overlaps or is unrelated. Cowan et al. (2006) examine the implication of such considerations for the endogenous emergence of long-lasting knowledge exchange relationships between innovating firms. In their setting firms however decide each period whom to cooperate with and do not build explicit links that remain over time. The agenda of this project is to link this approach to the standard network formation literature where forming links is costly and such links remain over time. Key questions are under which circumstances in such a setting stable R&D networks emerge where in the long-run the knowledge stocks in the network become uniform and under which circumstances persistent exit and entry of network members coupled with persistent heterogeneity of knowledge within the network occurs. Effects on the speed of knowledge creation will also be examined. Following the standard approach, initially myopic firms will be considered, but also the effect of farsighted behavior (Dutta et al. (2005), Page et al. (2005)) will be considered. Finally, the efficiency properties of the emerged structures will be evaluated.

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