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The Case of Jena

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Growth, Development and Structural Change of Innovator Networks
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Abstract: We attempt to extend the static analysis of innovator networks by providing case study based insights into the dynamic, developmental or evolutionary pattern of such networks. In the theoretical part, we develop some building blocs that are considered central to a theory of network evolution. Especially, we focus on the growth of innovator networks and their structural change over time, i.e. how new relationships come into existence and existing ties are cut, how new actors join the system, and other actors leave it. The factors shaping these structural properties, can explain how coherence might increase in some periods while it might decrease in others. We exemplify these patterns for the case of the Jena network of innovators during the period 1995-2001.

Keywords: Innovator network, internal/external relationships, network entry and exit

JEL Classification: O31, L14, R11

1. Introduction

The notion of collective invention has been introduced in the literature by Allen (1983) who provides evidence from the 19th century iron and steel industry where innovative success was the result of the cooperative activities of several, different actors. Anecdotal evidence such as Allen's or from the various studies on Silicon Valley or other success stories of regional innovation was enriched by studies on the regional dimension of knowledge flows (Jaffe et al. 1993). Insights into the process of innovation on the firm-level (Kline and Rosenberg 1986) or the national level (Lundval 1992) strengthened the view that innovation systems are the basic factor of innovation-based economic success.

There exists a large number of investigations building on the systems view in relating innovative activities and success.[1] Those analyses are often of a static nature and focus on the number and kind of actors involved (public versus private), the technology fields pursued, and the political devices installed. The focus shifts between the modes of interaction between actors (formally or informally), the kinds of interaction that can be distinguished (cooperative research projects versus researcher mobility), and the geographical dimension of interaction (within the region or extra-regional).

This paper is an attempt to extend the static view by providing case study based insights into the dynamic, developmental or evolutionary pattern of regional innovation systems. For that, we provide an analysis of the development of the innovation network of Jena between 1995 and 2001. At this point, we cannot provide a coherent theory of the evolution of networks, but we try to base our analysis on some theoretical building blocs that we consider central for such a theory in the future. In section 2 we briefly discuss the basic theoretical arguments. Section 3 introduces the case of Jena and our database, while in section 4 we present our empirical results. The final section 5 puts those results into the perspective of an evolutionary approach towards the development of a regional innovation system.

2. Theoretical building blocs

Innovation networks are built up by actors which cooperatively engage in the creation of new ideas and then economize on the results. To get an idea how those systems evolve, one may look at the structure of cooperative activities (number, intensity, type, continuity, results,

[1] For an overview see Edquist (2004).

geographical as well as the social dimension) and how they change over time. Thus, we consider the evolution of an innovation system driven by decisions to cooperate.

A main element of cooperative innovative activities is the exchange of technological know-how. In this context one may ask why actors are interested in this exchange. The resource based view of the firm suggests a firm to be considered as an ensemble of specific resources which are unique, valuable and difficult to imitate (Barney 1991). Technological knowledge and technological capabilities are considered to be of that type since they are accumulated over time, show path-dependency and by that are unique to the firm (Teece 1986). This provides a firm with a certain technology based competitive advantage which may allow her to reap higher profits. However, they also may constrain the firm in pursuing further progress because for that, additional or different knowledge and competencies are required.

The constraining property of knowledge resources in the above sense may induce firms to extend their knowledge base and their repertoire of capabilities. One way to achieve that would be investment in own learning and R&D. However, as such activities seem to be characterized by cumulativeness and path dependency, they may finally lead to a technological lock-in. In such a situation, a firm’s accumulated knowledge and competencies are not suitable anymore to solve the current problems. Hence, it may lay in the interest of that firm to get access to knowledge and competences provided by other actors, may that be firms or public institutions. Besides this, cost considerations may play a role in the sense that it may be less costly to acquire external knowledge, rather than building it up within the firm. For that to work, formalized R&D cooperative arrangements are one way, another one the informal exchange of knowledge. In both, the exchange of knowledge and competences is ruled either by a formal contract or by an informal agreement governed by trust and fairness.

For knowledge exchange to be effective, the following factors are relevant:

- A certain degree of technological proximity or technological relatedness between the actors is required in the sense that technical problems can be solved commonly (Mowery et al 1998, Cantner and Graf 2004, 2006, Cantner and Meder 2007).
- The knowledge bases of the (potential) cooperation partners should be different and show a certain degree of complementarity; at least should the partners expect those complementarities. In this context also important is the degree of reciprocity which especially in the case of informal know-how exchange gains importance.

- Even when the two former conditions are met, actors have to have some abilities or absorptive capacities to understand the technological knowledge of others (Cohen and Levinthal 1989).
- Geographical proximity (the other is located in not too far distance) as well as social proximity (the other is known or can easily approached) are often helpful to find the appropriate cooperation partner, especially when we think of informal exchange or the transfer of so-called tacit knowledge (Breschi and Lissoni 2003, Boschma 2005).
- In a dynamic context, for the exchange of knowledge between actors to be repeated and continued, factors such as success, trust, and learning to cooperate become relevant in addition.

The importance of those factors may change over time. Rather obvious is the building up of trust or the increasing learning economies that can be reaped. Other factors like technological proximity and the related cooperation potentials may diminish over time as actors may become technologically more similar and cooperation as well as knowledge exchange then may decrease. In that case the search for new cooperation partners may start and other technological potential may be exploited cooperatively with new partners. In a previous study, we find that the likelihood of two actors cooperating in period t is negatively affected by cooperation between these actors in period t-1 (Cantner and Graf 2006). Moreover, if potentials within the own social or geographical region diminish, the search and knowledge exchange will surpass those boundaries and become externally oriented. Aggregating those observations from the bilateral level to the system level of networks may induce certain pattern of system development. Here, Cantner and Graf (2004) find that the more a region is specialized technologically, and thus the less complementary know-how is available there, the more external relationships to exchange know-how are observed. Putting this result into a dynamic perspective, a system's development towards increasing cooperative arrangements and connectedness can be distinguished from a development towards fragmentation accompanied by loosening of coherence and cooperation. In the former case technological potentials – being abundant or built up by cooperation – are exploited cooperatively, whereas in the latter case just by cooperating less and less technological potentials remain available and the benefits of cooperation diminish.

For the present case study, we attempt to identify some elements of those development patterns. We start with observations on the changing composition of the network and of the structure of relationships within the network of innovators pertaining to Jena. Respective changes will then subsequently be related to the role of

- technological potentials available for cooperation that may change over time;
- permanent actors which stay within the network during the whole span of observation;
- actors who enter the network presumably expecting advantages due to cooperation;
- actors who exit the network which may be due to a low degree of integration and hence poor results;
- the geographical dimension in the sense, that to solve technological problems an actor may not find an appropriate cooperation partner near (regionally internal partners) by but only further away, outside the local system (regionally external partners).

Obviously, to find some explanation for the changing structure of innovation networks, we have to take an actor perspective and use information on the technological relationships among them. What we have to neglect or can only indirectly infer are the motivations and further determinants that lead an actor to engage in network cooperation.

3. The case and the data

The above introduced five dimension of a developing innovation system are analyzed for the case of the local innovation network of Jena between 1995 and 2001. Hence, we do not look at the local innovation system of Jena but at a subset of this system, the network of innovators. Thus, we leave out political actors, norms and institutions which are considered as additional core actors and elements of a local innovation system. In order to track the development of the Jena innovators network, we distinguish two sub periods, 1995-1997 labeled p1 and 1999-2001 labeled p2. We leave out 1998 in order to have the two sub periods of equal length of three years and to have a clear separation between them.

We construct the network of innovators by using information from applications at the German Patent Office and select those, with at least one inventor residing in Jena. For the period under consideration, we take into account 1114 patent applications, with 334 applicants and 1827 inventors from which 977 are located outside Jena. We distinguish between the technological potential to cooperate, the kind of relationships of the cooperating actors, and the geographical dimension of the relationships. From the patent information we have at hand, these relationships or dimensions can be constructed in the following way: First, there is a potential to cooperate between actors if they apply within the same technology class. Secondly, if for a specific patent we find more than one applicant (co-application), then we consider this as cooperation (*co*) between those applicants. Third, if we find patents by distinct applicants on which the same inventor is stated, we consider the applicants of these patents to be connected via scientist mobility (*smo*) – seemingly, this inventor worked for all the applicants. Fourth, the regional dimension is taken into account by looking at the location of the applicants. In case of a relationship between applicants located in Jena the respective knowledge flows are internally oriented. An external orientation of a relationship shows up when a local actor is linked to an actor located outside of Jena.

4. Results

Actor development

Table 1 gives a first view on the development of the network in terms of the actors involved. The network size increased as the total number of innovators jumped from 139 in the first period to 189 in the second period. 32 innovators are members of the network in both periods, 107 actors exited between p1 and p2 and 157 entered. Within the group of permanent innovators, 37.5 % are not located in Jena but are related to actors in Jena. The share of external partners which exit or which enter the network is larger than 50 % in both cases with a slightly higher percentage in the case of entering actors. This can be interpreted as a slight tendency of the Jena innovator network to become more externally oriented.

Table 1. Types of actors in the innovation network

		internal	external	sum	share of external
p1	exiting	49	58	107	54.2%
	persistent	20	12	32	37.5%
	sum	**69**	**70**	**139**	
p2	entering	66	91	157	58.0%
	persistent	20	12	32	37.5%
	sum	**86**	**103**	**189**	

The network of innovators and its change over time

In a next step, we look at relationships between the innovators via common inventors; i.e. the network of personal relationships (*pr*). Herein, we combine the two types, cooperation *co* and scientist mobility *smo* – as defined above. Figure 1 shows the *pr*-network where we distinguish the *co*-network with black edges and the *sm*-network with grey edges.

In table 2, we report the statistics for the networks of cooperation (co_t), scientist mobility (smo_t), and the (aggregate) network of personal relationships (pr_t). From the various indicators and their change we can infer how the connectedness of the three networks develops[2].

Table 2. Network statistics related to the *pr*-, *co*- and *smo*-networks

	$pr_{95\text{-}97}$	$pr_{99\text{-}01}$	$co_{95\text{-}97}$	$co_{99\text{-}01}$	$smo_{95\text{-}97}$	$smo_{99\text{-}01}$
No. of actors	139	189	139	189	139	189
Share of largest component	42.4%	49.7%	8.6%	31.2%	25.2%	32.3%
Share of isolates	30.2%	30.7%	51.1%	57.7%	54.7%	55.0%
Density	0.040	0.037	0.029	0.027	0.010	0.010
Mean degree[a]	2.201	2.815	1.065	1.543	1.137	1.344
Network centralization[a]	0.109	0.184	0.051	0.137	0.102	0.057
Clustering coefficient	2.452	2.191	3.634	2.833	0.856	0.648
Ave. distance[b]	3.581	2.799	1.699	2.974	2.634	3.325

[a] Networks have been dichotomized; [b] among reachable pairs

We start with the component structure. A component is a substructure of the network, where all members of the component can reach each other, while there is no connection to members of other components. Since we analyse relations that measure the flow of information and knowledge, a high share of actors in the largest component (the one presented in figure 1) means that many actors within the region can exchange knowledge and build up something like a common regional knowledge base. The analysis of components shows a trend towards decreasing fragmentation. Even though the network is growing, the share of innovators that are members of the main component increases from 42.4% to 49.7% in the *pr*-network, from 8.6% to 31.2% in the *co*-network, and from 25.2% to 32.3% in the *smo*-network. The share of isolates in the *pr*-network stays roughly constant with a decreasing tendency in the *smo*-network and an increasing one in the *co*-network.

[2] For further details on the definition and calculations of the various network measures, please refer to Wassermann and Faust (1994).

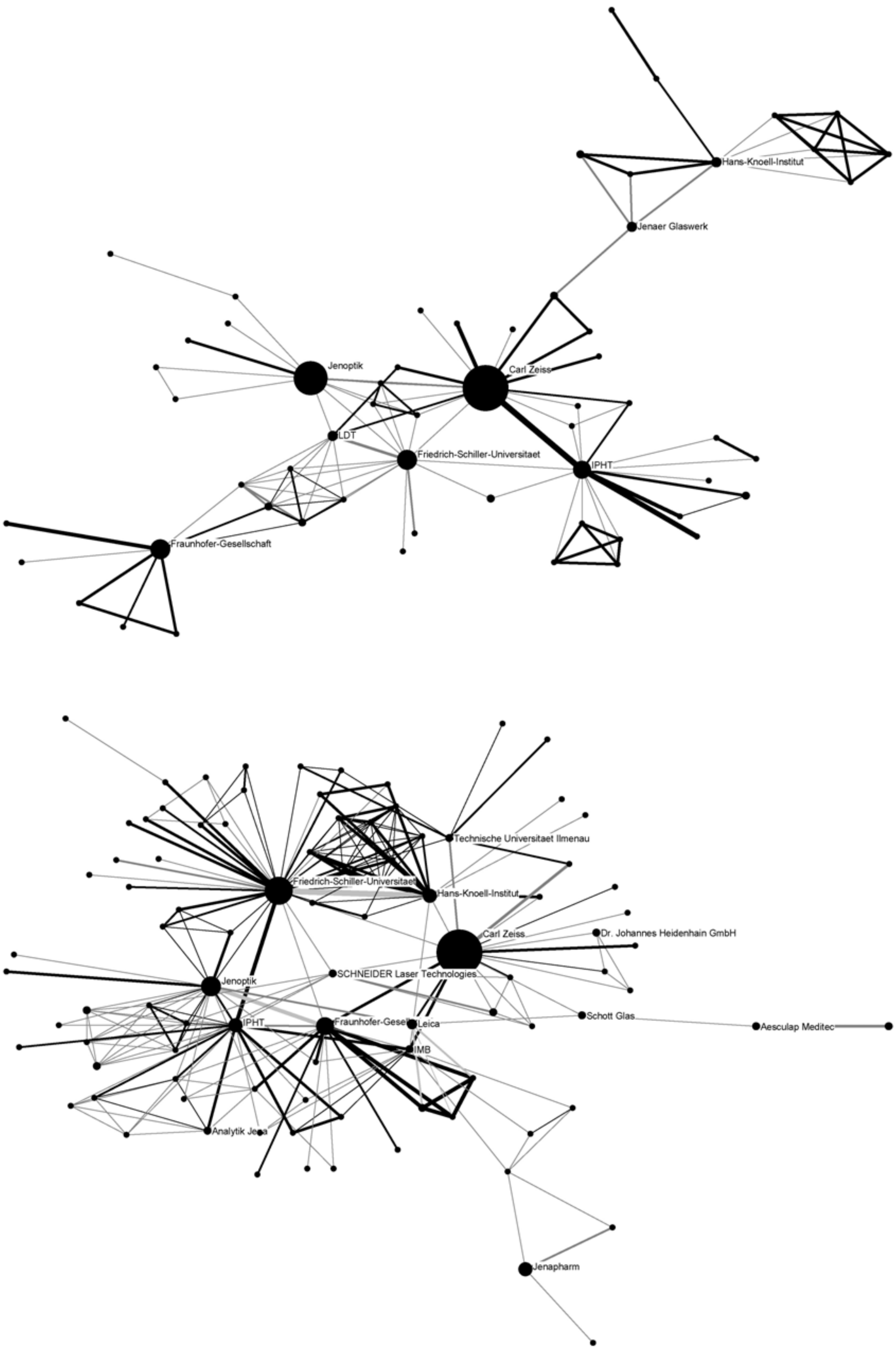

Figure 1. Innovator Network in p1 (top) and p2 (bottom) – cooperations (black) and scientist mobility (grey)

Density is another measure that provides some information about the intensity of knowledge flows. If g is the size of the network as measured by the number of actors and d_i is the degree, i.e. the number of connections, of actor i, $i = 1, \cdots, g$, then the density D of the network is defined as the number of all linkages divided by the number of possible linkages within the network $D = \sum_{i=1}^{g} d_i \big/ \left(g^2 - g\right)$. Looking at that indicator we find a decrease in the *co*-network (0.029 to 0.027) and a rather constant value for the *smo*-network (0.010). The overall effect is dominated by the effects of cooperation, which leads to a *pr*-network which is less dense in the second period (0.040 to 0.037). This result suggests that the relative intensity of knowledge flows decreased.

However, the density measure is not invariant to the size of the network. We therefore look at the mean degree as another measure of connectedness which is defined as $md = \sum_{i=1}^{g} d_i \big/ g$. It states how many connection each actor on the average has. Here we find an increasing connectedness in all three networks and thus an indication for an increased flow of knowledge and information among the actors.

Asking how this increased connectedness is distributed over the network, we can look at the centralization index. The degree centrality of actor i is the number of its ties divided by the number of possible ties $C_i = d_i / (g - 1)$. The network centralization is then given by $C = \sum_{i=1}^{g} \left(\max(C_i) - C_i\right) \big/ (g - 2)$. For the *pr*-network, centralization increases from 0.109 to 0.184, which implies an increased importance of central actors for the flow of knowledge in the whole network. Looking at the other two networks, we observe a sharp increase in the *co*-network (from 0.051 to 0.137) and a decrease in the *smo*-network (from 0.102 to 0.057). Connections through co-operation are therefore increasingly established among or with the most central actors, while knowledge flows through mobility are more often found between more peripheral actors.

Another structural measure for a network is the overall clustering coefficient, where an increase hints towards local coherence, i.e. intensified grouping of actors in densely connected clusters. It is calculated by averaging the clustering coefficients of all actors within the network. The node level clustering coefficients are calculated as the density of the neighborhood, i.e. the network of actors directly linked to the respective actor. For all three networks we find less clustering in the second compared to the first period and thus less intense grouping of the actors. The average distance between actors measures the ease of knowledge flows and is often related to the rate of knowledge diffusion (Cowan and Jonard 2004). For the *co*- and the *smo*-network, we find an increase whereas for the total *pr*-network this measure decreases. This seems to indicate that there is a complementary relation between knowledge flows via cooperation and via scientist mobility.

Summarizing these results, we find a decreasing fragmentation combined with a higher degree of connectedness where the large, core actors within the network increasingly focus on formal cooperation while the smaller, surrounding or peripheral actors rather intensify their contacts through informal, personal relations. In the following we, want to identify the determinants of this increasing connectedness of the Jena network of innovators which took place despite an increase in the total number of actors.

Potential to cooperate

As noted above, technological relatedness is one of the preconditions for actors to cooperate and to exchange knowledge. Any increase in this relatedness may be a cause for personal relations to become more frequent and for the whole system to become more interconnected. In this sense, technological relatedness or proximity can be interpreted as the potential to cooperate.

Innovators are assumed to be close in technology space if they have patented in the same technology classes. For the technological classes, we use a concordance between the IPC code of the patent classification and 30 technologies which has been elaborated jointly by the Fraunhofer-Institut für Systemtechnik und Innovationsforschung (FhG-ISI), the Observatoire de Sciences et des Techniques (OST), and the Science and Technology Research Policy Unit of the University of Sussex (SPRU). The more classes two innovators have in common, the higher is their degree of technological overlap and thus their technological relatedness. These technological relations are used to build up a network of technological overlap which we interpret as the potential to cooperate.

Table 3 shows the statistics with respect to this network. Obviously the cohesion of the network increases – according to the measures density and mean degree – with the number of actors from p1 to p2. Thus the potential to cooperate increased over time.

Table 3. Network statistics for the networks of technological relatedness

	tech95-97	tech99-01
No. of actors	139	189
Share of largest component	97.1%	94.7%
Share. of isolates	1.4%	0.5%
Density	0.149	0.165
Mean degree[a]	19.165	28.730
Network centralization	0.602	0.717
Overall graph clustering coefficient	1.228	1.200
Ave. distance (among reachable pairs)	2.003	1.879

[a] Networks have been dichotomized

Since we consider a very broad concept of technological overlap with only 30 technological classes, the networks of both periods are highly connected. For each we observe roughly 95 % of the actors being part of the largest component. The potential network has become increasingly connected as evidenced by the measures of density (0.15 to 0.17) and also by an increase of the mean degree from 19.2 to 28.7. We also find an increase in the centralization of the network from 0.6 to 0.7, which means that peripheral actors in the network are stronger connected to actors in the center and/or less connected to other peripheral actors. The overall clustering coefficient slightly decreases from 1.23 in the first period to 1.20 in the second period. At the same time, the average distance between actors decreases from 2.00 to 1.88.

Summarizing, we find increasing cohesion, which is interpreted as a stronger focus on core competencies or technologies, where the fields of activity of the central actors become increasingly important for the whole network. With respect to the increased connectedness of the *pr*-network we can conclude that the increasing potential to cooperate seemingly goes hand in hand with this change over time.

As we recall from table 1, the number of actors changes between p1 and p2 with only 32 actors being part of the network in both periods. We thus ask whether the observed increasing technological cohesion can be related to the following three groups of actors – entering , exiting, and permanent innovators. Calculating mean degrees for these different groups, we distinguish between relations within the group and between the groups. The resulting values and tests for the significance of differences between the mean degrees are given in table 4. Since we cannot assume a normal behaviour of the degrees of the network members, we perform the nonparametric Mann-Whitney or Wilcoxon rank sum test to examine our above reasoning. The tests are performed by column, i.e., we compare exiting innovators of the first period with the entering innovators of the second period and so on.

Table 4. Technological overlap: mean degree (within and between blocks)

	Within	**between**	**between**	**within**
1995-1997	exit	exit and permanent	permanent and exit	permanent
N	107	107	32	32
mean degree	8.729	6.738	22.531	15.125
sd	(5.984)	(4.187)	(22.361)	(14.914)
1999-2001	entry	entry and permanent	permanent and entry	permanent
N	157	157	32	32
mean degree	18.191	7.592	37.250	19.563
sd	(16.196)	(4.825)	(38.756)	(17.629)
	Significance of difference between mean degrees			
	Mann-Whitney		Wilcoxon rank sum test	
W	5854	7906.5	101.5	130
p-value	0.000	0.208	0.002	0.011

Note: One-sided tests are performed with H0 as no difference between samples and H1 in the direction of the observed differences.

Regarding the different roles of exiting innovators and entrants, we observe a stronger connectivity within the entering group itself (18.191 compared to 8.729 for the exiting group), but also with respect to the linkages with the permanent group (7.592 compared to 6.738 for exit). While the former observation, that entrants are a more homogeneous group, is significant, the latter is not on an acceptable level of significance (p-value of 0.208). The values in the third and fourth column are based on the same number of connections but in calculating the mean they are divided by a different number of focal actors. Accordingly, we notice more technological connections between the permanent innovators and the entering innovators (37.250) as compared to the exiting group (22.531). The permanent innovators themselves increase their technological overlap significantly between the two periods from 15.125 to 19.563.

With respect to our previous result of an increasing cohesion of the network of technological overlap, the findings here indicate that both, the permanent innovators as well as the entrants (compared to the exiting innovators) tend to increasingly concentrate on the technological core competencies of the network as a whole. And with respect to the increasing connectedness of the *pr*-network, we presume that the permanent actors' degree to cooperate should have increased between p1 and p2, and the degree to cooperate with entrants should have been higher than with exiters.

Entry and exit to the network

In order to develop further on this presumption, we compute mean degrees for several groups of actors in both subperiods with respect to the personal relationships. We again distinguish between relationships based on cooperations (*co*) and on mobility (*smo*). The respective results are stated in table 5 and 6.

Table 5. Cooperation: mean degree (within and between blocks)

	Within	**between**	**between**	**Within**
1995-1997	exit	exit and permanent	permanent and exit	permanent
N	107	107	32	32
mean degree	3.084	0.710	2.375	2.563
sd	(5.207)	(1.873)	(5.375)	(5.346)
1999-2001	entry	entry and permanent	permanent and entry	permanent
N	157	157	32	32
mean degree	2.242	1.516	7.438	3.938
sd	(4.424)	(2.623)	(17.005)	(6.710)
Significance of difference between mean degrees				
	Mann-Whitney		Wilcoxon rank sum test	
W	9191.5	7111	34.5	49
p-value	0.066	0.003	0.136	0.100

Note: One-sided tests are performed with H_0 as no difference between samples and H_1 in the direction of the observed differences.

In the last column of both tables the permanent innovators themselves (fourth column in tables 5 and 6) show a significant increase in linkages through cooperation (from 2.563 to 3.938) and especially in scientist mobility (from 0.938 to 2.500). Thus, parallel to the increased technological overlap in this group, the connectedness among the incumbents becomes more intense over time.

The first column in both tables regards the comparison of the connectedness between exiting and entering innovators within their respective group. The exiting innovators show significantly (p=0.066) more linkages through cooperation than the entering group (3.084 versus 2.242) and slightly, but not significantly more linkages through scientist mobility

(0.561 versus 0.497). The second and third columns report the mean degree between permanent and exiting innovators in p1 and between permanent and entering innovtors in p2. The two columns differ with respect to the group of actors for which this index is computed, for the exiting or entering innovators in column 2 and for the permanents in column 3. For the *co*-network in column 2, we find that entering innovators cooperate significantly (p = 0.003) more with the permanent ones than the exiting innovators did (1.516 versus 0.710). With respect to the *smo*-network, entering innovators have also more linkages through scientist mobility (0.637 versus 0.514) even though not to a significant degree.

Table 6: Scientist mobility: Mean degree (within and between blocks)

	within	**between**	**between**	**within**
1995-1997	exit	exit and permanent	permanent and exit	permanent
N	107	107	32	32
mean degree	0.561	0.514	1.719	0.938
sd	(1.361)	(0.883)	(2.976)	(1.900)
1999-2001	entry	entry and permanent	permanent and entry	permanent
N	157	157	32	32
mean degree	0.497	0.637	3.125	2.500
sd	(0.965)	(1.415)	(4.030)	(2.700)
Significance of difference between mean degrees				
	Mann-Whitney		Wilcoxon rank sum test	
W	8166.5	8613	66.5	20
p-value	0.695	0.668	0.008	0.000

Note: One-sided tests are performed with H_0 as no difference between samples and H_1 in the direction of the observed differences.

Summarizing these results, innovative entrants in Jena seem to be better integrated into the network of personal relations than actors who, for whatever reasons, stopped innovating. This finding is consistent with results of Powell et al. (1999) that the network position has an important influence on firm performance. The observations regarding the connectedness of entering and exiting innovators within their group are not contradictive to our argument. Actors that enter such a network are certainly more aware of incumbents than of actors which enter during the same period. Knowledge about other potential partners for knowledge exchange needs time to develop.

Regional dimension

Another question, regarding increasing connectedness of the Jena innovator network, is related to the issue whether this is due to an increase of internal relationships or whether more external partners are responsible for this development. In the former case, this could be in indication for the danger to get into a technological lock-in situation, in the latter case, external pipelines may protect against such kind of unfortunate situation (see Bathelt et al. 2004). From Table 1 we take that the share of external actors increased slightly from about 54 % in p1 to 58 % in p2, suggesting that knowledge exchange with external partners tends to intensify over time.

In Table 7, we present a more fine grained analysis of these external relations. We distinguish relations between only internal actors (*internal*) on the one hand and between an internal and an external partner (*external*) on the other. Their development from p1 to p2 as well as the respective development of the ratio between the two is stated for both types of relations (*co* and *smo*) and for different types of actors (private vs. public, persistent vs. non-persistent). For the co-network we find that both *external* and *internal* increase in absolute numbers over time. However, the increase in *internal* is comparatively larger, leading to a decrease of the ratio *external*/*internal*. Thus, the development of the *co*-network clearly shows an increasing inward orientation in relative terms (from 1,682 to 1,563) although in absolute terms the number of external actors in the network has been increasing. The same holds true for the *smo*-network (from 2,000 to 1,605).

In view of these results, in a further step we distinguish between private and public actors to see if certain types of actors are responsible for the observed development. The results in table 7 indicate that while in both groups, we observe an increasing inward orientation (the share *external/internal* always decreases), this tendency seems much more pronounced for the public actors compared to private actors – compare the decline for public actors in the *co*-network (*smo*-network) from 1.857 to 1.524 (from 1.769 to 1.273) for the public actors to the decline from 1.649 to 1.593 (from 2.091 to 1.741) for the private actors.

If we alternatively distinguish between persistent innovators and the ones that exit or enter, we find that for these groups, the development goes into different directions. We find that the entrants are on average more outward oriented than the actors that exited the network; hence in table 7 the non-persistent actors are responsible for an increasing outward orientation regardless of the type of relation (from 1.929 to 2.140 in the *co*-network and from 1.958 to 2.367 in the *smo*-network). The persistent innovators on the other hand, increasingly focus on internal relations; table 7 shows that this is especially true for linkages through mobility, where internal relations more than double from p1 to p2. One of the reasons for this development might be initiatives to foster academic start-ups and a culture of entrepreneurship in general during that period. Scientists and engineers who have been working for large employers in the region and founded new firms or work in these new establishments could account for that increased mobility.

Table 7. Internal and external relations in the network

all	*co*		*smo*	
	p1	p2	p1	p2
external	74	150	92	122
internal	44	96	46	76
external/internal	1.682	1.563	2.000	1.605
private	*co*		*smo*	
	p1	p2	p1	p2
external	61	86	69	94
internal	37	54	33	54
external/internal	1.649	1.593	2.091	1.741
public	*co*		*smo*	
	p1	p2	p1	p2
external	13	64	23	28
internal	7	42	13	22
external/internal	1.857	1.524	1.769	1.273
non-persistent	*co*		*smo*	
	p1	p2	p1	p2
external	54	107	47	71
internal	28	50	24	30
external/internal	1.929	2.140	1.958	2.367
persistent	*co*		*smo*	
	p1	p2	p1	p2
external	20	43	45	51
internal	16	46	22	46
external/internal	1.250	0.935	2.045	1.109

Summarizing these results we find that even though the share of external actors in the Jena network of innovators increased slightly over time, linkages within the region enlarged their share. This tendency is especially true for public actors but for private ones as well. Distinguishing actors according to their presence in the network, we find a development in opposing directions. Persistent actors are increasingly inward oriented, while for non-persistent actors we find that entrants are more outward oriented than the exiting innovators. The antenna function, persistent and central actors – especially universities – are assumed to fulfil, seemingly shows diminishing importance, at least in relative terms.

5. Conclusion

In this paper we discuss some issues pertaining to the development or evolution of innovation networks. Firms, heterogeneous in the technological knowledge and competences, that seek to cooperate do so for getting access to other firms knowledge and exchange it against own know-how. Connecting such cooperative actors within one region, one ends up at a system or network of innovating firms. Consisting of bilateral knowledge relationships, the network of innovators may change its size and its structure over time, new relationships come into existence, existing relationships may be cancelled, new actors join the system, and other actors leave it. Based on those structure generating factors one can presume that the system as a whole in some periods tends to get more coherent and the actors to be more connected, whereas in other periods the tendency to disconnect and to weaken the system may prevail.

Our study represents just the case where the technological potentials for cooperation increased over time accompanied by a growth in the number of actors involved and a higher connectedness among them. These tendencies are nicely related to the specific contributions of permanent, entering, and exiting actors, as well as of actors internal to the region of Jena and those which are external. Exiters tend to be less integrated into the innovators network than entrants. Although the share of external actors increased over time the share of external linkages diminishes over time. Thus we observe an increasing orientation of the network's innovation activities with internal partners. The fact that permanent actors strongly intensify their internal relations seems to be the main driver of this development.

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