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Comparing and visualising intra- and extra-firm networks of high-tech companies in Switzerland

Silke Zöllner, Lucerne University of Applied Sciences and Arts
Stefan Lüthi, Lucerne University of Applied Sciences and Arts
Christoph Hanisch, Lucerne University of Applied Sciences and Arts
Alain Thierstein, Technical University of Munich

1. Introduction

There is a widespread agreement in academic literature that knowledge has become the main source of regional development in advanced economies. A variety of knowledge sources have to be used by firms whilst more collaboration and division of labour among actors along the value chain are needed to launch innovations and to remain competitive. Based on the requirements for knowledge creation, most firms in the knowledge economy develop their location network as part of their overall business strategy, whereby highly specific human resources and core competencies are flexibly combined in order to create differentiation and competitive advantage. The locational strategy considers both where a firm's internal functions should be placed and where suppliers and customers should be located. These internal and external linkages are woven across physical space, not only connecting firms and parts of firms but also more or less dispersed cities and towns.

Switzerland, being a small and open economy, has been strongly integrated in international exchanges of goods and services for many decades. Although this is an accepted fact from an economic point of view, Switzerland's perception of the structure and dynamics of its own territory remains inward bound. However, over recent decades Switzerland has experienced the reorganisation of its functional-territorial division of labour. The growing relevance of the knowledge economy and its networks is a driving force slowly altering regional development and spatial functional specialisation.

In this paper, we explore structures of intra-firm and extra-firm networks of high-tech and manufacturing companies based in Switzerland. The findings are interpreted against the background of the Swiss spatial development policy in order to show the tension between political objectives and socioeconomic networking trends.

The analysis of intra-firm networks is based on the interlocking network model (INM) developed by the Globalisation and World Cities Study Group at Loughborough University (GaWC 2017). It provides one specific way to address the question how inter-city relations can be empirically measured despite the chronic lack of data on inter-city information flows. The method was originally developed to measure the connectivity between global cities based on multi-branch advanced producer services firms as they organise business activities across their offices worldwide. The model uses a proxy – intra-firm networks of multi-branch, multi-location enterprises – to estimate potential flows of knowledge-creating information between cities and towns. In this paper, the model is adapted to measure relations between cities within and beyond the functional urban system of Switzerland, based on intra-firm networks of high-tech companies.

This approach is supplemented with an analysis of extra-firm networks based on R&D cooperation. The data originates from the EMS European Manufacturing Survey (Fraunhofer ISI 2017); the Swiss participation encompasses a questionnaire-based survey of product and process innovations among Swiss companies of the industrial sector carried out every three years since 2001. The objective of the survey is the systematic analysis and comparison of the innovation behaviour as well as the performance (by means of economic indicators) of companies of the industrial sector over a longer period of time. Among others, the survey investigates the following elements: innovation strategies, the use of innovative organisational and technical concepts, R&D rates, turnover with new products, type of R&D-cooperation along the value chain, qualifications, relocation of production and R&D. In the EMS survey for Switzerland (2015), additional variables were collected regarding the spatial cooperation patterns of Swiss industrial companies. With this data, spatial network patterns of Swiss industrial companies can be assessed and compared with the data of intra-firm networks of high-tech companies of the INM and interpreted against the background of spatial development policy.

2. The knowledge economy as driving force of spatial development

Since we moved into the 21st century, globalisation and structural change towards a knowledge economy have taken on a new dimension, with decisive consequences for urban structure and the system of cities in Switzerland. Innovation-led companies are the central driver behind this process of economic renewal. Their performance can be viewed as a complex added-value chain spread across multiple national and international locations. Consequently, the corporate innovation process – i.e. the creation of new economic value in new products, processes, markets, and forms of organisation – has an important spatial impact. In addition, decisions on locations by companies whose focus is on the knowledge economy are largely characterised by proximity to customers and partners; face-to-face contacts are indispensable for sharing implicit knowledge and for the creation of innovation, even if spatial and relational proximity complement one another in many knowledge contexts (Asheim and Coenen 2005). Therefore, from a spatial perspective, functionally defined metropolitan regions are seen as a common denominator for the location requirements of knowledge-intensive firms and sectors. They offer the necessary critical mass for social interaction and ensure both international and inner-regional accessibility (Lüthi et al. 2010).

The connection between the knowledge economy and spatial development can be viewed in simple terms in the following model (see figure 1): knowledge-intensive companies compete with one another in terms of innovation across the globe. To enable them to hold their ground in this competitive environment, they require explicit knowledge that can be described systematically and formally and is transferable in a standardised form, as well as implicit knowledge, i.e. skills based on experience and interaction, which cannot be codified and can only be shared through regular face-to-face contact. Any such contacts can be implemented, firstly, with local partners, although they can also be organised across continents or even globally thanks to international hub airports and high-speed rail connections. Consequently, local and global specialist knowledge overlaps within spaces of competence that are networked internationally, aiding the formation of polycentric metropolitan regions.

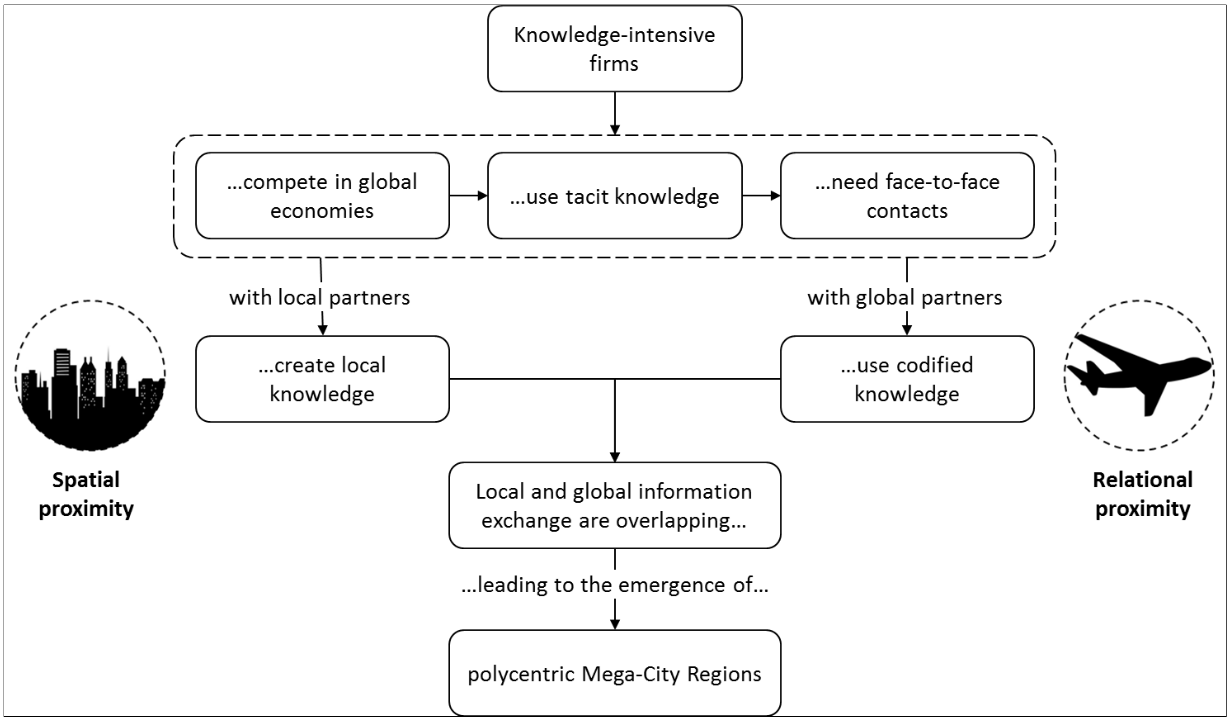


Figure 1: Functional and spatial logic of the knowledge economy (based on Lüthi 2011)

The model shows that spatio-economic development is primarily driven by the process of knowledge creation and its spatial requirements. This development largely filters out into the wider world – or into the region – through an international network of major cities. New services and products result from the fact that companies work together on the same objectives at different locations. They create a variety of networks with supply chains that spread out across the country and beyond like invisible webs. These value chains not only connect companies together, they also link locations, and form localised systems of value chains (Thierstein et al. 2006).

It is increasingly evident that even major cities or agglomerations like Zurich on their own do not have the critical mass required to facilitate highly specialised, internationally competitive knowledge production. Nowadays, self-supporting spatial development is a question not only of providing resources, but also of critical mass of variety in opportunities and similarities in realised potential (Asheim et al. 2007). The city of Zurich falls below the threshold for coping independently with central metropolitan functions. Even if one were to add the agglomeration or the canton of Zurich to the core city, the metropolitan region would remain a small player compared to regions such as Frankfurt/Rhine Main, the Rhine Ruhr, or the Randstad region in Holland. Despite its small size, Zurich is an effective player. The city is characterised by a high density of interactions and a complementary of diversification and specialization. In addition, the hub airport adds to Zurich's internationality and the dense commuting infrastructure supports the expansion of its urban landscape (Davoudi 2003:981). This spatial upscaling process of agglomeration economies and Zurich's concentration of global network economies leads to a multi-scalar outcome (Lüthi 2011), making Zurich a polycentric Mega-City Region.

The majority of knowledge-intensive companies acquire specialist knowledge within larger regions. For example, Zurich is an important research centre for high-tech industries such as medical technology or life sciences. However, it takes high-tech companies with the necessary experience to convert the expertise learned into marketable products in practice. While they are few and far apart from each other in Zurich, there are more of them in Basel and in the Jura Arc (Dümmler 2005). This allows other locations to be integrated into economic networks, turning the knowledge economy into a polycentric metropolitan region via the network structures. These regions always extend beyond the area in which political decision makers are currently operating and interacting. This is done dynamically and flexibly, which is why defining strict boundaries to these metropolitan regions is not only impossible, but would also send out the wrong signals to policy makers and planners, because metropolitan regions should not be interpreted as self-contained urban systems, as we will show in the following sections of this paper.

3. Spatial development policy and the NUTS-II regions in Switzerland

The development processes within the central economic regions of Switzerland do not reflect the preferred political strategies for regional planning, spatial development and economic development policy. Switzerland focuses too heavily on creating an image of national and spatial cohesion, as a community where territorial solidarity prevails. There is scant awareness or acknowledgment of these places of economic concentration, the driving forces in urban economies, or of the leading role played by a few economic regions (Thierstein et al. 2006).

The new Swiss spatial development concept, for example, was rubber-stamped in 2012 by the central government, the cantons, as well as city and local councils (Swiss Federal Council et al. 2012). It is political and normative in character and classifies the country into twelve so-called areas of action (‘Handlungsräume’). These consist of five small and medium-sized areas of action (Lucerne, Città Ticino, the Jura Arc, Aareland and north-east Switzerland), three Alpine areas of action (Gotthard, western Alps and eastern Alps) and four metropolitan areas of action around major cities, three of which are referred to as metropolitan regions: the metropolitan region of Zurich, the tri-national metropolitan region of Basel and Métropole Lémanique. The 'capital city region of Switzerland' (greater Bern area) forms a separate category because it is less dynamic from an economic perspective, but plays a special role as Switzerland's political centre. The definition of this '3+1 formula' is based on a political and normative negotiation process. The spatial development concept was subject to extensive political consultation. The overwhelming majority of opinions supported the drafting of the concept in principle, but sought numerous detailed improvements. A minority rejected the draft proposals, most notably key players in the areas of agriculture, industry and tourism. In principle, the Swiss spatial development concept is concerned with increasing the country's international competitiveness and achieving functional integration through polycentric spatial development, without creating structural inequality between the regions at the same time.

In order to demonstrate the conflicts between political objectives and socio-economic networking trends in Switzerland, the seven NUTS-II regions of Switzerland – which correspond to the Swiss macro regions according the Federal Statistical Office (FSO 2016 a) – are analysed in depth from the perspective of internal and external location networks of high-tech and manufacturing businesses. They are based on the hierarchical system of NUTS (Nomenclature of Territorial Units for Statistics) allowing European comparability of spatial and territorial data (EUROSTAT 2015). In the following, we give a short overview of the economic structures in these seven regions.

Figure 2 shows the NUTS-II regions' share of gross value added (GVA) of the national GVA. Zurich, Espace Mittelland and Région Lémanique show the highest share and these three regions contribute to 60% of total national GVA.

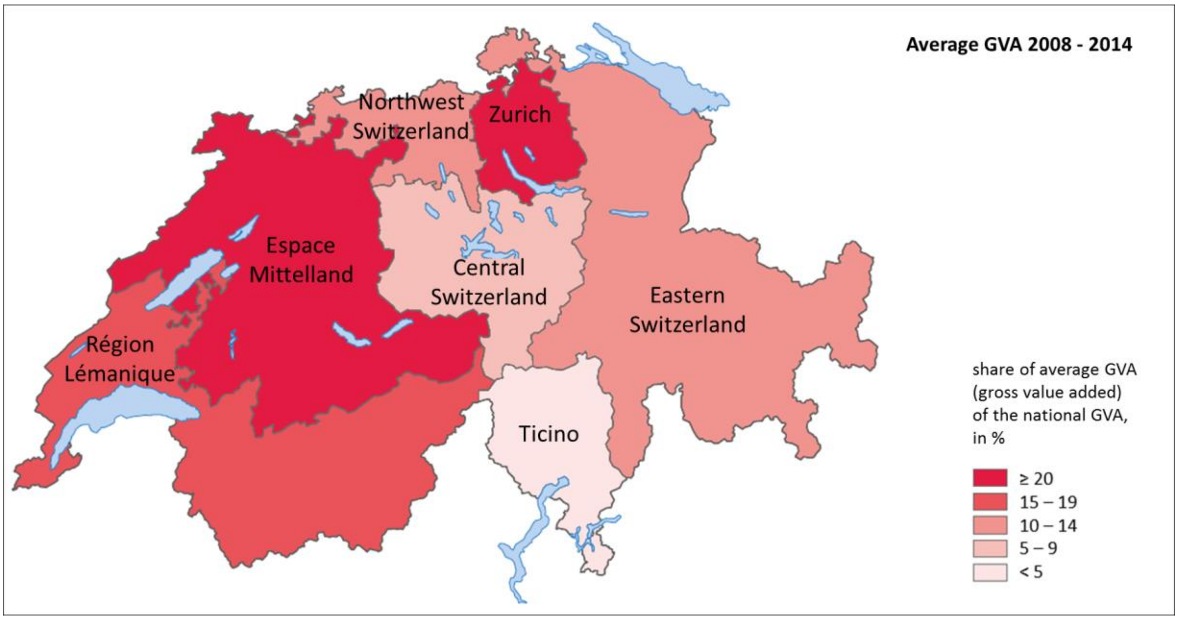


Figure 2: Average GVA 2008 - 2014 (adapted from FSO 2017 a, p. 2)

However, the regions are not as unbalanced as it seems. There exists a linear relationship between regional GVA and population (FSO 2017 a). When the GVA per capita is calculated, the regional differences disappear. Still, Zurich shows the highest positive residual (figure 3). This can be explained with the high amount of commuter flows into Zurich having a positive effect on regional GVA.

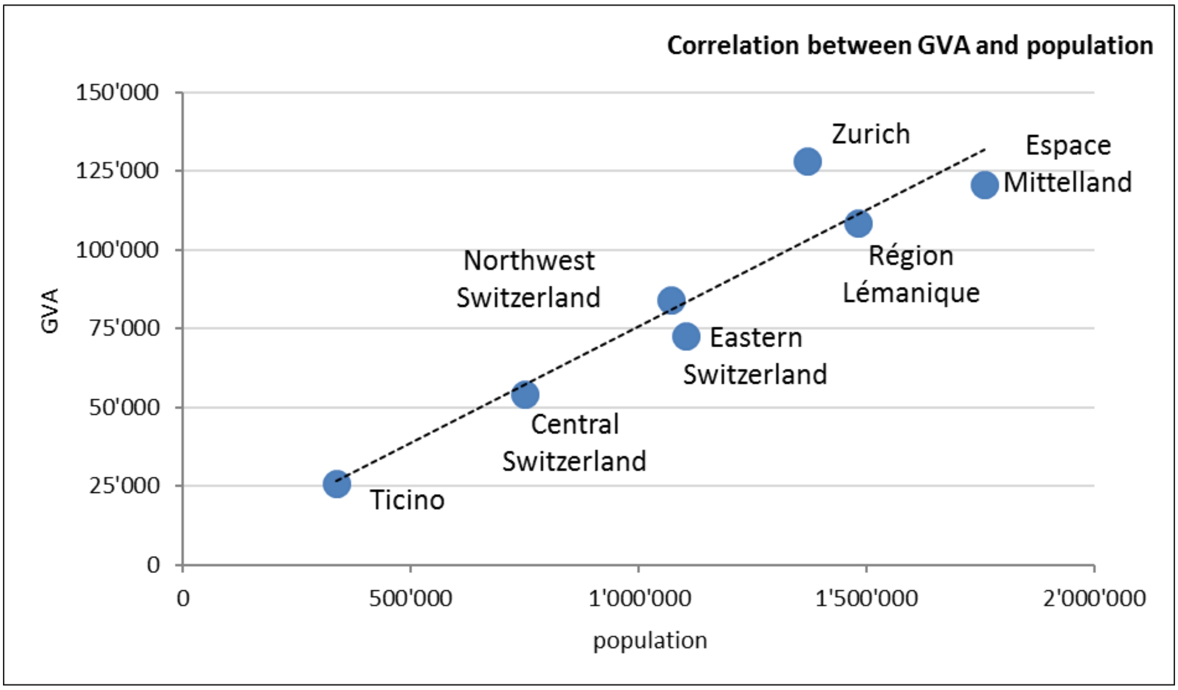


Figure 3: Correlation between GVA at current prices and population according to NUTS-II regions, averages 2008 - 2014 (own illustration, based on FSO 2015 and FSO 2016 c)

In the following sections, high-tech as well as manufacturing subsectors are analysed. Data about the GVA in the NUTS-II regions is however only available for the aggregated sectors industry and construction (consisting of the General Classification of Economic Activities NOGA Codes B, C and F). The three most dominant regions are i) Espace Mittelland with 23% of total Swiss GVA in industry and construction, ii) Northwest Switzerland with 19% and iii) Eastern Switzerland with 17% (FSO 2017a) (see Table 1).

Since the previous section identified the knowledge economy as the driving force of spatial development, two innovation indicators are presented here: R&D spending from the input side and patent applications from the output side. Table 1 displays R&D spending in the private economy according to the seven regions of interest. It is striking that Northwest Switzerland accounts for almost half the spending share, which can be explained with its strong base of chemical and pharmaceutical research. Besides Ticino, all regions show an approximately even share of R&D spending (FSO 2017b).

Countrywide the private economy accounts for 71% of R&D spending, academia for 27% and the confederation and private organisations without pecuniary reward each for 1% (FSO 2017d).

Table 1: Gross Value Added (GVA), Research and Development (R&D) spending and patent applications in Swiss NUTS-II regions (FSO 2017a, FSO 2017b, FSO 2017c).

NUTS-II regions	**GVA* in industry and construction, average 2008-2014, in % of total Swiss GVA in industry and construction**	**R&D** spending private economy, 2015, in % of total Swiss R&D spennding private economy**	**Patent applicaitons at the PCT*** by Swiss inventors, difference between 2000 and 2013, in %**
Région Lémanique	13%	13%	**+84%**
Espace Mittelland	**23%**	12%	+23%
Northwest Switzerland	19%	**47%**	+68%
Zurich	13%	11%	+61%
Eastern Switzerland	17%	7%	+71%
Central Switzerland	10%	10%	+41%
Ticino	5%	1%	+58%

* Gross Value Added
** Research and Development
*** Patent Cooperation Treaty

Switzerland scores high regarding the number of patent applications at the Patent Cooperation Treaty PCT. It had the highest amount of patent applications among all OECD countries in 2014, measured in relation to the number of inhabitants (FSO 2017c). Data on NUTS-II level is only available for the industry as a whole. Table 1 shows the growth rate in patent applications of Swiss inventors from 2000 to 2013. The growth rate for the Région Lémanique is by far the highest. Interestingly, five out of seven regions draw up the balance sheet with a growth rate above 50%.

The next two sections explore intra- and extra-firm networks and take up aspects from this economic overview.

4. Intra-firm networks

Intra-firm connectivity – in the form of transnational corporations (TNCs) networks – has come to be seen as important shapers of the contemporary global economy (Dicken 2007). As the size, the organisational complexity and the geographical spread of TNCs increase, intra-firm networks between their geographically dispersed parts are becoming highly significant. On the one hand, a study by the OECD (2008) shows that the importance of TNCs is linked to their strengths in a range of knowledge-based assets that allow them to take advantage of profitable opportunities in foreign markets. They are able to set up subsidiaries and affiliates abroad, to co-ordinate production and distribution across many countries, and to shift their activities according to changing demand and cost conditions. As a consequence, cross-border trade between TNCs and their affiliates – often referred to as intra-firm trade – accounts for an increasing share of international trade in today's global economy (OECD 2008).

At the same time, some barriers to the exchange of information and the diffusion of innovation have become less significant due to the fast development in ICTs (OECD 2008). Castells (1989), for example, notes that the functional linkages between the business headquarters and the decentralised business units became only possible because of ICT, which enabled the establishment of worldwide intra-firm information systems (Castells 1989). Similarly, Faulconbridge's empirical study (2007) about London's and New York's advertising and law clusters shows that both advertising and law firms hold close contacts with internal overseas offices, forming a kind of global learning network based on relational proximity and regular conversations with colleagues and peers worldwide (Faulconbridge 2007).

The Interlocking Network Model (INM)

In this paper, we analyse the intra-firm networks of 160 Swiss high-tech firms (see table 1, appendix) based on the interlocking network model (INM). It provides one specific way of addressing the question how inter-city relations can be empirically measured and uses a *proxy* – intra-firm networks of multi-branch, multi-location enterprises – to estimate potential flows of knowledge-creating information between cities (Taylor 2001). Once the relevant knowledge-intensive firms are identified, information is gathered on their office locations worldwide. The prime source of this information is the firms' corporate websites. It is necessary to scavenge all relevant information available online, supplemented by additional material such as annual reports or company brochures.

For each firm, two types of information are collected (Taylor et al. 2002): First, information about the *size* of a firm's presence in a city. In the best case, information can be found on the number of professionals working in each of the firm's offices. Secondly, information about the *extra-locational functions* of a firm's office in a city is gathered. This includes headquarters functions as well as other extra-territorial functions.

Based on this information, all office locations are rated, typically on a scale of 0 to 5. A location that houses a company's headquarter scores 5. A location that houses a standard office scores 2. If an office has a special relevance within the firm network, the scoring is upgraded to 3 or 4. If the overall importance of an office is low, the scoring is downgraded to 1. The end result is a *service activity matrix* (V_{ij}), defined by cities in the rows and firms in the columns. Each cell in the matrix shows the rating of an office location in a city: the so called *service value (v)*. This service activity matrix is used to calculate the network connectivity, a measure that estimates how well connected a city is within the aggregated intra-firm network. Here, different kinds of connectivity values can be calculated (Taylor 2001):

The connectivity between two cities (a, b) of a certain firm (j) is analysed by multiplying their service values (v), representing the so-called *elemental interlock* (r_{abj}) between two cities for one firm:

$$r_{abj} = v_{aj} \cdot v_{bj} \quad (1)$$

This approach seems reasonable when the following assumptions are made (Derudder and Taylor 2005, p. 74-75): First, offices generate more flows within their own firm network than to other firms in their sector. Second, more important offices generate more flows, which has a multiplicative effect on inter-city relations. Based on these assumptions, the elemental interlocks for all firms located in two cities are summarised, in order to calculate the total connectivity between the two cities. This leads to the so-called *city interlock (r_{ab}):*

$$r_{ab} = \sum_j r_{abj} \qquad (2)$$

Aggregating the city interlocks for a single city produces the *interlock connectivity (N_a)*. This measure describes the importance of a city within the intra-firm network of all analysed knowledge-intensive enterprises:

$$N_a = \sum_i r_{ai} \quad (a \neq i) \qquad (3)$$

Finally, relating the interlock connectivity for a given city to the city with the highest interlock connectivity in the sample shows its relative importance in relation to all other cities that have been considered. These scores – creating a scale from 0 to 1 – can be used to indicate hierarchical tendencies within the world city network.

Even though the INM is an innovative way to calculate inter-city business relations, some limitations have to be acknowledged. The main limitation is the absence of extra-firm networks in its conceptualisation. Intra-firm trade in transnational corporations accounts for an increasing share of international trade in today's global economy (OECD 2008), but intra-firm networks are only one set of relevant connections among many others (Coe et al. 2010). It is now widely acknowledged that the most advanced activities of knowledge-intensive firms are deeply inscribed into external networks of suppliers, subcontractors and business clients. Extra-firm linkages are of increasing significance because firms have to rely not only on in-house knowledge, but also on resources external to the firm (see section 5).

A second limitation is that the strength and importance of actual linkages between cities are not recorded by calculating city interlocks. Whether information is passing between cities by email, telephone or business travel can only be discovered by other means of analysis. The connectivity measures derived from the interlocking network model are therefore a proxy based on assumptions about the intensity of flows between offices. Nordlund (2004) for example criticised the assumption that the elemental interlock between two large office locations is greater than between a large and a small office location as there may in reality be more interaction between large and small offices because of command, control and support functions (Nordlund 2004). Even if this assumption is accepted for the global scale, where advanced producer service firms tend to operate across rather than through segmented markets (Sassen 1991), this may not hold true to the same extent for other scales. Multiple office locations within a nation state or large city-region, for example, may indicate intensive intra-firm flows but could also signal a subdivision into separate markets serviced by different office locations with few flows across (Hoyler et al. 2008b, p. 1097).

Intra-firm networks on the national scale

Let us now take a closer look at the empirical results (Lüthi and Cavelti 2013). Figure 4 shows the spatial patterns of the intra-firm connectivity between high-tech firms within the Swiss economy. The thickness of the lines illustrates the connectivity between the NUTS-II regions. These connectivity values are standardised in terms of the highest interlock connectivity in Switzerland, which is the connection between Espace Mittelland and Eastern Switzerland. This high value is because many high-tech firms have relatively important and therefore highly-rated locations in both regions.

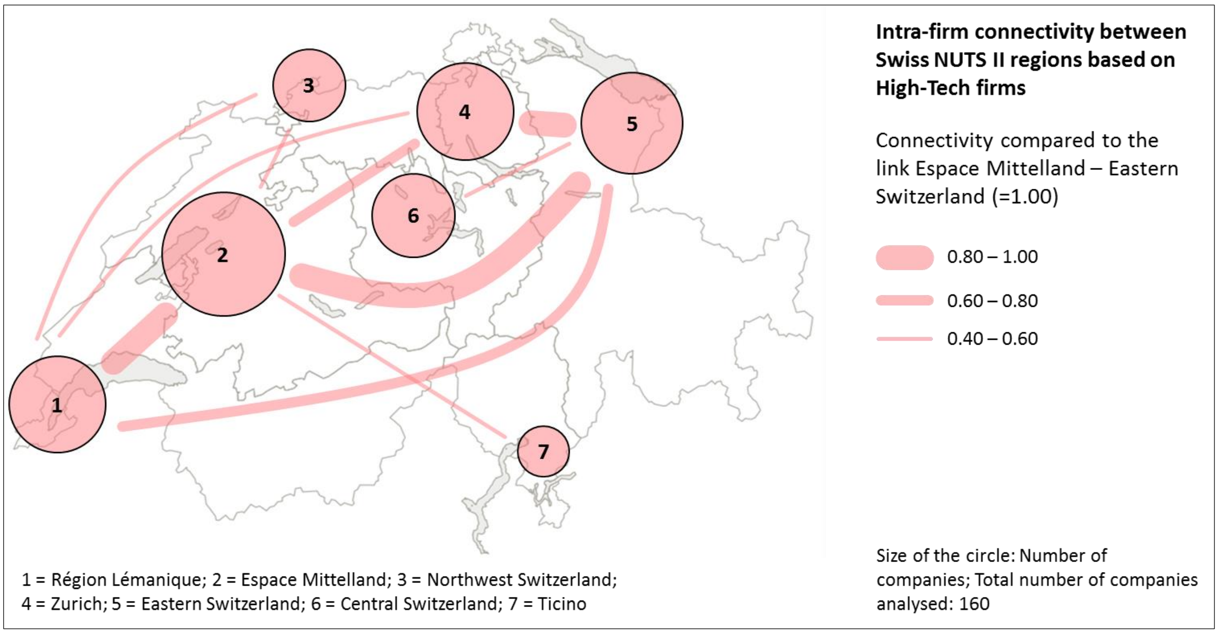


Figure 4: Intra-firm connectivity between Swiss NUTS-II regions based on high-tech firms (own illustration)

Figure 4 essentially shows two high-tech functional regions in Switzerland; one in Northern Switzerland, with a strong connection between Greater Zurich and Eastern Switzerland, and one in Western Switzerland, with close ties between the Région Lémanique and Espace Mittelland. There are many high-tech companies located in the latter, particularly in the Jura Arc. The strong links between Espace Mittelland and Eastern Switzerland are also striking. Many of the high-tech companies in the Jura Arc evidently combine the technology skills of the Région Lémanique with the industrial tradition of Eastern Switzerland. A finding as stark as this had not been expected. In defining their location strategies, high-tech companies evidently use both the benefits of spatial proximity and the potential of relational proximity, i.e. that of locations with certain similarities in terms of their industrial and cultural frameworks.

This observation can be confirmed by comparing the mapped network structure to the economic data presented in section 3. Espace Mittelland accounts for the highest share of GVA of the total Swiss GVA in industry and construction. At the same time, Espace Mittelland shows a high centrality in figure 4. Eastern Switzerland accounts for a quite high share of GVA (17%), which is again visible in the network structure of figure 4. However, one region seems to be an exception: Northwest Switzerland accounts for the second highest share of GVA in industry and construction. In figure 4, however, the node shows a low connectivity (0.46 to Espace Mittelland and 0.43 to the Région Lémanique). A Spearman correlation between national connectivity and GDP (i.e. GVA plus taxes, minus subsidies) in these seven regions results in 0.64. It indicates a medium relationship and supports the finding of a lower connectivity of Northwest Switzerland, despite is high position regarding the share of GVA in industry and construction. The branch structure in Northwest Switzerland is a possible explanation for this finding. The region is highly specialised in the chemical and pharmaceutical industry, incorporating a high level of value added. This industry is spatially concentrated only in Northwest Switzerland, which gives a reason for the low connectivity to other Swiss regions.

Intra-firm networks on the global scale

Figure 5 shows the spatial dimension of the high-tech intra-firm connectivity on the international scale. For each of the seven Swiss NUTS-II regions, the three most closely connected locations are listed. The thickness of the lines reflects the total international connectivity of the region created by the intra-firm networks of the 160 high-tech companies.

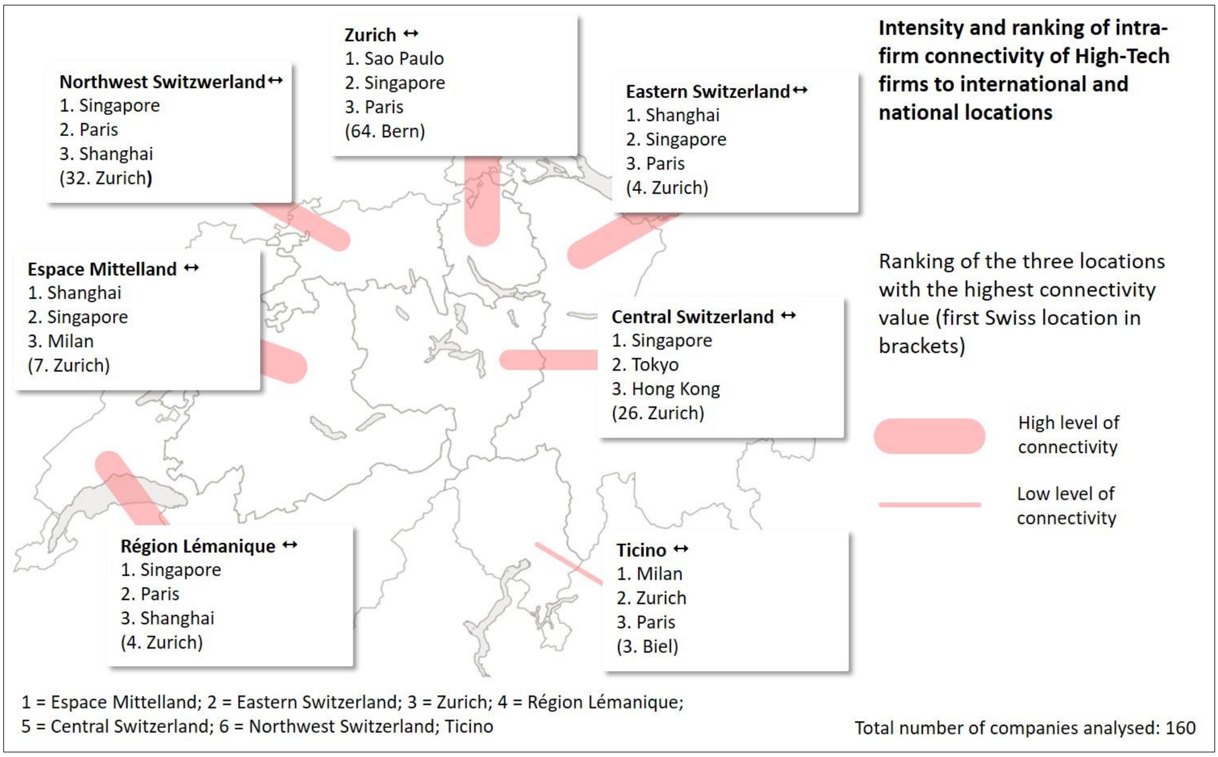


Figure 5: Global connectivity in Swiss NUTS-II regions based on high-tech intra-firm networks (own illustration)

The globalisation of intra-firm networks becomes particularly clear in the case of high-tech companies. All Swiss NUTS-II regions are dominated by international connectivity. The reason for this lies in the physical fragmentation of production whereby the various stages are optimally located across different sites as firms find it advantageous to source more of their inputs globally. This finding is supported by several studies, showing that high- and medium high-tech industries are on average more internationalised than less technology-intensive industries or services sectors (OECD 2008, Yeung 2009). Linking the international connectivity to an economic performance indicator reveals an interesting finding. A Spearman correlation between global connectivity and GDP results in 0.96, indicating a strong relationship between the variables. In our population of high-tech firms, a higher GDP is related to increased global connectivity. We cannot draw a conclusion about causality at this point. However, literature confirms a causal relationship between connectivity and GDP (Oxford Economics 2013).

However, as we shall see in the following sections, the globalisation of intra-firm networks does not mean that geographical proximity is unimportant. De Backer and Basri (2008) for example show that location decisions for research and development facilities are not only based on the host country's technological infrastructure, but also on the presence of other firms and institutions that may create spillover benefits that investing firms can absorb. In a similar way, Simmie (2003) argues that knowledge-intensive firms combine a strong local knowledge capital base with high levels of connectivity to similar regions in the international economy. By doing so they are able to combine and decode both codified and tacit knowledge originating from multiple regional, national and international sources.

Intra-firm networks and the functional-urban hierarchy

A way to show the hierarchical polycentric pattern within the Swiss space economy is to plot the connectivity values in a graph. Figure 6 shows the functional urban hierarchy for the global and the national scale based on the high-tech intra-firm networks: On the x-axis, the Swiss NUTS-II regions are displayed; on the y-axis, the connectivity values relative to the top region. A strongly concave curve progression indicates a steep functional urban hierarchy, whereas a convex progression shows a rather flat one.

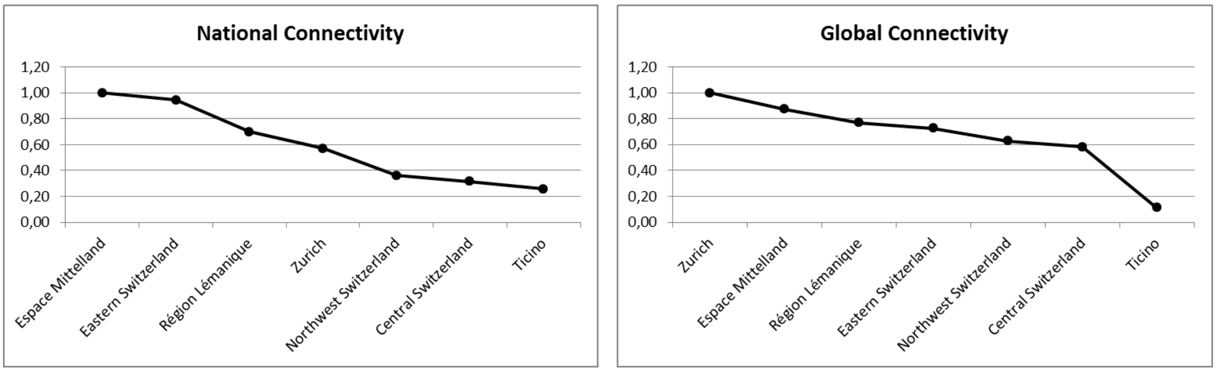


Figure 6: Functional-urban hierarchy based on intra-firm high-tech networks (own illustration)

The curve progression for both national and global connectivity indicates a relatively polycentric urban pattern. In terms of national connectivity, there are two top regions: Espace Mittelland and Eastern Switzerland. Note that Zurich ranks only fourth in terms of national connectivity, but holds the top position in terms of global connectivity. Espace Mittelland and Eastern Switzerland, on the other hand, no longer stand out regarding global connectivity.

To the dedicated observer of socioeconomic dynamics of the Swiss territory these results do not come as a surprise. The "localism" of Espace Mittelland and Eastern Switzerland indicates that the connectivity of these regions is mostly due to links within Switzerland itself. Zurich, on the contrary, is a truly "un-local" region, at least with regard to interlocking networks of high-tech companies. These results seem to fit perfectly with a recent debate in Switzerland about the status of metropolitan regions. The new Swiss spatial development concept denies the Bern region (which is part of Espace Mittelland) the status of a metropolitan region but instead labels the capital city of Switzerland as 'Hauptstadtregion' – capital city region – which has led to a certain irritation for policy makers. Bern perceives itself as being strong and large enough to be called a (European) metropolitan region. Looking from outside inwards, however, plays a trick on the capital city. With regard to interlocking networks of high-tech firms, the Bern region is a region with relatively predominant links within the country, which underlines its high degree of "localism" (see also Thierstein and Lüthi, 2011).

5. Extra-firm networks

In the previous section, the focus was on how firms organise and configure their internal networks. But, of course, as Coe et al. (2010) rightly highlight, this is only a small part of the story of how the knowledge economy is organised. Intra-firm hierarchies of leading knowledge-intensive companies are only one set of connections among many (Coe et al. 2010). Intra-firm and extra-firm networks complement each other (Lüthi et al. 2010) and it is now widely admitted that the most advanced activities of knowledge-intensive firms are deeply inscribed into wide, external networks of suppliers, subcontractors and business clients, many of whom are small- and medium-sized enterprises (Storper 1992). These extra-firm linkages are of increasing significance because firms have to rely not only on in-house knowledge, but also on resources external to the firm (Howells 2000).

In many cases, outsourcing strategies in respect of single activities are more efficient, leading to an increased quality of products and services. Many firms concentrate on their key competencies which are produced in-house, while activities that do not belong to the core business are outsourced to other companies. Even networks and strategic alliances between competitors open the opportunity for formal and informal information exchange within the same field of business (Porter 1990). According to Gomes-Casseres (1996), the overwhelming majority of strategic networks are between competitors reflecting a new form of business relationship: a *“new rivalry... in the way collaboration and competition interact”* (Gomes-Casseres 1996:2). Under these conditions, there is a high potential for developing new products and services needing both upstream and downstream inputs and costumers. Coe et al. (2010) argue that one important element of today’s organisational dynamics is vertical specialisation along the value chain. According to Gereffi et al. (2005), this trend has been much further accelerated since the late 1990s, particularly in the electronics, automobile, finance and logistics sectors (Gereffi et al. 2005).

Database: the Swiss Manufacturing Survey

Our analysis of the extra-firm networks is based on the EMS for Switzerland survey 2015, which aims to systematically monitor manufacturing industries. The survey addresses firms with 20 or more employees, from all manufacturing sectors. The eight-page questionnaire includes amongst others, questions on the implementation of innovative manufacturing technologies, organizational innovations, cooperation, relocation, performance indicators, products and services. The EMS for Switzerland was first launched in 2001, followed by surveys in 2003, 2006, 2009, 2012 and 2015. In 2015, all Swiss firms in the manufacturing industry (5'585 firms) were asked to answer the questionnaire either paper-based or online. 770 companies returned an exploitable questionnaire, which amounts to a response rate of 13.8%. Because some of the responding companies did not fully complete the question being relevant for this paper (see figure 13, appendix), only 669 answers could be analysed. The responding rate varies considerably between the seven Swiss NUTS-II regions (see table 2, appendix). The final firm sample was stratified by both region and firm-size, so that the number of extra-firm relations for each NUTS-II region could be estimated on a statistical basis. The post stratification was done in R (R Core Team 2016) with the Survey package (Lumley 2017).

Focus on R&D cooperation

The focus of the extra-firm network analysis is on R&D cooperation. R&D cooperation are important for high-tech firms in order to compete in the global economy (Dümmler 2005). R&D also plays an important role in defining the high-tech industry. One of the most convincing definitions of high-tech is provided by Rogers and Larson as far back as 1984: *„A high-tech industry is characterised by: (1) highly skilled employees, any of whom are scientists and engineers; (2) a fast rate of growth; (3) a high ratio of Research and Development (R&D) expenditure to sales; and (4) a worldwide market for its products. Not only is the technology very advanced, but it is also continuously changing, at a much faster rate of progress than other industries"* (Rogers and Larsen 1984:29).

In the questionnaire (see figure 13, appendix) the Swiss manufacturing companies were asked whether they do co-operate in the field of R&D with customers, suppliers, other companies, universities or other research institutions. If yes, the companies had to indicate the location of the corresponding partner (Swiss canton or country). In the analysis, all R&D cooperation are evaluated, without differentiating between the types of the cooperative partner. For Switzerland, the number of cooperation is evaluated at NUTS-II level in order to compare the results with the analysis of the intra-firm networks (see section 4). At the international level, the number of cooperation is aggregated to the following countries or regions, primarily to achieve a statistically credible sample size: Austria, France, Germany, Italy, Netherlands, UK, other European countries, Asia, USA, other countries.

Extra-firm R&D cooperation on the national scale

Figure 7 shows the number of extra-firm R&D cooperation between the seven Swiss NUTS-II regions based on manufacturing firms with at least 20 employees. The thickness of the links illustrates the statistically estimated number of cooperation; the size of the circle shows the number of manufacturing firms with at least 20 employees within the corresponding NUTS-II region (statistical population).

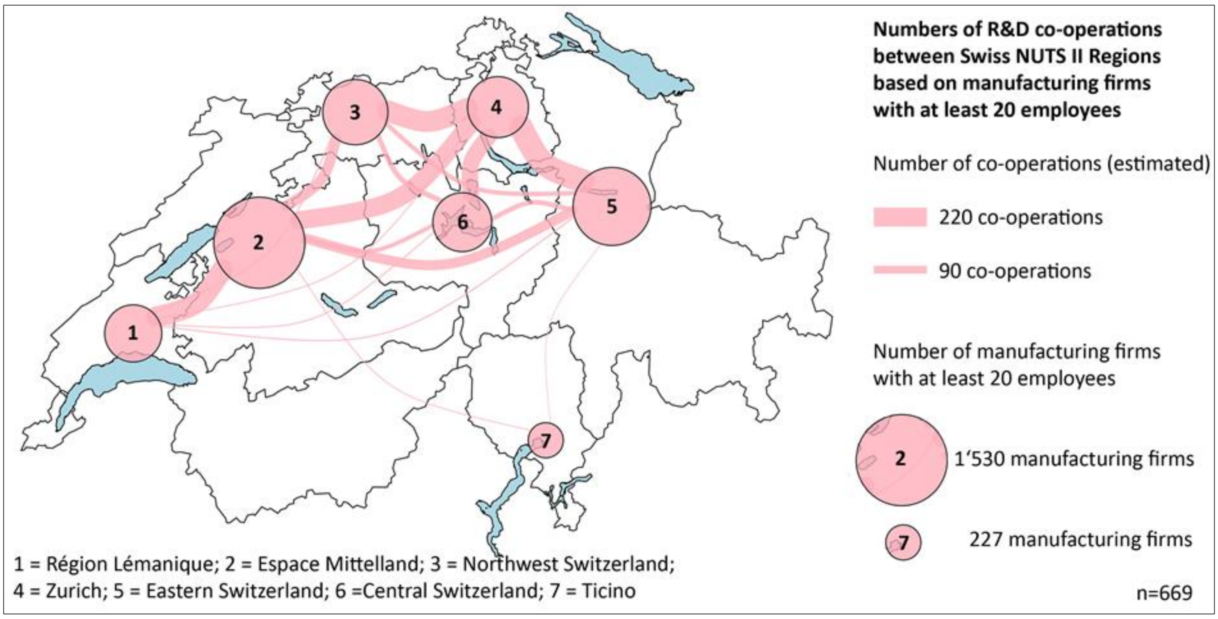


Figure 7: Number of R&D cooperation of Swiss manufacturing firms on the national scale (own illustration)

Figure 7 identifies the Zurich region as an intensively networked node in the net of R&D cooperation. Zurich is strongly linked to Northwest and Eastern Switzerland. Similarly, to the findings of the intra-firm analysis, two main regions with regard to R&D cooperation seem to emerge: on the one hand, Northern Switzerland with Zurich in the centre having strong connections to Northwest Switzerland, Eastern Switzerland, Central Switzerland and Espace Mittelland. The axis between Eastern Switzerland with its traditional high-tech industry (e.g. in the Rhine Valley) via Zurich to Northwest Switzerland (incl. Basel) with its internationally competitive chemical and pharmaceutical industry forms the central backbone of the high-tech industry in Northern Switzerland. Espace Mittelland acts as a kind of gateway between Northern Switzerland and the Lémanique region.

A further salient feature is the fact that there are only few links between Northern Switzerland and the French- and Italian-speaking parts of Switzerland. The main reason might lay in language and cultural barriers. Firms in French-speaking urban centres like Geneva or Lausanne have a tendency to focus on markets in the Francophone or Latin parts of the world, or an associated post-colonial background, while Zurich and Basel concentrate more on German- and English-speaking markets (Thierstein et al. 2008).

We now relate these observations to the economic information about R&D spending in section 3. Northwest Switzerland accounts for almost half the share of R&D spending (47%). However, the region only has an estimated number of 311 R&D co-operations. This is less than Eastern Switzerland (330) or Espace Mittelland (478) and ranks fourth out of seven regions. A possible explanation is the strong focus of the region in the chemical and pharmaceutical industry. This requires a high amount of investment. A similar pattern can be observed in the Région Lémanique. It accounts for the second highest share of R&D spending (13%). The region though only has an estimated number of 291 R&D co-operations, which ranks fifth out of seven regions. Here a possible explanation can be a stronger international cooperation as will be explored in the next paragraph. These observations tell us that by only looking at the national cooperation pattern of manufacturing firms, we do not obtain the complete picture.

Extra-firm R&D cooperation on the global scale

Figure 8 indicates the number of R&D cooperation on the global scale. Again, the thickness of the lines illustrates the statistically estimated number of R&D cooperation; the size of the circle shows the number of manufacturing firms with at least 20 employees within the corresponding NUTS-II region. For each of the Swiss NUTS-II regions, the most closely connected nations and regions are listed (listed are only those regions/nations with more than 18 cooperation).

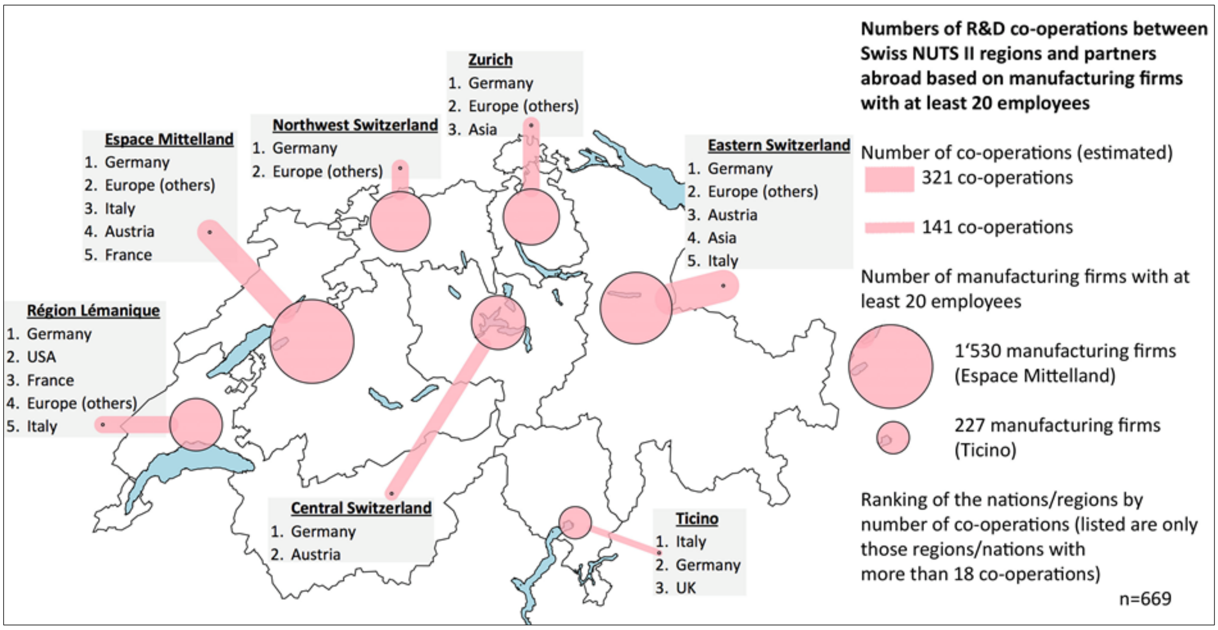


Figure 8: Number of R&D cooperation of Swiss manufacturing firms on the global scale (own illustration)

Figure 8 shows a variety of overlapping spatial patterns. Firstly, Germany seems to be an important destination for R&D cooperation in Swiss manufacturing firms, even in Western Switzerland and Ticino, where this was not to be expected to this large extent due to linguistic and cultural barriers. For Eastern and Central Switzerland, the number of R&D cooperation to Germany nearly corresponds to the sum of all their cooperation on the national level. A second spatial pattern concerns the regional dimension of R&D cooperation; most clearly in Ticino, where R&D cooperation with Italian partners can frequently be observed. To a lesser extent, this also applies to the Région Lémanique and the French-speaking part of Espace Mittelland (Jura Arc), where relevant relations exist with partners in France. A final observation concerns the strong orientation of R&D cooperation of Swiss manufacturing firms with European partners. Only Zurich and the Lémanique region – to a lesser extent also Eastern Switzerland – are showing relevant out-of-Europe connections. Here, the empirical results indicate once more that spatial proximity seems to play an important role especially in the context of knowledge-intensive activities such as R&D. R&D cooperation between firms require regular face-to-face contacts. These contacts are easy to organise with local partners (given that such partners are located in the region) or at locations with good international accessibility (e.g. hub-airport). We need to keep in mind that the type of cooperation partner is aggregated in order to achieve a statistically sound sample size. Hence, these observations cannot be differentiated into cooperation with customers, suppliers, other companies, universities or research institutions.

Share of manufacturing firms with extra-firm R&D cooperation

Figure 9 finally compares the share of manufacturing firms in the Swiss NUTS-II regions in terms of national and international R&D cooperation. The figure needs to be read in the following way: In Eastern Switzerland, 50% of the manufacturing firms maintain R&D cooperation. Out of these 50%, firms can cooperate on national scale, on international scale or both, therefore the respective bars do not add up to the total percentage of R&D cooperation.

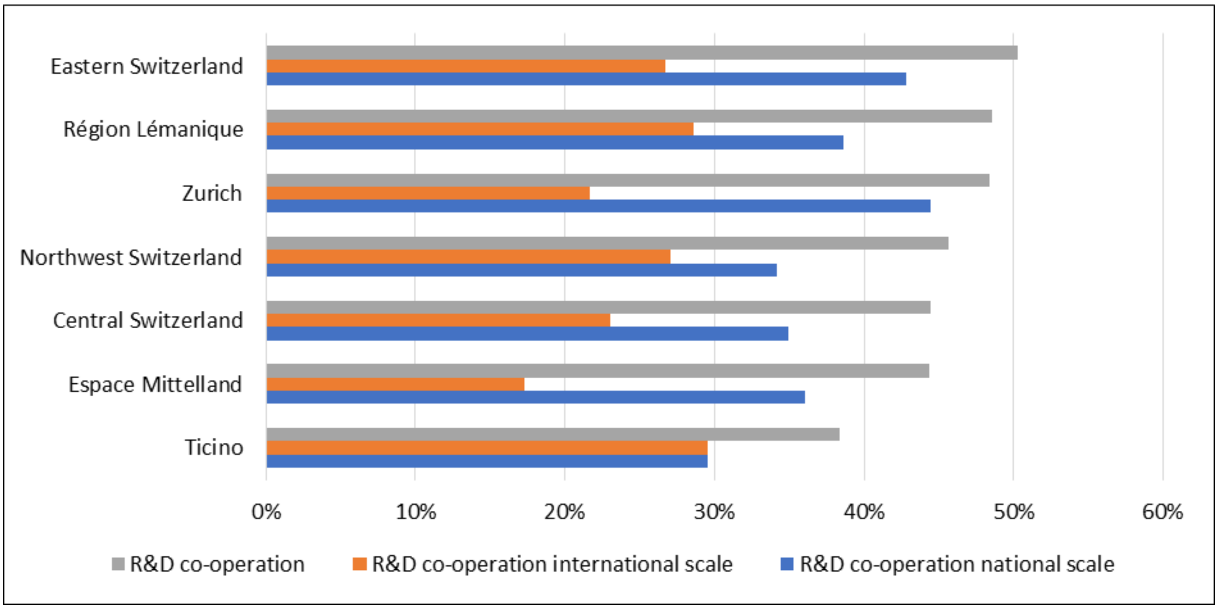


Figure 9: Share of manufacturing firms (≥ 20 employees) with R&D cooperation (own illustration)

Ticino shows the biggest share of manufacturing firms with international R&D cooperation, followed by Région Lémanique and Northwest Switzerland. These are all cross-border metropolitan areas. Particularly Ticino might not be able to provide the necessary critical mass and diversity of R&D competences, so that companies are forced to look for partners at international level, for example in the nearby metropolitan area of Milano with Italian speaking partners. Zurich, on the other hand, shows the biggest share of manufacturing firms with national R&D cooperation, followed by Eastern Switzerland and Région Lémanique. This result may be surprising at first sight, because the intra-firm analysis in section 5 indicates that Zurich is particularly internationally oriented. A possible explanation for this observation is the large number of research institutions and universities with a high reputation in the Zurich and Lémanique regions. These institutions enable firms to build up regional R&D cooperation with high-quality partners and services. However, further details on these contexts have to be examined with further analyses of the EMS data and qualitative research methods.

Relating these findings to the number of patent applications from section 3 (table 2), similar patterns can be detected. Manufacturing firms in Eastern Switzerland and the Région Lémanique for example show the highest share of R&D cooperation and both also show the highest growth rates in overall number of patent applications.

6. Comparison

This section graphically combines the information given so far. First, the national and international connectivity of high-tech firms is combined in one figure. Second, the national and international R&D cooperation of manufacturing firms is combined in another figure. These two networks are then described and compared.

Figure 10 unifies the national and global perspective regarding the connectivity of high-tech firms. In section 4, the connectivity values are standardised in terms of the highest interlock for national and international connectivity separately. But in figure 10, absolute connectivity values are shown. We see that the national intra-firm connectivity among the seven NUTS-II regions is quite low, it displays a very thin network across Switzerland. In contrast, the international connectivity of high-tech firms is much higher, indicating the international alignment of these firms. High-tech firms are mostly connected to destinations outside Europe by intra-firm networks.

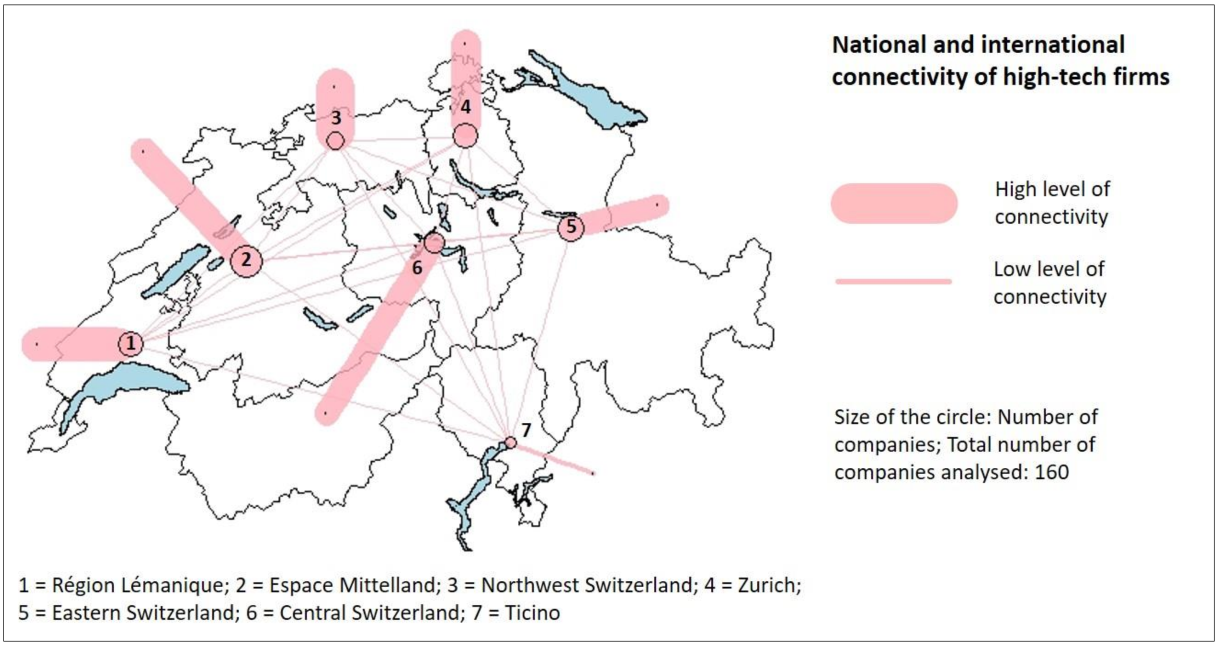


Figure 10: National and international connectivity of high-tech firms (own illustration)

Figure 11 unifies the national and global perspective regarding R&D cooperation of manufacturing firms. Here, absolute numbers of estimated co-operations are shown. The national network is strong in terms of the number of co-operations between the NUTS-II regions. Nevertheless, also the international network shows a high amount of cooperation as we have seen in figure 8. Manufacturing firms maintain most R&D cooperation with neighboring countries, hereby Germany is the most important partner. To a lesser extent, firms maintain cooperation to other European countries and to an even lesser extent to outside Europe.

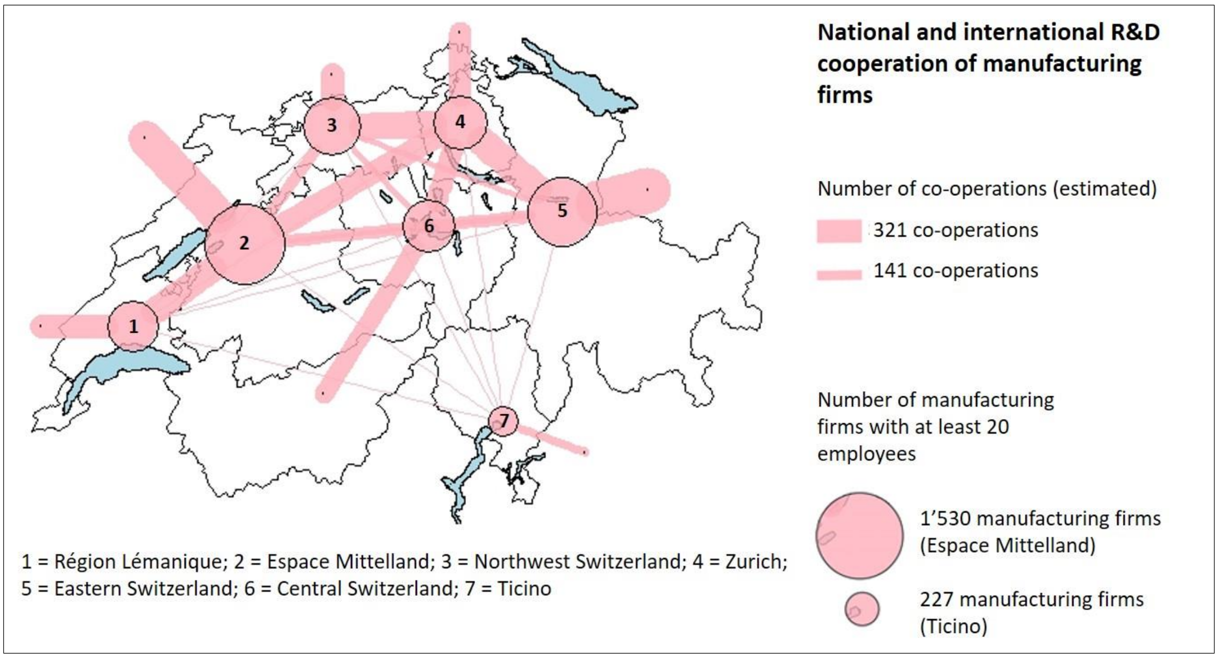


Figure 11: National and international R&D cooperation of manufacturing firms (own illustration)

Combining the national and international perspective, we find that the intra-firm high-tech network is much more internationally aligned. It has a broader geographical spread, most cooperation happens outside of Europe. This finding is consistent to literature (OECD 2008, Yeung 2009). The R&D network of manufacturing firms has a more narrow geographical spread, most cooperation happens in neighboring countries. This finding is also consistent with the well-known importance of spatial proximity (Asheim and Coenen 2005).

On regional level, the picture is further differentiated. Ticino's three most important high-tech cooperation partners are located in a neighboring country. The two most important R&D cooperation partners for manufacturing firms are also located in a neighboring country. Only the third most important R&D cooperation partner for manufacturing firms is located elsewhere in Europe. This means that Ticino shows a truly local pattern of cooperation. The situation looks different for Central Switzerland. The three most important high-tech cooperation partners are located outside of Europe. The two most important R&D cooperation partners for manufacturing firms are located in a neighboring country.

The national networks also differ considerably: At first sight we observe a network of low intra-firm connectivity among high-tech firms. Zooming in, we see one high-tech functional region in Northern Switzerland between Zurich and Eastern Switzerland. For R&D among manufacturing firms, the overall pattern reveals a network of high numbers of cooperation. Zooming in, we see two focal regions: the axis between Eastern Switzerland via Zurich to Northwest Switzerland and the axis between the Région Lémanique and Espace Mittelland.

We conclude that it is essential to consider both the national and international network when analysing cooperation patterns or connectivity values. Further, different scales reveal different information. Neglecting one perspective leads to a deformed representation of the network and lastly to wrong conclusions about its structure. This argument brings us back to the importance of the relational perspective in contrast to the attribute based perspective. Zurich, for example, is sometimes called a polycentric Mega-City Region. It has a high amount of firms and contributes with a high share of GVA to the total Swiss GVA. Given these attributes, we expect a high connectivity for the Zurich region. Looking at the international intra-firm connectivity of Zurich, this is confirmed. However, the national intra-firm connectivity is much lower. It is hence problematic to infer the relational-based perspective from an attribute-based analysis. This needs to be emphasized against the background of the still largely attribute-based spatial development policy in Switzerland. We aim to encourage a network thinking in the sense that spatial development increasingly includes relational information and overcomes the area-based thinking, acknowledging that relations, e.g. between firms and cities, shape spaces in Switzerland.

7. Conclusion

Regions – even mega-city regions – cannot be studied in isolation. Each region is connected to other places in the world in many different ways and through many different actors who form networks on different spatial scales. More than the pure locational perspective, this relational perspective makes it possible to highlight how different parts within and beyond regional borders are interacting with each other. The debate in the social sciences about the importance of geographical proximity has an already extensive body of work (Lüthi et al. 2010; Boschma 2005; Torre and Rallet 2005) and begun to acknowledge that local and global ties contribute positively to knowledge generation. Geographical clustering promotes a depth of knowledge production and is driven by the globalisation of markets and services facilitated by developments in information and communication technologies. Knowledge-intensive businesses are agents that build spatially concentrated knowledge gateways between the regional, supra-regional and global economies.

Methodologically, the real impact of changing value chains on spatial development is difficult to grasp. On the one hand, there is an increased concentration of highly advanced and knowledge-intensive functions in just a few centres, while on the other hand a diffusion of associated functions and urban sprawl can be found. These contradictory processes pose an enormous challenge for researchers and policy makers, as both polycentric and monocentric tendencies are outcomes of the same process towards a more knowledge-intensive economy. In this paper, we try to deal with this challenge by approaching the analysis in several steps and on different spatial scales. We start with analysing intra-firm connectivity of high-tech firms on a national scale, followed by an international scale. We then move to analysing R&D cooperation of manufacturing firms on a national scale, also followed by an international scale. We then compare the two networks in a final step.

As a small, open economy, Switzerland is centrally dependent on being integrated into international trading and exchange networks. This creates the need for physical integration through transport infrastructure as well as connectivity through firm networks. The critical mass of diverse and dense labour markets, corporate activities, knowledge facilities and access infrastructure makes it clear that Switzerland has only a few metropolitan regions that can be seen as internationally important. However, the decentralised structure of the federal state, with its resulting distribution of tasks and resources, frequently counteracts the superior view from a global perspective.

Switzerland is still struggling to develop a wide-scale assessment which, by necessity, is cross-border in nature. The perception of regions is still greatly characterised by the country's fragmented and decentralized federal structure with twenty-six autonomous cantons and 2,240 municipalities as of 2 April 2017. The administrative demarcation of the seven NUTS-II regions has still not provided any satisfactory solution since it only reflects todays realities of functional, spatial interrelationships to a small extent. At scientific and regional planning level, there is still a need to examine and review spatial concepts for urban systems, and to conduct detailed analyses of functionally structured metropolitan regions. Spatial and location-specific development policy for Switzerland therefore needs to go well beyond existing planning and perception levels, and to translate this additional leap in scale into effective developmental prospects for the country. All in all, the central challenge facing spatial development policy in Switzerland is to actively manage regionally concentrated and globally networked urban systems, and not to prevent the development of a functional urban hierarchy.

The new Swiss spatial development concept takes a first step in recognising that life in Switzerland increasingly happens in regions which are neither inside municipal nor cantonal borders. It demands the promotion of cooperation in functional spaces. However, the Swiss spatial development concept does not answer the questions i) how these functional spaces in Switzerland look like and ii) through which specific vectors of connectivity these spaces are shaped. This explorative paper tried to give a very first answer by exploring intra-and extra firm networks of high-tech and manufacturing companies. A difficulty is, though, that the present work uses two different data sources. Hence, two different statistical populations exist, which cannot be directly compared. Regarding the GaWC method for intra-firm networks, the population is too small to survey these firms for their extra-firm networks. Regarding the EMS survey, a possibility is to include a question about company-internal information flows in the questionnaire. The post-stratification and the network analysis can then be applied to the same dataset. As a further research outlook, it will be interesting to systematically study the knowledge economy in Switzerland and to subsequently develop a regression model which will be able to predict and explain changes in connectivity between regions based on spatial structures, firm location strategies, economic indicators, employment and mobility indicators and other relevant variables including their respective interactions.

References

Asheim, Bjørn; Coenen, Lars; Moodysson, Jerker and Vang, Jan (2005): Regional Innovation System Policy: A Knowledge-Based Approach. Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE), Lund University. RePEc:cil:wpaper:24. Retrieved from http://EconPapers.repec.org/

Boschma, Ron (2005): Proximity and innovation: a critical assessment. In: Regional Studies 39(1): 61-74.

Castells, Manuel (1989): The Informational City. Information Technology, Economic Restructuring and the Urban-Regional Process. Malden: Blackwell.

Coe, Neil; Dicken, Peter; Hess, Martin and Yeung, Henry Wai-Cheung (2010): Making connections: Global Production Networks and World City Networks. In: Global Networks 10(1): 138–149.

Davoudi, Simin (2003): Polycentricity in European spatial planning: from an analytical tool to a normative agenda. In: European Planning Studies 11(8): 979-999.

De Backer, K. and E. Basri (2008): The internalisation of R&D, in OECD (ed.): Staysing competitive in the global economy. Paris: OECD, 219-48.

Dicken, Peter (2007): Global Shift. Mapping the Changing Contours of the World Economy, 5. Ed. London: SAGE Publications.

Dümmler, Patrick (2005): Wissensbasierte Cluster in der Schweiz: Realität oder Fiktion? Das Beispiel der Medizinaltechnikbranche. Zürich: ETH Zürich.

EUROSTAT (2015): NUTS – Nomenclature of territorial units for statistics: overview. Retrieved from http://ec.europa.eu/eurostat/web/nuts/overview

Faulconbridge, James (2007): London's and New York's advertising and law clusters and their networks of learning: relational analyses with a politics of scale? In: Urban Studies 44(9): 1635-1656.

Fraunhofer ISI (2017): European Manufacturing Survey. Retrieved from http://www.isi.fraunhofer.de/isi-de/i/projekte/fems.php

FSO Federal Statistical Office (2015): STATPOP Statistik der Bevölkerung und der Haushalte. Retrieved from https://www.pxweb.bfs.admin.ch/Selection.aspx?px_language=de&px_db=px-x-0102020000_201&px_tableid=px-x-0102020000_201/px-x-0102020000_201.px&px_type=PX

FSO (2016 a): Steckbrief Grossregionen. Retrieved from https://www.bfs.admin.ch/bfs/de/home/statistiken/raum-umwelt/nomenklaturen/grsreg.assetdetail.415713.html

FSO (2016 b): AVOL Arbeitsvolumenstatistik Fact Sheet. Retrieved from https://www.bfs.admin.ch/bfs/de/home/statistiken/arbeit-erwerb/erhebungen/avol.assetdetail.6965.html

FSO (2016 c): VGR Volkswirtschaftliche Gesamtrechnung: Volkswirtschaftliche Gesamtrechnung: Bruttowertschöpfung nach Kanton und Aktivitäten. Retrieved from https://www.bfs.admin.ch/bfs/de/home/statistiken/volkswirtschaft.assetdetail.1180559.html

FSO (2017 a): Strukturelle Analyse der regionalen BIP 2008 – 2014. Retrieved from https://www.bfs.admin.ch/bfs/de/home/statistiken/volkswirtschaft.assetdetail.2905879.html

FSO (2017 b): Forschung und Entwicklung (F+E)-Aufwendungen der Privatwirtschaft. Retrieved from https://www.bfs.admin.ch/bfs/de/home/statistiken/bildung-wissenschaft/technologie/indikatorsystem/zugang-indikatoren/w-t-input/f-e-aufwendungen-privatwirtschaft.assetdetail.2200121.html

FSO (2017 c): Patente und Patentfamilien. Retrieved from https://www.bfs.admin.ch/bfs/de/home/statistiken/bildung-wissenschaft/technologie/indikatorsystem/zugang-indikatoren/w-t-output/patente-patentfamilien.html

FSO (2017d): Forschung und Entwicklung (F+E)-Aufwendungen. Retrieved from https://www.bfs.admin.ch/bfs/de/home/statistiken/querschnittsthemen/wohlfahrtsmessung/alle-indikatoren/wirtschaft/ausgaben-f-und-e.assetdetail.2644558.html

GaWC (2017): Globalization and World Cities Research Network. Retrieved from http://www.lboro.ac.uk/gawc/

Gereffi, Gary; Humphrey, John and Sturgeon, Timothy (2005): The governance of global value chains. In: Review of International Political Economy 12(1): 78-104.

Gomes-Casseres, Benjamin (1996): The Alliance Revolution: the New Shape of Business Rivalry. Cambridge, MA: Harvard University Press.

Howells, Jeremy (2000): Knowledge, innovation and location. In: Bryson, John R.; Daniels, Peter W.; Henry, Nick and Pollard, Jane (ed.), Knowledge, Space, Economy. London, New York: Routledge: 50-62.

Hoyler, Michael; Freytag, Tim and Mager, Christoph (2008b): Connecting Rhine-Main: The Production of Multi-Scalar Polycentricities through Knowledge-Intensive Business Services. In: Regional Studies 42(8): 1095–1111.

Lüthi, Stefan; Cavelti, Guido (2013): Netzwerk-Assessment Schweiz, BHP – Brugger und Partner AG, Zürich.

Lüthi, Stefan; Thierstein, Alain; Bentlage, Michael (2016): Metropolregion Nordschweiz: zu gross um wahr zu sein? In: Danielzyk, Rainer; Münter, Angelika; Wiechmann, Thorsten (Hrsg.): Polyzentrale Metropolregionen. Rohn: Detmold.

Lüthi, Stefan; Thierstein, Alain and Goebel, Viktor (2010): Intra-firm and extra-firm linkages in the knowledge economy: the case of the emerging mega-city region of Munich. In: Global Networks 10(1): 114-137.

Lüthi, Stefan (2011): Interlocking firm networks and emerging Mega-City Regions. The relational geography of the knowledge economy in Germany. (Doctoral dissertation). Munich: Munich University of Technology.

Lumley, Thomas (2017): R Package: Survey. Analysis of Complex Survey Samples. Version: 3.31-5.

Nordlund, Carl (2004): A Critical Comment on the Taylor Approach for Measuring World City Interlock Linkages. In: Geographical Analysis 36(3): 290-296.

OECD (2008): Staying Competitive in the Global Economy. Compendium of Studies on Global Value Chains. Paris: OECD.

Oxford Economics (2013): The Economic Value of International Connectivity. Retrieved from http://www.oxfordeconomics.com/publication/download/259167

Porter, Michael E. (1990): The Competitive Advantage of Nations. London and Basingstoke: Macmillan Press.

Rogers, Everett M. and Larsen, Judith K. (1984): Silicon Valley Fever. Growth of High-Tech Culture. New York: Basic Books.

R Core Team (2016): R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Retrieved from https://www.R-project.org

Sassen, Saskia (1991): The Global City: New York, London, Tokyo. Princeton, NJ: Princeton University Press.

Simmie, James (2003): Innovation and urban regions as national and international nodes for the transfer and sharing of knowledge. In: Regional Studies 37(6): 607-620.

Storper, Michael (1992): The limits to globalization: technology districts and international trade. In: Economic Geography 68(1): 60-93.

Swiss Federal Council; KdK; BPUK; SSV und SGV (2012): Raumkonzept Schweiz. Bern: Schweizerischer Bundesrat, Konferenz der Kantonsregierungen KdK, Bau-, Planungs- und Umweltdirektorenkonferenz BPUK, Schweizerischer Städteverband SSV, Schweizerischer Gemeindeverband SGV.

Taylor, Peter J. (2001): Specification of the world city network. In: Geographical Analysis 33(2): 181-194.

Taylor, Peter J.; Catalano, Gilda and Walker, David R. F. (2002): Exploratory Analysis of the World City Network. In: Urban Studies 39(13): 2377-2394.

Thierstein, Alain; Lüthi, Stefan; Kruse, Christian; Gabi, Simone and Glanzmann, Lars (2008): Changing value chain of the knowledge economy. Spatial impact of intra-firm and inter-firm networks within the emerging Mega-City Region of Northern Switzerland. In: Regional Studies 42(8): 1113-1131.

Thierstein, Alain; Kruse, Christian; Glanzmann, Lars; Gabi, Simone und Grillon, Nathalie (2006): Raumentwicklung im Verborgenen. Untersuchungen und Handlungsfelder für die Entwicklung der Metropolregion Nordschweiz. Zürich: NZZ Buchverlag.

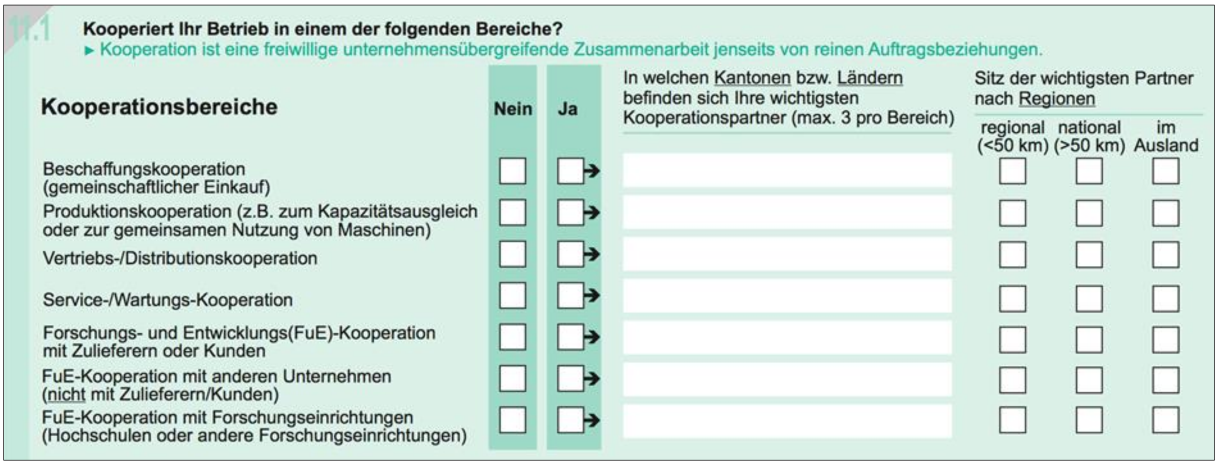
Thierstein, A., & Lüthi, S. (2011): Swiss Cities. In P. J. Taylor, P. Ni, B. Derudder, M. Hoyler, J. Huang, & F. Witlox (Eds.), Global Urban Analysis. A Survey of Cities in Globalization (pp. 236–240). London: Earthscan.

Torre, André and Rallet, Alain (2005): Proximity and localization. In: Regional Studies 39(1): 47-59.

Yeung, Henry Wai-Chung (2009): Regional development and the competitive dynamics of global production networks: an East Asian perspective. In: Regional Studies 43(3): 325-351.

Appendices

Figure 13: Questionnaire Swiss Manufacturing Survey 2015 (extra-firm networks)



11.1 Kooperiert Ihr Betrieb in einem der folgenden Bereiche?
► Kooperation ist eine freiwillige unternehmensübergreifende Zusammenarbeit jenseits von reinen Auftragsbeziehungen.

Kooperationsbereiche	Nein	Ja	In welchen Kantonen bzw. Ländern befinden sich Ihre wichtigsten Kooperationspartner (max. 3 pro Bereich)	Sitz der wichtigsten Partner nach Regionen: regional (<50 km)	national (>50 km)	im Ausland
Beschaffungskooperation (gemeinschaftlicher Einkauf)	☐	☐ →		☐	☐	☐
Produktionskooperation (z.B. zum Kapazitätsausgleich oder zur gemeinsamen Nutzung von Maschinen)	☐	☐ →		☐	☐	☐
Vertriebs-/Distributionskooperation	☐	☐ →		☐	☐	☐
Service-/Wartungs-Kooperation	☐	☐ →		☐	☐	☐
Forschungs- und Entwicklungs(FuE)-Kooperation mit Zulieferern oder Kunden	☐	☐ →		☐	☐	☐
FuE-Kooperation mit anderen Unternehmen (nicht mit Zulieferern/Kunden)	☐	☐ →		☐	☐	☐
FuE-Kooperation mit Forschungseinrichtungen (Hochschulen oder andere Forschungseinrichtungen)	☐	☐ →		☐	☐	☐

Table 2: Swiss Manufacturing Survey 2015: responding rate per NUTS-II region

NUTS-II regions	Number of evaluable responses (sample)	Total manufacturing firms with at least 20 employees (statistical population)
1. Région Lémanique	59	601
2. Espace Mittelland	187	1530
3. Northwest Switzerland	92	784
4. Zurich	87	684
5. Eastern Switzerland	122	1120
6. Central Switzerland	99	639
7. Ticino	23	227
TOTAL	**669**	**5585**

Table 3: High-tech firms analysed with the INM (intra-firm networks)

Chemistry & Pharmacy	
• EMS-CHEMIE AG	• Siegfried AG
• F. Hoffmann-La Roche AG	• Sigma-Aldrich Production GmbH
• Lonza AG	• Sika AG
• Novartis Pharma AG	• aenova
• BASF Schweiz AG	• Galenica AG
• Clariant AG	• Schweiter Technologies
• CSL Behring AG	• CRUCELL SWITZERLAND AG
• DSM Nutritional Products AG	• IVF HARTMANN AG
• Firmenich SA	• Spirig Pharma AG
• Givaudan Suisse SA	• UCB Farchim SA
• Syngenta AG	• Zambon Switzerland Ltd
• B. Braun Medical AG	• Linde
• BACHEM AG	• Merck Gruppe
• CABB AG	• Eckart Suisse SA
• Ferring International Center SA	• TRB CHEMEDICA SA
Electronics	
• Oerlikon Group	• Landis+Gyr (Europe) AG
• ABB Schweiz AG	• Lémo S.A.
• Siemens Schweiz AG	• WAGO Contact AG
• ROLEX SA	• Schurter AG
• ALSTOM (Schweiz) AG	• Hamilton Bonaduz AG
• Bruker BioSpin AG	• Kistler Instrumente AG

• Endress+Hauser Flowtec AG	• Von Roll AG
• ETA SA Manufacture Horlogère Suisse	• Trapeze ITS Switzerland GmbH
• Le petit-fils de L.U. Chopard & Cie SA	• ALPINE-ENERGIE Schweiz AG
• Swatch Group	• Delta Energy Systems (Switzerland) AG
• Richemont International SA	• Mettler-Toledo
• Leica Geosystems AG	• Kaba
• maxon motor ag	• Bulgari Horlogerie SA
• Huber+Suhner AG	• Schaffner EMV AG
• Baumer Electric AG	• Synthes Produktions GmbH
Information- and communication Technology	
• EMC Computer Systems AG	• Thales Suisse SA
• Crypto AG	• Tyco Fire & Integrated Solutions (Schweiz) AG
• Alcatel-Lucent Schweiz AG	• MEI Inc.
• Aastra Telecom Schweiz AG	• Atis Uher SA
• HID Global Switzerland SA	• SkiData (Schweiz) AG
• Keymile AG	• Wey Elektronik AG
• Schmid Telecom AG	• IBM
• Stoppani AG	• HP
• Swissphone Telecom AG	• Wincor Nixdorf
• Kontron Compact Computers AG	• Intel
• Talaris (Switzerland) AG	• Ricoh
• Zünd Systemtechnik AG	• Logitech
• Comlab AG	• Avaya
• Schweizer Electronic AG	• ETAVIS
• Spectratime SA	• Eaton Automation AG
Machinery	
• V-ZUG AG	• Bucher Industries
• Schindler Aufzüge AG	• Habasit AG
• Bühler AG	• Mikron SA
• Maschinenfabrik Rieter AG	• E. Bruderer Maschinenfabrik AG
• PILATUS Flugzeugwerke AG	• Starrag Group
• Liebherr Machines Bulle S.A.	• TRUMPF Grüsch AG
• Burckhardt Compression AG	• Applied Materials Switzerland Sàrl
• MAN Diesel & Turbo Schweiz AG	• Güdel AG
• Robert Bosch AG	• Komax AG
• Bystronic Laser AG	• Benteler
• Meyer Burger AG	• Festo AG
• Tornos SA	• Rheinmetall Defence
• Ammann Schweiz AG	• Johnson Controls
• KraussMaffei Gruppe	• Thyssen Krupp
• Walter Reist Holding	• Schmolz + Bickenbach AG
• Stadler Bussnang AG	• Doppelmayr/Garaventa Group
• ANDRITZ HYDRO AG	• Emile Egger & Cie S.A.
• Ateliers Busch S.A	• Mori Seiki International SA
• Georg Fischer JRG AG	• Bobst Group
• BELIMO Automation AG	• Gleason
Medical and optical instruments	
• Phonak AG	• Carl Zeiss
• Zimmer GmbH	• JENOPTIK
• Trisa AG	• Leica Microsystems
• Abbott Laboratories Vascular Enterprises Limited	• Karl Storz
	• Johnson and Johnson
• Smith & Nephew Orthopaedics AG	• Gambro
• Straumann AG	• Biotronik
• KerrHawe SA	• Ciba Vision

• Bernafon AG • Medacta International SA • Optiswiss AG • Gemü GmbH • Kyphon Sàrl / Medtronic • Nouvag AG • Symbios Orthopédie S.A. • Hader SA / Arseus	• Dräger • Ypsomed AG • Steris • COLTENE Holding AG • LifeWatch AG • Nobel Biocare Holding AG • Tecan Group AG