GROUP D

TOPIC

Technological capability and technological proximity in Thuringia (1991-2010)

Course: Seminar Innovation

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A. Motivation

Thuringia has a long history as an industrial region with expertise in the automobile, optical, mechanical and later, electronic industries. Moreover, in 1993, two Thuringian ministries (i.e. the Ministry of Science and Arts, and the Ministry of Economic Affairs and Infrastructure advised the government to focus Thuringian and federal support on future-oriented technologies in order to develop regional industry-science clusters. Besides technological aid schemes, the Thuringian government has set up a dense infrastructure of technological transfer agencies and incubator centers (Laurila et al., 2003). Technological innovation is embedded in the institutional and historical environment; therefore, it is not easy to achieve rapid technological innovation (Park, 2017). Thuringia has both advantageous conditions, namely institutional and historical environment, to foster technological capability.

Over the past decade, technological innovation is regarded as an important engine of economic growth. The technological capability could be considered as the resource which enables a firm to generate innovations in products, processes, and engineering projects and further discussed the accumulation path of technological capability. Therefore, technological capability plays an essential role in achieving rapid technological innovation.

Technological proximity is a significant determinant in cooperation, absorptive ability, and innovation activities. To utilize mutual technological know-how, the owners of such know-how should possess certain technological proximity (Cantner and Meder, 2007). Similar technological backgrounds facilitate the acquisition of heterogeneous resources, technological learning and development.

In this seminar, we pay attention to explore the technological capability and technology proximity at regional level of Thuringia over the period 1991-2010.

We would like to analyze more detail by divided this Thuringia data into 4 sub-regions and 4 periods which are the East, the North, the South, and Center; 1991-1995, 1996-2000, 2001-2005, 2006-2010 respectively. After this study, we would like to compare the technological capability and technology proximity between these areas over 4 periods mentioned above.

B. The data

This study is based on regional-level data collected in OECD REGPAT and European Patent Office (EPO) patent quality database. The OECD REGPAT database provides regionalized data at a very detailed level covering more than 2000 regions across OECD countries. Patent data in OECD REGPAT have been linked to regions using the addresses of the applications and inventors, providing a new set of measures that are useful for our analyses. REGPAT allows patent data to be used in connection with other regional data such as GDP or labor force statistics, and other patent-based information such as citations, technical fields and patent holder's characteristics (industry, university, etc.). EPO patent quality database proposes several indicators and an experimental composite indicator aimed at capturing the quality of patents, intended as the technological and economic value of patented inventions. OECD REGPAT and EPO patent quality data are linked by Applicant ID. Patent data can be regionalized on the basis of the address of either the inventor or the holder, with regions using NUTS3 code. To address the questions of technological capability and proximity over time, we reply on these patent data in the period 1990 to 2010.

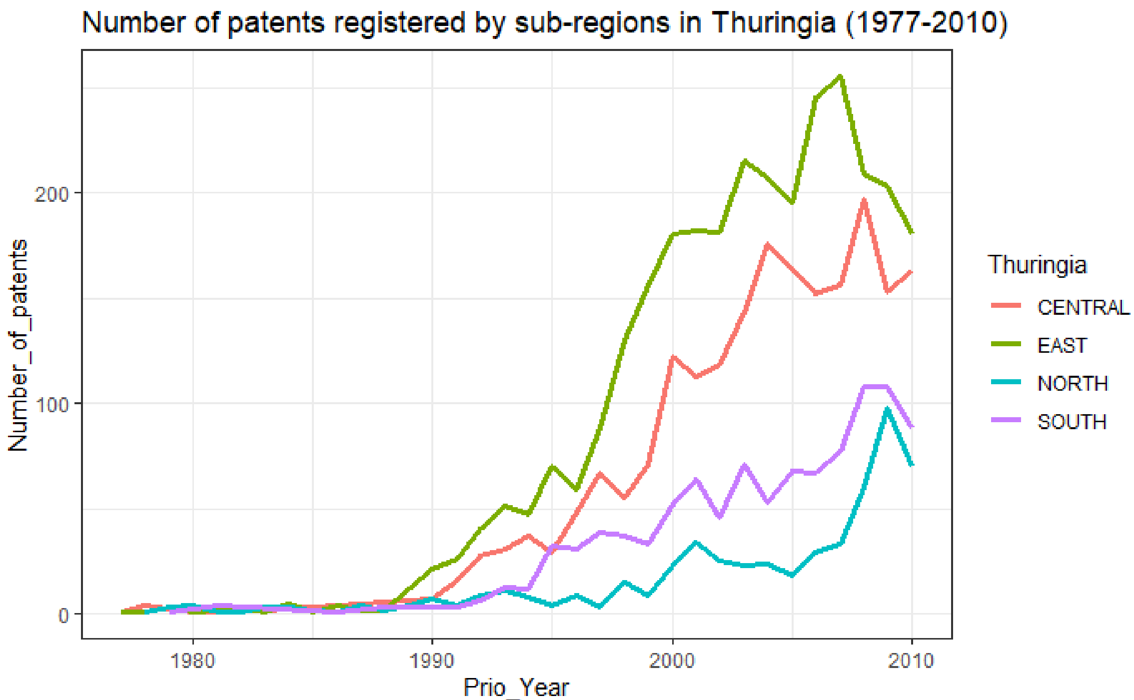
We add a new variable namely "openness to external knowledge" to study the external knowledge absorptive capacity of Thuringia. Our procedure is as follows: First, we extract all unique applications, personal identities, and inventor share of all patents registered in Thuringia from 1991 to 2010. Secondly, we calculate the sum of inventor share for every patent. A patent generated by more than one inventor, and having the sum of inventor share (excluding outside Thuringia) smaller than 1 will be considered as a patent having an openness to external knowledge. By doing so, we distinguish between the commuting patterns, which people make long-distance commutes to work, and external knowledge (from other states).

After merging all the data with all variables needed, we divide Thuringia data into 4 sub-regions (east, north, south, and central).

C. Technological capability and technological proximity in Thuringia 1990-2010

I. General view about Thuringia patent activity

1. Number of patents of Thuringia by sub-regions:



As Thuringia also started with a relatively low level of patent activities, the ascent was initially very fast. Before the 1990s, the number of registered patents was too low at all sub-regions in Thuringia. The patenting activities have been developed since the innovation activities were got more attention from the two Thuringian ministries in 1993. It is clear from the graph that the number of patents registered by all four sub-regions increased constantly and reached their peak around 2007-2008. After the significant rise, the number of patents experienced a sharp decline in the 2010s. It could be explained by the fact that the whole economic activities, including innovation and invention, suffered from the serious impact of the Great Recession in 2008-2009.

2. IPC3 class of Thuringia by sub-region

Table 1. Top 5 3-digit IPC classes of Thuringia (1977-2010)

Thuringia	Ipc3	total	Thuringia	Ipc3	total	Thuringia	Ipc3	total	Thuringia	Ipc3	total
CENTRAL	A61	370	EAST	A61	736	SOUTH	H01	92	NORTH	H01	128
CENTRAL	G01	289	EAST	G01	585	SOUTH	B60	89	NORTH	A61	64
CENTRAL	H01	196	EAST	G02	526	SOUTH	G01	75	NORTH	G01	57
CENTRAL	G02	168	EAST	C07	302	SOUTH	H02	68	NORTH	C12	37
CENTRAL	C07	158	EAST	H01	277	SOUTH	B23	67	NORTH	F16	29

In this part, we find the top 5 IPC3 class by sub-region and study which industries be specialized by each region.

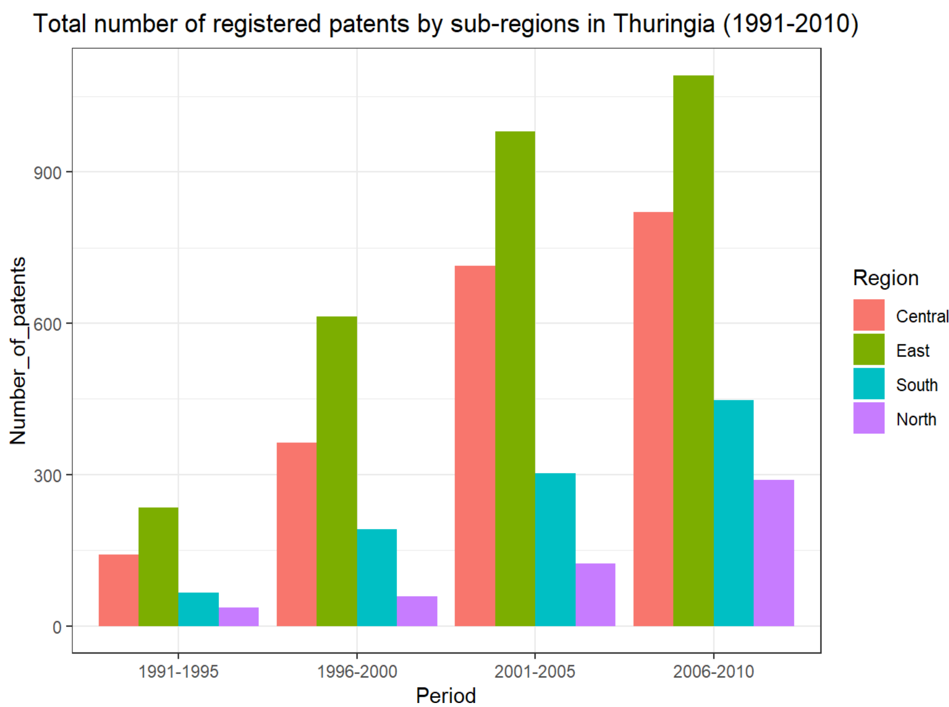
It can be shown in the table that the central and east developed patent activities in the same direction. Their industries focus on IPC3 class A61 (medical or veterinary science), G01 (Measuring, Testing), G02 (Optics), C07 (Organic Chemistry), and H01(basic electric elements). However, in the south, and the north, there has slightly different. In the south, the region patent activities focus on developing IPC3 class not only H01, G01 but also H02 (Electric Power), B23 (railway) and B60 (Vehicle in General). In the north, besides H01, A61 and G01 the region also developed in C12 (Biochemistry) and F16 (Mechanical Engineer).

II. Technological Capability

Technological capability represents the capability to incorporate additional and distinct resources needed to generate and managing technology change and including skills, knowledge and experience, and institutional structures and linkages (Bell and Pavitt, 1992). In this seminar, the technological capability will be measure by 4 indicators: the number of patents, the average scope of patents, the average forward citation of patents, and the external knowledge absorbing from outside Thuringia.

1. Number of Patents by sub-regions in different 4 periods

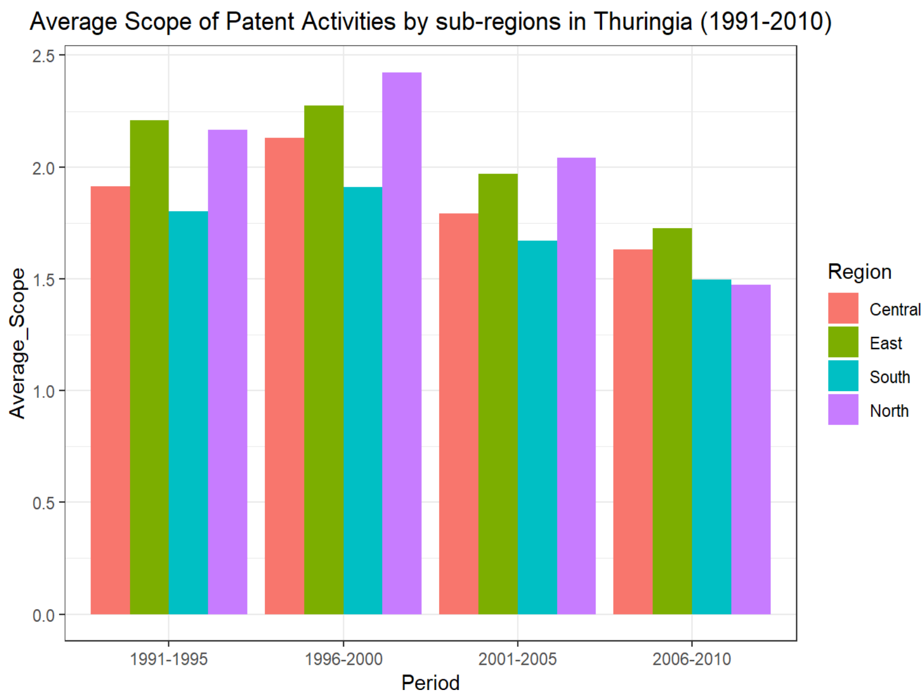
The number of patents can be an indicator of the accumulation of output of technological innovation**.** The number of patents is a very straightforward quantity indicator of technological capability that an increase in the number of patents can be regarded as an increase in the absolute size of the technological innovation. This indicator is known as one of the useful measures of technological capability, and be used by some researchers, including Park (2017).



There is a dramatic difference between the number of patents registered by sub-regions in Thuringia from 1991 to 2010. In the first period from 1991 to 1995, the total number of patents registered by all sub-regions was too low, approximately below 300 patents. The patenting activities of four sub-regions developed continuously throughout the period from 1991-2010; sub-regions, in 2006-2010, had more than three times patents as much as they had in the first period. In terms of this quantity measure of technological capability, East and Central outperformed the other sub-regions. One of the most important reasons is that in the East and Central, there has a variety of University as well as Research Institution which contributes to a large number of patents.

North Thuringia had the lowest number of patents during the period. The ratio between the number of patents registered by North and East Thuringia increased (0.15 and 0.27 in 1991-1995, and 2006-2010 respectively). We also indicate the same pattern of the ratio between the number of patents of other sub-regions with East Thuringia. In general, the gaps between other sub-regions and the technological leader of Thuringia (East Thuringia) reduced during the period.

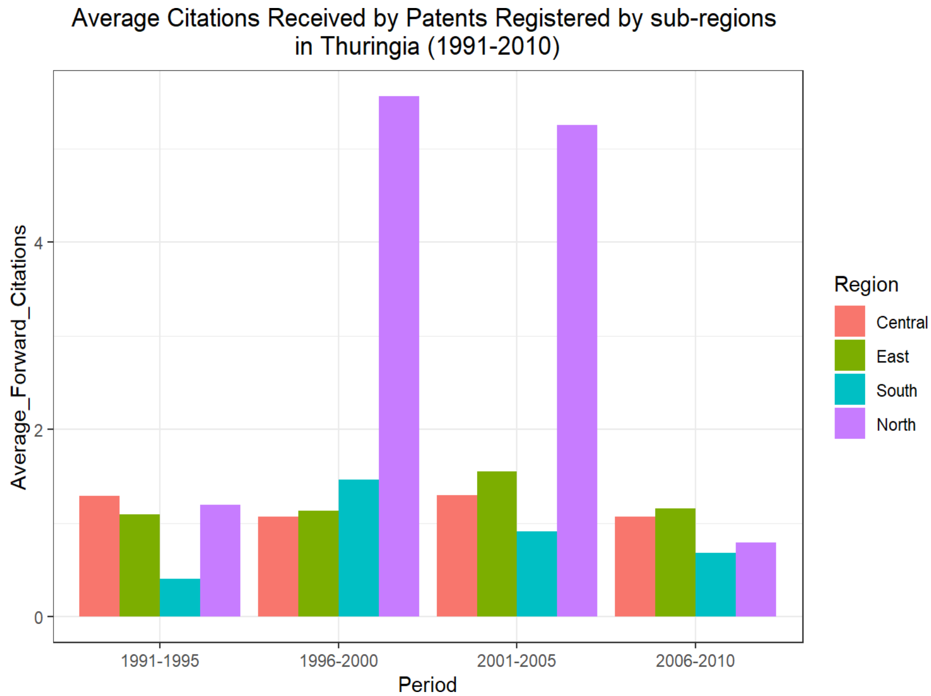
2. Average scope of patents by sub-region in different 4 periods



The scope of patents is often associated with the technological and economic value of patents. The scope of a patent is defined as the number of distinct 4-digit subclasses of the International Patent Classification the invention is allocated to. The broader scope of patenting activities means that technological innovation occurred across a broad range, and the patent has higher potential technological and market value.

Generally, the average scope of a patent generated by sub-regions in Thuringia fluctuated. This quality measure of technological capability of all sub-regions witnessed a slight increase from 1991-1995 to 1996-2000, following by the gradual decrease to 2006-2010. While North Thuringia was always left further behind regarding the number of patents throughout the period, the average scope of a patent registered by North Thuringia was higher than others' in 1996-2000 and 2001- 2005, and a bit smaller than the average scope of a patent from East Thuringia which had the broadest sector coverage in patent registrations in Thuringia in 1991-1995. The average scope of a patent of North and East was almost higher than or equal to 2 in the first three periods.

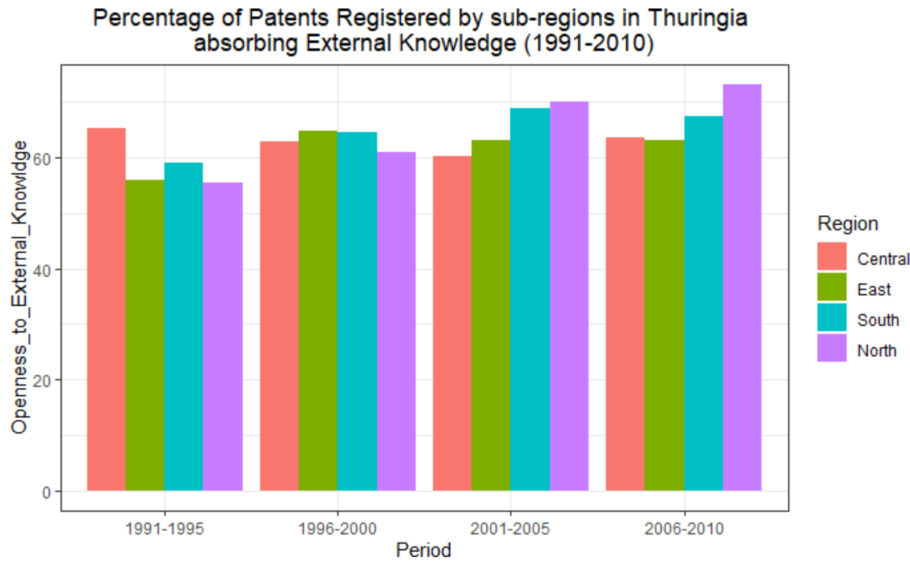
3. Average forward citation of patents by sub-regions in different 4 periods



Forward citations are the citations received by a patent–can be used to assess the technological impact of inventions their cross-technology, geographical impact. The technological impact of inventions can indicate the economic importance of patents. The value of a patent and the number and quality of its forward citations have repeatedly been found to be correlated (OECD, 2009). Therefore, then number of forward citations is a good indicator to study technological capability.

In analyze result, the average citations received by patents registered by North in the second and third periods were significantly higher than patents of other sub-regions. It could be explained by the fact that the number of patents in the North was too low so that individual patents had a large impact on the overall view. There were two patents in the north by the Max-Planck-Society on RNA which are highly cited, which should be considered as outliers. Generally, the average citations of patents registered by four sub-regions are smaller than 2, except for North Thuringia in 1996-2000 and 2001-2005. It seems to be difficult to state which sub-region has the most valuable patent during the whole period based on the average measure.

4. Openness to external knowledge by sub-regions in different 4 periods



Interaction of innovative actors across regional innovation systems plays an important role in technological innovation; i.e. actors can reach and select state-of-the-art knowledge or technique. In this seminar, we relate patent applicants or patent inventors to construct an openness to external knowledge at regional level. We follow the assumption that people usually live not far away from the place where they work (Holger Graf, 2011).

Overall, sub-regions in Thuringia had more than 55 percent of their patents that were invented by at least one inventor living outside Thuringia. In this seminar, we assume that the patent having at least one inventor whose address is not in Thuringia has a greater opportunity to absorb external knowledge. Therefore, the percentage of this type of patent could be used to represent the openness of a sub-region to external knowledge. The proportion of patents registered by Central and East Thuringia having external knowledge inconsiderably fluctuated from 1991-1995 to 2005-2010. Around 60% of patents in Central and East Thuringia had an external source of knowledge. Noticeably, there were more and more patents using external human resources in North and South Thuringia; these percentages of patents absorbing external sources of knowledge increase by nearly 8% during the period.

II. Technological Proximity

Since we have over 100 3-digit IPC classes, it is quite challenging to see whether the patenting activities of regions are similar or not by simply looking at all IPC classes of each region. To access the similarity of the technology domain of patents registered by regions, we construct the technological proximity or technological distance. It will provide a specific value that facilitates our comparison.

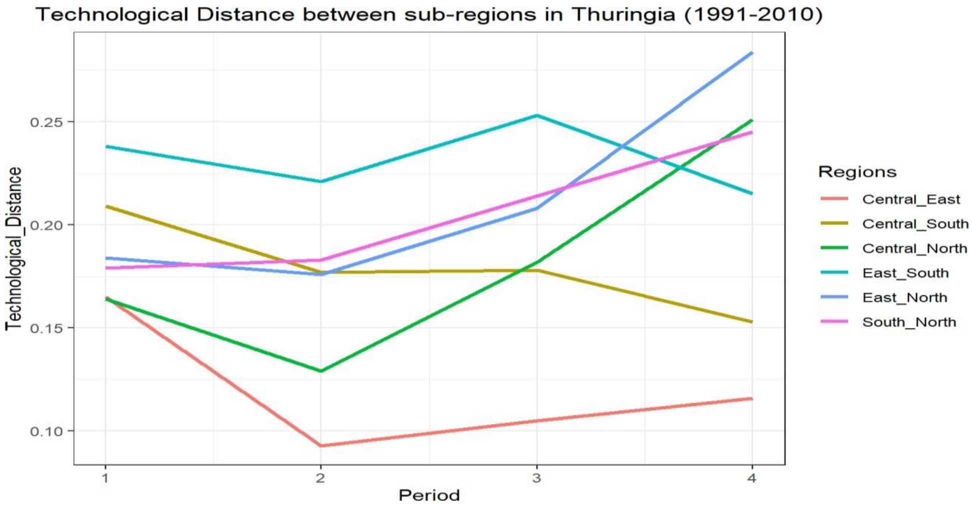
In order to measure technical proximity, we use 3-digit patent classifications listed on each region's patents, provided by the International Patent Classification (IPC). The distance between regions' technological capabilities is indicated by calculating the difference in regions' shares of patents in various patent classes. Two regions are close if they tend to patent in the same technological domains. In other words, their distribution of patents across classes are similar. Typically, this type of analysis employs only the first classification of patents to determine technological allocation. However, Mary et al. (2008) figured out that increasing sample sizes by aggregating years or using all of the listed patent classes on a patent, rather than just the first helps to improve the precision of patent-based measures of technological proximity. In our seminar, we follow both suggestions by aggregating years and proceed with analysis using 3-digit patent classifications.

Constructing technical proximity includes two steps. Firstly, we build up a vector of 3-digit IPC classes shares for each sub-region. Patent k's location in technological space is represented with a 1 on the dimension associated with each listed class and zeroes elsewhere. The region's location in knowledge space is estimated by summing the vectors representing each of the M patents, patent class element by element, then dividing the elements by the number of classes listed across all M patents used in the calculation. The elements of each region's vector of 3-digit IPC classes shares sum to 1, and the elements of p estimate the shares of the region's knowledge that reside in each of the technological domains.

After that, we calculate Euclidean distance (E) to compare two IPC classes shares vectors.
Technological proximity between region i and j is defined as

$$\sqrt{\sum_{c=1}^{N}\left(p_i^c - p_j^c\right)^2},$$

where N =129 (the number patent classes in 2010).



The distances between Central, East, and South Thuringia fluctuated during the period. However, these distances, generally, reduced to some extent. The difference in patenting activity of East and South was much larger than the differences between others from 1991-1995 to 2001-2005. The patenting activities of Central and East were nearly the most similar in Thuringia in the first period. Moreover, the specialization of patenting activities of Central and East became closer and closer. Their distance was smallest in 1996-2000, three of their top five 3-digit IPC class were similar (G01, A61, and C07), following by a slight increase in the next periods. Remarkably, the technological distances between North and the rest part of Thuringia became more extensive, except for a decrease in the technological distance between Central, and East with North Thuringia in 1996- 2000. In 2006-2010, the technological distance between North and others became significantly larger than the distance between Central, East, and South.

D. Summary

In this seminar, we have studied the technological capability and technological proximity of sub-regions of Thuringia over the period 1990-2010 through patent activities. Thanks to the government policy, the patent activities of Thuringia in 4 sub-regions witnessed an increase over the study period.

We propose that patent data is able to capture technological capability. First, the total number of patents can be a measure of technological capability: the more patents one has, the higher one's technological capabilities. Regarding the number of patents, East and Central outperformed the other sub-regions. Second, the number of the sectors under which the patent has been registered can also represent technological capabilities, namely the diversity or scope of the capabilities. One average, patents registered by East and North Thuringia have a broader scope than the rest of this state. Third, the number of citations a patent has received can be another measure of technological capabilities, namely the quality of the innovation. The average number of citations received by patents owned by sub-regions in Thuringia is too low, particularly, this measure is less than 2 for all regions during the period, except for North Thuringia. Finally, the ability to cooperate with investors from outside regions also can be a measurement for technological capability. More than 55 percent of patents registered by sub-regions in Thuringia absorbed the external source of knowledge. The openness to external knowledge of North, South and East Thuringia increased while Central experienced a slight decrease.

After examining the technological capability of sub-regions in Thuringia individually, we construct the measure for the similarity between technological knowledge domains of these sub-regions. In order to increase the precision of the technological proximity, we apply Euclidean distance function using the aggregated data by years, and 3-digit IPC classes. Overall, while the technological distances between the North and the rest part of Thuringia became more extensive, the knowledge domain of patenting activities of South, Central and East became more similar.

Our seminar had potential limitations. Firstly, one of our measures for technological capability is the number of forward citations; therefore, we can only carry out our analysis and comparison for the patent data by 2010 in order to let some time pass for a patent receive the forward citation. As a result, we are unable to see changes in the technological capabilities of Thuringia after the Great Recession in 2008-2009. Secondly, in terms of the number of forward citations, the average measure could not be an appropriate proxy for the actual number of forward citations received by a patent in Northern Thuringia. There were two patents in the north by the Max-Planck-Society on RNA which are highly cited, which should be considered as outliers. It is misleading to use average measure; therefore, there is room for improvement. One can employ a statistical inference, i.e. independent samples t-Test, to investigate the statistical difference in the means of the number of forward citations received by patents registered by the North and the rest of Thuringia.

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