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The Multiple Facets of Regional Innovation

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Abstract

Measuring innovation activities involves critical decisions in selecting appropriate indicators and levels of observation. The present article contributes to the literature on this subject by addressing innovation measurement on the regional level. The dimensionality of regional innovation is examined by applying a principal component analysis on seven innovation output indicators in European regions from the Community Innovation Survey and two traditional indicators, i.e. patent applications and R&D expenses. The analysis reveals that regional innovation indeed needs to be regarded as a multidimensional concept involving technological, commercial and service innovation. These distinct innovation activities exhibit clear regional patterns with both technological and service innovation concentrated in highly developed territories and urban areas displaying particularly strong innovation performance in services. In addition, commercially successful innovation appears clustered in backward regions and may thus be seen as imitation efforts and technology transfers from areas at the innovation frontier. Overall, the elaborated findings suggest that the selection of innovation indicators in empirical analyses demands appropriate motivation and theoretical guidance.

JEL codes: R11, O31, O33

Keywords:

Regional innovation

Innovation dimensions

Principal component analysis

Patent applications

Community Innovation Survey

1. Introduction

Contemporary scientific literature (Howells, 2005; Hudson, 2011; Raspe and Van Oort, 2006; Romer, 1990) as well as economic policy papers (OECD, 1996; European Commission, 2005, 2010) consider the knowledge-based economy to be fundamental for the development of industrial nations. This finding is based on the idea that knowledge is an essential component of technological progress as well as innovation and as such shifts the transformation curve of an economy. In the wake of this literature innovative activity has come to be accepted as a cornerstone of economic competitiveness and social prosperity (OECD, 2010).

An important line of research posits that innovative activity is not a linear process stretching sequentially from basic research to commercial marketing (Kline and Rosenberg, 1986). Thus, strong non-linear dynamics and feedback loops can be assumed, which naturally complicate questions of causality. From an economic policy perspective, agendas stimulating the production of knowledge aim at various economic levels (firm, territorial, national). Consequently, innovation is not confined to firm boundaries but occurs in networks with multiple interacting participants. In this context, the location of and limited access to knowledge highlights the importance of the regional dimension for innovative activity as a platform for social and institutional networks. These enable sustained personal interaction and frequent exchange of knowledge. According to this particular perspective, attempts have been made to frame regional networks within the concepts of innovative milieus (Camagni, 1995; Crevoisier, 2004) or regional innovation systems (Cooke et al., 1997). Hence, innovative activity is conceived from a regional perspective in the present paper.

The operationalization of the innovation concept is essential for all empirical analyses, independently of their analytical emphasis (focusing on either the effects or sources of innovation) and their theoretical context. However, innovation is not a directly observable phenomenon and comprises a multiplicity of aspects, as shown by the efforts to standardize research and development (R&D) and innovation undertaken in the Frascati Manuals (OECD, 2002) and the Oslo Manuals (OECD, 2005). This gives rise to a contentious issue in the regional economic literature, on which the present article focuses: the majority of empirical analyses use the number of patents (in diverse delineations and standardizations) as metric for measuring the intensity of regional knowledge production. At the same time, a line of argumentation extends through the literature to critically or self-critically make reference to the theoretical and methodical limitations of this indicator. This critique, however, seems not to have had a decisive impact on indicator selection in empirical analyses. Consequently, there is a need to clarify whether the critical objections are substantial, or, although theoretically justifiable, are irrelevant for empirical regional innovation research.

This article aims to contribute to this discussion by examining the question: is regional innovation a uni-dimensional phenomenon suitably measured with patent statistics, or does it consist of several independent dimensions that require multiple indicators? For this purpose, using the conceptualizations of innovation put forth in the scientific discussion we develop a framework to organize innovation based on the systematizations contained in the Oslo Manual. This scheme captures various important innovation aspects without asserting any claim to completeness. For a set of theoretically accurate and regionally available indicators we assess which part of innovation is captured particularly well by which innovation indicator. Subsequently, this set of indicators is examined for its dimensionality.

If all indicators target the same dimension, the question as to which innovation indicator should be used in empirical analyses would be of secondary relevance. In this case it would be conceivable that theoretically differing aspects of innovation are determined by the same factors in a uniform regional innovation regime in such a way that they vary concertedly and carry only their common information. However, if the indicators represent multiple independent dimensions of innovation, it would be interesting to know the innovation characteristics these dimensions exhibit.

The article proceeds as follows: Section 2 illustrates several innovation concepts and their application in the regional innovation literature. Subsequently, the framework for arranging the various innovation aspects is introduced. Section 3 presents nine innovation indicators and their corresponding databases and proposes to assess which indicator captures which innovation aspect particularly well. In Section 4, the dimensionality of the regional innovation indicators is examined by applying principal component analysis (PCA). A comparison of the resulting dimensions and economic indicators is conducted in order to facilitate the interpretation. Finally, Section 5 discusses the results and implications of the research.

2. Literature

The innovation literature is still home to an ongoing debate about the correct operationalization of innovation in empirical studies (Archibugi, 1992; Griliches, 1990; Kleinknecht et al., 2002; Smith, 2005). This lacking consensus has given rise to various theoretical conceptualizations of innovation and caused several indicators to be applied in an effort to measure the production of new knowledge so far. This indicates the complexity of the innovation concept and the difficulties involved in measuring it appropriately.

Patent counts, i.e. the number of patents applied for or granted, are the predominant innovation metric employed in regional innovation studies. Patents are used to measure regional innovative performance, because they represent newly developed knowledge that can be assigned to the place of origin of their creators. Hence, the data are available for long-running time periods as well as for sub-national territories.

Data on patents have been integrated in various ways. In studies of the determinants of innovation, patent statistics are often applied to measure economically useful new knowledge in the knowledge production function framework initiated by Griliches (1979). As a general measure of innovation, patents are thus employed to reflect the total innovative output of a region (Bottazzi and Peri, 2003; Moreno et al., 2005, 2006; Hauser et al., 2007; Buesa et al., 2010). The number of patents is also applied to proxy new knowledge in analyses of the effects of innovation (Bilbao-Osorio and Rodríguez-Pose, 2004). In this context, patents can be classified according to technology classes following the International Patent Classification (IPC) (Antonelli et al., 2011; Quatraro, 2010) in order to reflect different components of the regional knowledge base. Additionally, several studies have used patent data in the form of patent citations, in order to better examine flows of valuable new knowledge across regions (Maurseth and Verspagen, 2002; Paci and Usai, 2008).

The second traditional indicator of innovative activity is statistics on expenditures R&D efforts. Similar to patent statistics, R&D data have been collected for long periods and are internationally comparable. However, R&D constitutes an input factor of innovation and is therefore commonly employed as an independent variable in the knowledge production function (Fritsch and Slavtchev, 2011; Hauser et al., 2007) or as measure of innovative activities in studies of the effects of innovation (Rodríguez-Pose and Crescenzi, 2008). Furthermore, in combination with patent data or other innovation-related variables, R&D data have been used to calculate specific composite indicators reflecting regional innovation (Crescenzi, 2005).

More recently, in order to directly address newly introduced innovations, information on new product announcements was collected from technical and trade journals. The methodology for these indicators originates from Edwards and Gordon (1984) and is applied on a territorial level by Acs et al. (2002). This direct focus on innovations makes it possible to effectively assign them to the industries where they are developed (Coombs et al., 1996). However, the time-consuming process of data collection makes such data very rare.

The availability of several possible innovation metrics does not solve the problem of innovation measurement. The ongoing debate shows that each innovation indicator is characterized by strengths and weaknesses. Due to their importance in innovation measurement, the limitations of patent data are particularly discussed in a challenge to the suitability of this indicator to measure innovation. The main objections can be summarized in the following points. A major problem entailed with patents is that they primarily capture inventions and not commercial innovations (Smith, 2005). The indicator also misses all non-patentable innovations and those not patented for firm-strategic reasons. Furthermore, their sector specificity is accentuated by the differing patenting activity across industries (Blind et al., 2006; Brouwer and Kleinknecht, 1999; Cohen et al., 2000; Harabi, 1995; Levin et al., 1987). The ability of patent data to reflect innovations also varies with their typology: product innovations are better reflected than are process innovations (Arundel and Kabla, 1998; Blind et al., 2003; Brouwer and Kleinknecht, 1999; Cohen et al., 2000). Since patents are rarely used in the service sector (Blind et al., 2003; Hipp and Grupp, 2005), the production of new knowledge in these industries is only weakly (if at all) captured by patent data. Moreover, patents do not provide information on the economic value of the protected technology (Hall et al., 2001) and vary substantially with respect to their economic impact (Gambardella et al., 2008; Pakes and Griliches, 1980).

The limited ability of R&D data to reflect innovative activity is expressed by the fact that they constitute only one of several input factors to innovation. The data measure only parts of the resources devoted to innovative activities and do not reflect the transformation efficiency of the innovation process (Coombs et al., 1996). Consequently, they do not provide information on the output side of the innovation process (Kleinknecht et al., 2002).

Discomfort with the existing innovation indicators and the stark contrast between theoretical and empirical operationalization of innovation have led to the development of a set of instruments that should more accurately reflect the outcome of innovation activities. The implementation of these instruments is provided by the OECD in the document 'The Measurement of Scientific and Technological Activities, Proposed Guidelines for Collecting and Interpreting Technological Innovation Data,' known as the 'Oslo Manual' (OECD, 2005). A major attempt to implement these concepts is the Community Innovation Survey (henceforth referred to as CIS) that surveys firm innovation in the European Union. Besides input factors of innovation, the Oslo Manual accounts for the complexity of the innovation process by assessing various aspects of innovation output. Essentially, the Oslo Manual uses established differentiations to classify innovations as follows.

Firstly, innovations need to be distinguished by type. Technological innovations pertain to product and process innovations, whereby product innovations are further distinguishable into goods and services innovations. Secondly, innovations are characterized according to the degree of novelty of the developed technology. The minimum requirement made of an innovation is that it be new to the firm. These innovations reflect the adaptation and imitation of knowledge. If the innovating firm introduces the innovation in its market before its competitors, the innovation is classified as new to the market. Market novelties constitute knowledge previously not existing in this form in the context of the firm's market. Thirdly, this approach to innovation also includes the outcome of innovation, which is reflected, among other things, in the market success of the commercialized innovation. These differentiations serve as the basis for a simple innovation classification framework (see Table 1). The framework clearly comprises twelve different aspects for the analysis of innovation. In Section 3 of this article, the construction of regional innovation indicators will pick up on the twelve fields in Table 1.

The various innovation metrics employed capture different of these aspects better than others. This underlines the need to identify indicators able to more accurately reflect innovation. Such instruments are provided at the firm level by the CIS. Although the individual indicators do not reflect all parts of the framework in Table 1, they are at least able to explicitly target specific aspects of innovation.

- INSERT TABLE 1 ABOUT HERE -

CIS data offer a unique range of research possibilities and several different indicators of technological innovation output. Consequently, the definition of innovation varies across the studies using these data. A first part of the firm-level CIS literature focuses on impacts of particular factors on the introduction of specific types of innovation and the degree of novelty of innovations (Reichstein and Salter, 2006; Frenz and Ietto-Gillies, 2007, 2009; Vaona and Pianta, 2007; Mention, 2011). A second research stream examines innovation strategies and the use of knowledge sources (Cassiman and Veugelers, 2002; Laursen and Salter, 2004; Srholec, 2009). A third set of studies focuses on the effects of innovation on performance measures (Duguet, 2006; Griffith et al., 2006; Hall et al., 2009).

Although the use of CIS data in firm-level innovation studies is substantial, their use in regional approaches is still rare (for an exception see Evangelista et al. (2001). However, the suitability of regionalized CIS data for economic analysis is reflected in their application in the Regional Innovation Scoreboard (RIS) (Hollanders et al., 2012, 2009a)[1]. The objective of the RIS is to benchmark regions according to their innovation performance. For this purpose, regions are assessed on different innovation-related characteristics, partly based on regionalized data derived from the CIS. Applying cluster analysis, the RIS identifies groups of regions with similar innovation systems and assigns them to four performance groups (innovation leaders, innovation followers, moderate innovators and modest innovators). Consequently, the RIS focuses on ranking regions on the basis of their innovation strengths and weaknesses and does not aim to develop a more refined understanding of innovation measurement at the regional level. The latter is the focus of the present article.

[1] The regionalization of CIS data is not without problems and needs to regard some important methodological issues and limitations (see Evangelista et al. ,2001; Hollanders et al. 2009b). Firstly, innovative activities cannot be assigned to the actual place where they are performed. This is because the unit of observation employed by CIS is the enterprise and not the production plant. A second issue concerns the limited regional stratification of the CIS sample for some countries, which may result in small sample sizes for regions and the underrepresentation of certain industries.

3. Data and method

3.1. Data and measures

The CIS serves as the fundamental data source for the present analysis. The survey collects input and output information on the innovation activities of European firms over a three-year period. The survey is conducted in European Union member states plus Iceland, Norway, Serbia and Turkey. The harmonized survey methodology follows the Oslo Manual (OECD, 2005)[2]. In the CIS, technological innovations refer to significantly improved products (goods or services) and processes. These innovations should at least be new to the enterprise under investigation. They may, however, be developed in cooperation with other enterprises or by other companies or institutions. We derive the data from the sixth wave (CIS2008) of the survey, which covers the period from 2006 to 2008.

Additionally, to facilitate interpretation of the results we integrate the two traditional innovation metrics (R&D expenditures and patent applications) as benchmark indicators. Patent statistics are taken from Eurostat's regional database and describe the average yearly patent applications made between 2006 and 2008 by inventors resident in a region. The data for Norway, for which there are no Eurostat data, were collected from the EPO and show the average yearly patent applications made between 2006 and 2008 by applicants resident in Norway. R&D expenditure data are collected from Eurostat and integrated as the average intramural expenses (million Euros) from 2006 to 2008 from the private sector, government sector, higher education sector and private non-profit sector.

Given that the CIS data are available only for a subset of European regions, we composed a final dataset of 60 regions[3]. Due to varying regional CIS sample sizes in different countries and in order to increase the number of units in the dataset, the levels of analysis are chosen as a combination of NUTS1[4] (Cyprus (1), Germany (16), Ireland (1), Estonia (1), Latvia (1), Lithuania (1), Norway (1), Portugal (1), the Slovak Republic (1), Slovenia (1), Spain (6) and the United Kingdom[5] (12))[6] and NUTS2 (Austria (9), the Czech Republic (8)) ranked regions[7]. The variation in regional CIS sample sizes is caused by the

[2] For metadata and methodological issues see: http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/en/inn_esms.htm.

[3] Regionally classified CIS data are not available as a centralized database. Thus, aggregated data had to be collected separately from each national statistics office after requesting data access from it.

[4] Eurostat's *Nomenclature of territorial units for statistics* (NUTS) classification divides the European economic territory for statistical and analytical purposes. For more information see: http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction.

[5] Source: ONS

[6] For Cyprus, Ireland, Estonia, Latvia, Lithuania, Norway, Slovakia and Slovenia the country level corresponds to the NUTS1 level. Portugal consists of three NUTS1 regions. However, the Azores and Madeira are very small and structurally weak autonomous regions relative to the region Continente. Hence, also Portugal was included as a single unit. The Spanish Canarias region is not included due to data inavailability.

[7] In order to assure robustness of the results, all calculations are also performed at a homogeneous NUTS1 level. This yields substantially the same results. These results are not reported here, but can be made available by the authors on request.

limited regional stratification of the survey in certain countries. Consequently, the total of 91,948 firms on which the CIS indicators are based are not evenly distributed among the regions (ranging from 64 firms in Germany's Saarland to 10,707 in eastern Spain; the mean number of firms per region is 1,532). The data for Germany, the Czech Republic, Spain and the United Kingdom are based on the NACE[8] rev. 2 divisions for CIS core and additional coverage[9], as set out in the CIS2008 methodological recommendations, whereas the data for the remaining territorial units include only the CIS core-coverage industries[10].

We elaborate a total of nine variables reflecting regional innovation. To eliminate size differences as a possible source of distortion, all indicators are included as either percentages or standardized values. Patent and R&D expenditure data are both standardized per million inhabitants of a region. All CIS-based indicators are constructed at the firm level and then aggregated on the regional level (see Table A.1 in the Appendix for detailed information on the construction of firm-level CIS indicators). Subsequently, we assess the innovation indicators according to their effectiveness in reflecting the conceptual innovation aspects of the Oslo Manual (innovation typology, novelty and economic success) shown in Table 1 and labelled 1 to 12. From the CIS we specifically select those indicators that best describe these innovation aspects. The constructed variables and the covered innovation aspects are shown in Table 2.

- INSERT TABLE 2 ABOUT HERE -

Since patent protection demands certain standards of novelty and originality, the indicator focuses on market novelties and does not regard imitations. Consequently, the patent indicator covers market novelties in the form of goods innovations well (aspects 3 and 4; see Table 1). However, differentiation according to the economic success of innovations is not possible, since the indicator does not provide information on this criterion. Furthermore, it also captures patented services (aspects 7 and 8) and process innovations (aspects 11 and 12). Since these two types of innovation are less likely to be patented than are goods, they are reflected only weakly by patent data. R&D expenditures incur for all innovation activities. Therefore, the indicator covers all 12 innovation parts to some extent, but cannot differentiate for the individual aspects.

[8] The *Nomenclature statistique des activités économiques dans la Communauté européenne* (NACE) is the classification system of European industries. For more information see: http://epp.eurostat.ec.europa.eu/portal/page/portal/nace_rev2/introduction.

[9] According to the CIS methodological recommendations the following NACE rev. 2 divisions refer to CIS core coverage: 05-09, 10-33, 35, 36-39, 46, 49-53, 58, 61, 62, 63, 64-66, 71. Additional coverage includes the following NACE rev. 2 divisions: 41-43, 45, 47, 55-56, 59-60, 68, 69, 70, 72, 73, 74, 75, 77, 78, 79, 80, 81, 82. Agriculture and forestry and fishing (NACE 01-03) are excluded from the present analysis.

[10] Again, in order to check the sensitivity of our results, all calculations are also performed for the territorial units where the indicators are constructed using the industries that comprise core and additional coverage. This sensitivity yields substantially the same results.

The CIS offers several indicators describing the output of innovative activities. These refer to the introduction of specific innovation types as well as novelty and turnover shares of innovative products. The introduction of the various innovation types is surveyed with binary variables (assigning the value 1 if the enterprise introduced such innovation). The aggregation gives the percentage of firms in a region that introduced the respective innovation type. As mentioned above, the CIS distinguishes product innovations as being goods or services. The share of goods innovators covers innovation aspects 1 to 4, but does not allow classification according to novelty or success. The same holds for the two indicators reflecting the share of services innovators (covering aspects 5 to 8) and the share of process innovators (aspects 9 to 12).

Similarly, the novelty of product innovations is measured with two binary variables referring only to the introduction of products (here, the CIS does not distinguish between goods and services) new to the firm or products that were also new to the market. The aggregated indicators describe the regional share of new-to-firm product innovators (covering innovation aspects 1, 2, 5 and 6) and the regional share of new-to-market product innovators (covering innovation aspects 3, 4, 7 and 8). The economic success of product innovations is captured with two additional variables. The variables designate the firms' turnover shares of product innovations new to the market and the turnover share of those product innovations that were only new to the firm. Consequently, the aggregated variables reflect the mean turnover share of new-to-firm innovations (aspects 2 and 6) and the mean turnover share of new-to-market innovations (aspects 4 and 8) for all firms in a specific region. No novelty or economic success data are available for introduced process innovations.

3.2. Method

The objective of the present analysis is to examine the dimensionality of regional innovation. Of the different methods used for such purpose, principal component analysis (PCA) has been widely applied. By pooling correlated variables in principal components or factors, this multivariate statistical method can be used to uncover the number and content of latent structures of a dataset. Consequently, we process all nine regional innovation indicators with PCA. Essentially, the objective is to analyse whether all variables represent a single dimension of regional innovation. In this case, all indicators would reflect regional innovation similarly, and the most suitable indicator (in terms of practicality) could be chosen to proxy innovation. Alternatively, the different dimensions of regional innovation can be identified and interpreted with regard to their theoretical substance. In this case, selection of the innovation proxy requires appropriate motivation, and the simultaneous examination of multiple innovation dimensions possibly increases the information value of an analysis. For this purpose, the elaborated innovation dimensions are compared to regional measures referring to economic performance (GDP per capita and GDP per capita growth), localisation economies (manufacturing employment, employment in high and medium-high technology manufacturing and employment in knowledge-intensive services) and urbanisation economies (population with urban residence and population density). These measures are given in Table 3 (with summary statistics reported in Table A.2 in the Appendix).

- INSERT TABLE 3 ABOUT HERE -

4. Empirical results and discussion

We process all nine variables with PCA applying a Varimax rotation[11]. According to the Kaiser criterion, the PCA extracts three components with an overall explained variance of 83.3 %[12]. Bartlett's Test of sphericity produces highly significant results and the Kaiser-Meyer-Olkin criterion of sampling adequacy is 0.659, suggesting general suitability for the variables to be used in the PCA. The communalities and the rotated component matrix of the PCA are shown in Table 4.

- INSERT TABLE 4 ABOUT HERE -

The communalities denote the percentage of explained variance of the variables. All communalities are satisfactory and range from 0.67 to 0.92. The extracted components are illustrated in Table 4. The loading structure provided by the PCA illustrates that regional innovation should indeed be regarded as a multidimensional concept. Six variables load on component 1 with factor loadings exceeding 0.5, ranging from 0.54 to 0.93. These variables are the CIS indicators referring to the percentage of firms with introduction of goods and process innovations, the number of patent applications, both variables describing the degree of novelty of introduced product innovations and the R&D expenditures. This component is termed 'Technological Innovation' due to the variables loading on it.

The third component denotes the innovation intensity in the service sector (and is thus named 'Service Innovation'). The low loading on all variables relative to product innovation illustrates that these activities are not a by-product of technological innovation and that for service innovations patents are irrelevant for all practical purposes. Putting the sole emphasis on patent statistics as innovation indicators is thus somewhat problematic in the context of a highly developed economy. This observation is underlined by the high loading of the variable R&D expenditures that is equally distributed on the first and third component. Hence, R&D efforts are presumed in both components and increase innovations in the service

[11] A PCA with the alternative Oblimin rotation shows no significant correlations among the resulting factors.
[12] The eigenvalue of the third component is slightly less than 1. However, considering the objective of this study it is still regarded as an independent component explaining a substantial part of the variance (16.6%).

sectors. Besides service innovations and R&D expenditures, the only variable with a somewhat higher loading on the third component is ‘New-to-firm product innovators,’ where the term product includes both goods and services and thus might indicate novelties in the second category.

The second elaborated component, termed ‘Commercial Innovation’, is qualitatively completely different: it is characterized by a high share in turnover of new products, which reflects a stark break in the product lineup. As driving forces we can identify the improvement of production processes and ready access to dynamic markets. It is particularly noteworthy that high values for the component are associated with low values for R&D expenditures. Renouncing R&D investments is made possible by implementing new processes that require new production facilities to be purchased. The latter are not registered as intramural R&D expenditures (OECD, 2005). The component ‘Commercial Innovation’ also indicates that the definition ‘new-to-market’ may refer to products that are already established in other markets and successfully implemented in the home market of the firm. As a matter of fact, the variable ‘Turnover share of new-to-firm product innovations’ loads only on the second component, whereas the variable ‘Turnover share of new-to-market innovations’ also exhibits a minor loading on ‘Technological Innovation’.

When turning the interpretation from the composition of the components to the loadings of the individual variables, another interesting picture emerges: On the one hand, process innovations are part of innovation activities striving for highly patentable and technological innovation outcomes. On the other hand, they help firms in somewhat backward markets become up-to-date with cutting edge technology in more highly developed regions. Investments in R&D do not seem to play a sizable role in this catch-up process; however, they are vital in developing authentically new products and services. The market introduction of such novelties apparently requires considerable time, as suggested by a relatively low coefficient of ‘Turnover share of new-to-market products’ of 0.30 for ‘Technological Innovation’.

- INSERT TABLE 5 ABOUT HERE -

Interpretation of the three components is facilitated by investigating the correlations with macro-economic characteristics given in Table 5. The regional factor scores of ‘Technological Innovation’ are correlated with high GDP per capita, low economic growth and a large share of labor force in manufacturing. The negative correlation between income and growth is typical for highly developed areas. High values for this component are indicative of advanced industrial regions with radical innovation activities that require considerable time for commercialization in saturated markets.

The component ‘Service Innovation’ exhibits a structure similar to that of the first, except that degree of development is manifested in the service sector. Regions that score high on this component are represented mainly by development hotspots in urban areas.

High values for the component ‘Commercial Innovation’ are associated with low income levels and high growth rates. These regions do not exhibit a specialized labor force either in the service sector or in manufacturing industries. Various factors facilitate the successful introduction of new products into the home markets through adoption of technology and imitation of novelties: high growth in domestic markets, traditional access to equally backward but dynamic regions and the technological differential as compared to highly developed areas.

When interpreting the three components it is important to take into account their orthogonality. Thus, a region may exhibit high values for both technological and service innovation (components 1 and 3). The scatterplots in Figures 1 and 2 illustrate such a combination. Naturally, given the exploratory nature of the study, abstracting from the overall profile and interpreting the position occupied by particular regions requires due caution. However, several observations can be identified that fit neatly with conventional wisdom: Baden-Württemberg and Vienna as regions positioned equally well with regard to technological and service innovation; London with a clear emphasis on novelties in the service sector; Prague, Estonia and Latvia exhibiting strong catch-up dynamics with high values for ‘Commercial Innovation’.

Regions that score high values for either technological or commercial innovation are comparatively easy to categorize (i.e. exhibit clear innovation strategies). Areas with low values for both dimensions can be considered as either focusing on service innovation or being overall backward. A more challenging puzzle is constituted by territories that display high values for both components and thus combine characteristics of a high technology economy and a catch-up region, such as Vienna and Upper Austria. This phenomenon may be due to Eastern Austria's geographic proximity to and traditional integration with the new member states of the EU. These regions enable the neighboring Austrian areas to benefit disproportionately from the restructuring and convergence processes in the central and eastern European countries.

- INSERT FIGURE 1 ABOUT HERE -

- INSERT FIGURE 2 ABOUT HERE -

5. Conclusion

The research question stated at the outset can be broken down into two related components: Is regional innovation a concept consisting of more than one dimension, and does the reliance on patent statistics produce considerable opportunity costs in the form of neglected aspects of regional innovative activity? For both of these questions the results suggest clear answers.

First, for a comprehensive analysis of regional innovation several dimensions need to be considered, only one of which is currently reflected in patent statistics. Given that we used only an exemplary subset of CIS innovation output indicators, it is very well possible that more than three dimensions can be identified. An in depth investigation might produce additional dimensions of regional innovative activity with an extended dataset that incorporates also input factors in innovation activities such as human capital, institutional framework or network structures.

Second, the analyses provided in the paper clearly show that a concentration on one innovation indicator inevitably entails a loss of important information. In particular, patent statistics do not reflect relevant innovative activity in the service sector (e.g. London occupies a comparatively low position in traditional innovation rankings) and focus on cutting-edge technology (in the form of patented and patentable knowledge) while neglecting the commercial value of novelties and the impulse derived from the transfer of knowledge to new markets. The latter point captured by the second component seems to be of particular importance for convergence processes in the EU.

Besides documenting the multi-dimensionality of regional innovation, the presented findings also make an appeal for greater care in selecting appropriate innovation indicators in future economic analyses. Instead of falling back on justifications derived from data availability, the selection of indicators should be guided by the theory underlying the research question at hand. In order to enable such investigations, access to regional data from sources like CIS has to be comparably as easy as access to regional patent statistics. At the time of this writing each national statistics office must be contacted separately to retrieve the regional affiliation of CIS data. Hence, the potential explanatory power of the data is considerably and unnecessarily restricted.

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Appendix

- INSERT TABLE A.1 HERE -

- INSERT TABLE A.2 HERE -

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Table 1
Classification of innovation aspects as suggested by OSLO Manual (OECD, 2005)

		Firm novelty		Market novelty	
		no success	**success**	**no success**	**success**
Products	**Goods**	1	2	3	4
	Services	5	6	7	8
Processes		9	10	11	12

Table 2

Regional innovation indicators developed from the Community Innovation Survey and Eurostat Regio Database

Name	Source	Description (aggregated indicator[a])	Innovation aspects (Table 1)
Goods innovators	CIS2008	% of goods innovators	1, 2, 3, 4
Services innovators	CIS2008	% of services innovators	5, 6, 7, 8
Process innovators	CIS2008	% of process innovators	9, 10, 11, 12
New-to-firm product innovators	CIS2008	% of new-to-firm product innovators	1, 2, 5, 6
New-to-market product innovators	CIS2008	% of new-to-market product innovators	3, 4, 7, 8
Turnover share of new-to-firm product innovations	CIS2008	Mean turnover share of new-to-firm product innovations	2, 6
Turnover share of new-to-market product innovations	CIS2008	Mean turnover share of new-to-market product innovations	4, 8
Patent applications	Eurostat/European Patent Office (EPO)	Patent applications per million inhabitants	3, 4, 7, 8, 11, 12
R&D expenditures	Eurostat	R&D expenditures (million Euros) per million inhabitants	1 to 12

Notes:

[a] Aggregation method: Binary CIS indicators result in regional share (percentage) of firms that introduced the respective innovation type (or novelty degree of innovations); turnover share variables are aggregated to the mean turnover share of innovative products over all firms in a region. The patent and R&D indicators are standardized with the number of million inhabitants of the region.

Table 3

Regional economic indicators as proxies for economic development & growth and localisation & urbanisation economies

Name	Source	Description
GDP pc	Eurostat regional database	GDP (gross domestic product) per capita (purchasing power parity)
Δ GDP pc	Eurostat regional database	GDP (gross domestic product) per capita (purchasing power parity) (yearly growth rate 2003 to 2008)
Employment manufacturing	Eurostat (Labor Force Survey)	Manufacturing employment (NACE rev. 2 divisions: 10 to 33) as share of total employment (in 2008)
Employment HTC + HTC_M	Eurostat (Labor Force Survey)	Employment in high and medium-high technology manufacturing (as share of total manufacturing) (in 2008)[a]
Employment KIS	Eurostat (Labor Force Survey)	Employment in knowledge-intensive services (as share of total services employment) (in 2008)[b]
Urban residence	Eurostat regional database	Share of population living in NUTS 3 regions classified as urban areas (in 2008)[c]
Population density	Eurostat regional database	Population per km² (in 2008)

Notes:

[a] Calculated according to Eurostat's classification of manufacturing industries regarding their global technological intensity: Sum of employment in high-technology manufacturing (NACE rev. 2 sections 21 and 26) and medium-high technology manufacturing (NACE rev. 2 divisions 20 and 27 to 30).

[b] According to Eurostat, the following NACE rev. 2 divisions are classified as knowledge-intensive services (KIS): 50, 51, 58 to 63, 64 to 66, 69 to 75, 78, 80, 84 to 93.

[c] Calculation of this indicator is based on the European Union urban-rural typology. This typology classifies regions as 'predominantly rural,' 'intermediate' or 'predominantly urban' (Eurostat, 2010). This typology is not available for Norway. Hence, this variable is not calculated for this country.

Table 4
Communalities and loading matrix from principal component analysis on regional innovation indicators

Variables	Communalities	Components		
		1	2	3
Goods innovators	0.88	0.93	0.11	0.06
New-to-market product innovators	0.89	0.90	0.19	0.21
Patent applications	0.81	0.80	-0.38	0.17
New-to-firm product innovators	0.88	0.76	0.24	0.49
Process innovators	0.77	0.69	0.54	-0.03
R&D expenditures	0.67	0.54	-0.33	0.53
Turnover share of new-to-firm product innovations	0.88	-0.13	0.93	-0.05
Turnover share of new-to-market product innovations	0.82	0.30	0.86	-0.04
Services innovators	0.92	0.10	-0.04	0.95
Eigenvalue		4.28	2.28	0.94
% of explained variance (cumulative)		41.89	66.71	83.34

Notes:
Principal component analysis with Varimax rotation. Kaiser-Meyer-Olkin measure of sampling adequacy: 0.659; number of observations: 60. Grey background denotes factor loadings exceeding 0.5.

Table 5
Correlations of components from PCA with economic indicators

Variables	Technological Innovation	Commercial Innovation	Service Innovation
GDP pc	0.31	-0.24	0.41
	(0.02)	(0.07)	(0.00)
ΔGDP pc growth	-0.13	0.38	-0.31
	(0.32)	(0.00)	(0.02)
Employment manufacturing	0.29	0.30	-0.34
	(0.02)	(0.02)	(0.01)
Employment HTC + HTC_M[a]	0.41	-0.49	0.21
	(0.00)	(0.00)	(0.11)
Employment KIS[b]	-0.13	-0.54	0.49
	(0.33)	(0.00)	(0.00)
Urban residence	-0.07	-0.28	0.47
	(0.60)	(0.03)	(0.00)
Population density	0.02	-0.10	0.47
	(0.90)	(0.45)	(0.00)

Notes:
[a] HTC + HTC_M: High technology and medium-high technology manufacturing sectors
[b] KIS: Knowledge intensive services
Number of observations: 60 (59 for urban residence, due to the unavailability of data for Norway); p values in parentheses.

Table A.1

CIS indicator construction (firm level)

Indicator name	Section[a]	Question	Codification
Goods innovators	2.1	During the three years 2006 to 2008 did you introduce: New or significantly improved goods?	Yes: 1 No: 0
Services innovators	2.1	During the three years 2006 to 2008 did you introduce: New or significantly improved services?	Yes: 1 No: 0
Process innovators	3.1	During the three years 2006 to 2008 did you introduce (min. 1): New or significantly improved methods of manufacturing or producing goods or services; new or significantly improved logistics, delivery or distribution methods for inputs, goods, or services; new or significantly improved supporting activities for processes, such as maintenance systems or operations for purchasing, accounting, or computing?	Yes: 1 No: 0
New-to-firm innovators	2.3	Were any of your product innovations (goods or services) during the three years 2006 to 2008: Only new to the firm?[b]	Yes: 1 No: 0
New-to-market innovators	2.3	Were any of your product innovations (goods or services) during the three years 2006 to 2008: New to your market?[c]	Yes: 1 No: 0
Turnover share of new-to-firm innovations	2.3	Turnover share in 2008 of goods or services innovations introduced from 2006 to 2008 that were only new to the firm.	Share
Turnover share of new-to-market innovations	2.3	Turnover share in 2008 of goods or services innovations introduced from 2006 to 2008 that were new to the market.	Share

Notes:

[a] Refers to the section number of the relevant question in the CIS2008 Eurostat-harmonized questionnaire.

[b] The firm introduced a new or significantly improved good or service that was already available on the market from competitors.

[c] The introduced good or service may have already been available on other markets.

Table A.2
Summary statistics for regional economic indicators

	Mean	Standard dev.	Minimum	Maximum	Observations
GDP pc	25844	8095	13800	47300	60
ΔGDP pc growth	4.1 %	2.0 %	1.0 %	10.0 %	60
Employment manufacturing	21.2 %	11.3 %	5.0 %	56.0 %	60
Employment HTC + HTC_M[a]	37.8 %	13.9 %	8.0 %	82.0 %	60
Employment KIS[b]	53.4 %	5.4 %	40.0%	65.0 %	60
Urban residence	39.9 %	36.4 %	0.0 %	100.0 %	59
Population density	477	991	15	4852	60

[a] HTC + HTC_M: High technology and medium-high technology manufacturing sectors
[b] KIS: Knowledge intensive services

Figure 1: Scatterplot for component 1 ('Technological Innovation') versus component 2 ('Commercial Innovation')

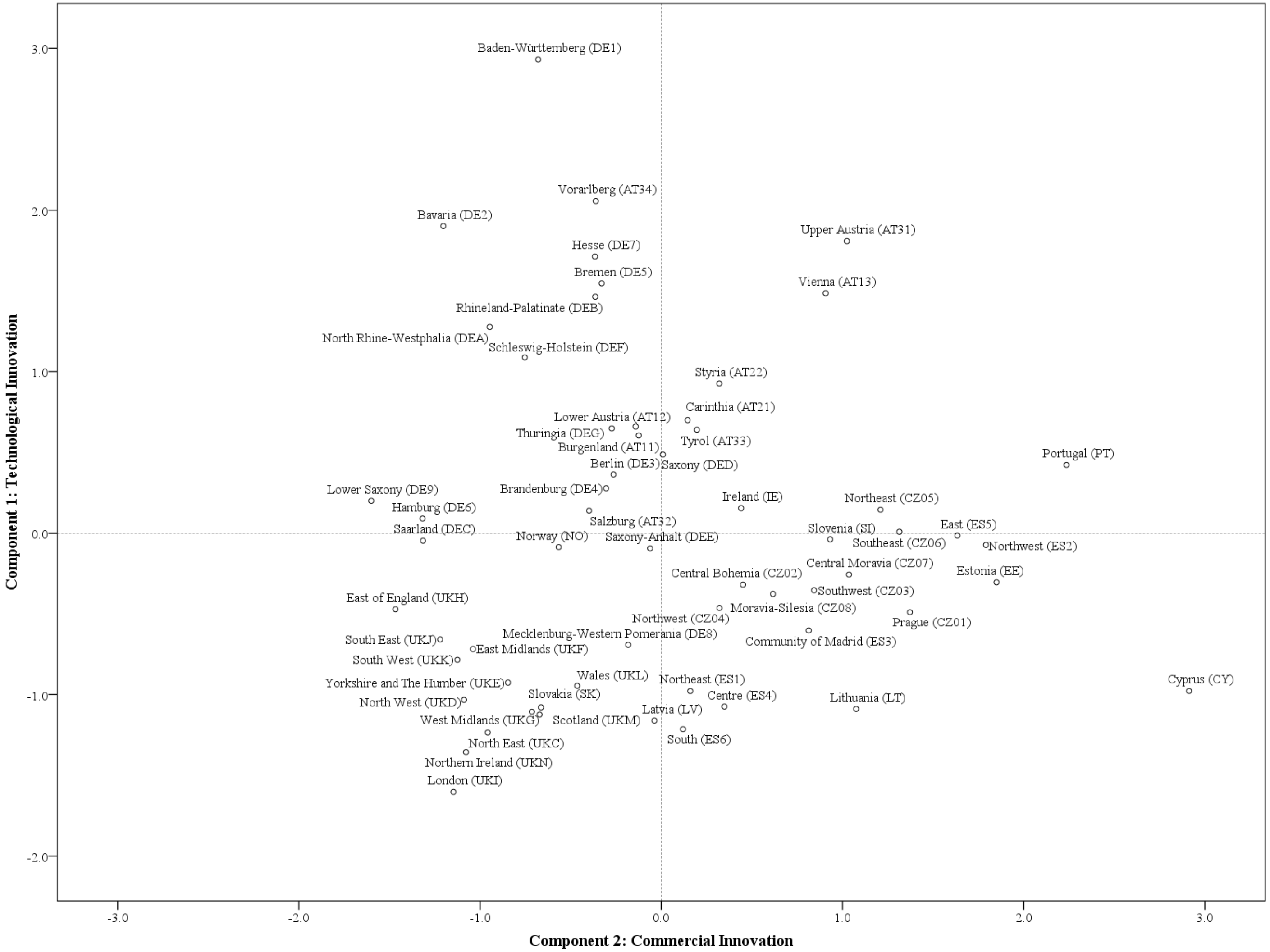
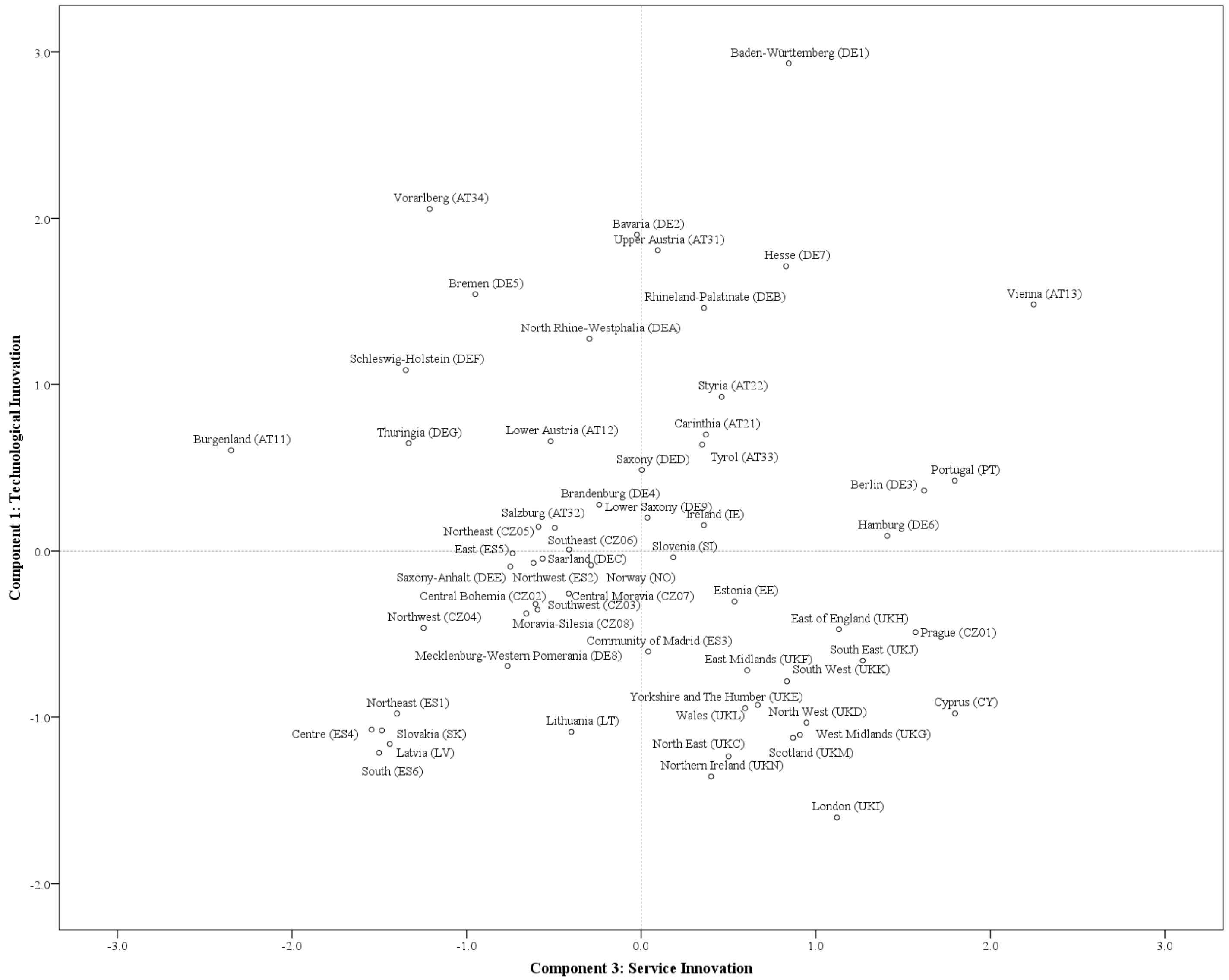


Figure 2: Scatterplot for component 1 ('Technological Innovation') versus component 3 ('Services Innovation')



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The multiple facets of regional innovation

Abstract
Measuring innovation activities involves critical decisions in selecting appropriate indicators and levels of observation. The present article contributes to the literature on this subject by addressing innovation measurement on the regional level. The dimensionality of regional innovation is examined by applying a principal component analysis on seven innovation output indicators in European regions from the Community Innovation Survey and two traditional indicators, i.e. patent applications and R&D expenses. The analysis reveals that regional innovation indeed needs to be regarded as a multidimensional concept involving technological, commercial and service innovation. These distinct innovation activities exhibit clear regional patterns with both technological and service innovation concentrated in highly developed territories and urban areas displaying particularly strong innovation performance in services. In addition, commercially successful innovation appears clustered in backward regions and may thus be seen as imitation efforts and technology transfers from areas at the innovation frontier. Overall, the elaborated findings suggest that the selection of innovation indicators in empirical analyses demands appropriate motivation and theoretical guidance.

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