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Layers of co-existing innovation systems

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Layers of co-existing innovation systems

Abstract

The innovation systems approach, which has taken a prominent position in the academic literature, has also influenced policy-makers around the globe. Most research analyses innovation systems taking a national, regional or sectoral perspective, following a 'technological imperative'. Yet changes in institutional conditions and the importance of non-technological innovation question the accuracy and the relevance of the existing boundaries of innovation systems. These developments ask for a better understanding of how innovation systems integrate within and across different levels. Drawing on a novel combination of configurational and econometric analysis, we analyse 384 Swiss firms and identify five co-existing innovation systems: two generic innovation systems, the *autarkic* and the *knowledge-internalisation*; one regional innovation system, the *protected hierarchy*; and two sectoral innovation systems, the *public sciences* and the *organised learning*. The generic innovation systems entail the 'Science, Technology and Innovation' (STI) and the 'Doing, Interacting and Using' (DUI) learning modes. These systems are structurally distinct and do not integrate. In contrast, all regional and sectoral innovation systems integrate the learning modes of the generic innovation systems and complement them with idiosyncratic elements. The perspective on co-existing innovation systems that we develop here indicates the existence of two layers of innovation systems: a 'central' layer that hosts generic innovation systems and that constitutes the foundation for a second 'surface' layer that hosts regional and sectoral innovation systems. We discuss the implications of layers of co-existing innovation systems for policy-makers and future research.

Keywords

Innovation systems; technological and organisational innovation; firms' learning behaviour; institutional frameworks; fsQCA; SUR model.

1. Introduction

Since the 1980s, much of the economics and management literature has focused on explaining who drives innovation, why some countries are more innovative than others, and how policy-makers can facilitate innovation (Edquist, 2005b; Lundvall, 1992; Nelson and Rosenberg, 1993). A widespread approach in this literature has been the analysis of innovation systems, 'a network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies' (Freeman, 1987). The dominant interest of researchers in the innovation system literature lies in understanding the institutional and organisational arrangements leading to technological change (Carlsson et al., 2002; Lundvall, 2007).

Innovation systems have been conceptualised on different analytical levels. Some researchers adopt a spatial, e.g. a national (e.g. Freeman, 1987) or regional (e.g. Cooke et al. 1997) dimension, and others a sectoral or technological (e.g. Malerba, 2004) dimension for defining the boundaries of an innovation system. However, for changes in institutional conditions and the growing importance of large multi-national corporations (MNCs) the appropriateness of existing conceptual boundaries of innovation systems is diminishing (Sharif, 2006; Whitley, 2007). Yet whilst researchers have already suggested that innovation systems may co-exist (Howells, 2005; Lundvall, 1992), how innovation systems integrate within and across different analytical levels has received only scant attention.

Moreover, earlier research largely focused on explaining the propensities of innovation systems for generating radical or incremental technological types of innovation (Lundvall, 2007). In contrast, more recent studies have found 'organisational innovation' – new organisational structures, processes or practices – to be highly relevant for the innovative activities of firms (Evangelista and Vezzani, 2010; Lam, 2005; Tether and Tajar, 2008). These findings ask for the innovation system approach to reduce its current 'technological imperative' (Damanpour and Aravind, 2011, p. 2) in favour of a broadened scope that includes organisational innovation.

The changes in the institutional conditions of innovation systems and the economic relevance of organisational innovation thus require a more substantive understanding of how co-existing innovation systems integrate. Such an understanding is important because it promises to help researchers identify intersections of innovation systems, specify similarities and differences in the propensities of innovation systems for generating different innovation types, and determine the unique function of individual innovation systems in a possibly broader innovation system. Moreover, understanding how innovation systems integrate will facilitate policy-making by identifying not only those innovation systems directly affected but also those only indirectly affected by public innovation policies.

For integrating innovation systems we build on a model proposed by Whitley (2007), who argues that innovation systems – irrespective of their specific boundaries – share three key characteristics: authority-sharing and organisational-learning mechanisms within firms, firms' involvement in the public sciences, and the extent of authoritative inter-firm coordination, i.e. how strongly knowledge is coordinated through relations between economic actors. To define the conceptual dimensions of our empirical analysis, we use the three key characteristics of Whitley's (2007) model.

In our study, we examine a sample of 384 firms in Switzerland. Switzerland provides a useful setting for understanding how innovation systems integrate within and across regions and sectors because the country is highly successful in promoting innovation. This success is often attributed to the country's unique institutional features, such as a flexible labour market, a large supply of highly skilled workers, and an educational system that provides a diverse range of skills (European Commission, 2013). In particular, during the recent economic crisis, the Swiss dual-track Vocational Education and Training system (VET) – which trains apprentices in classrooms and in firms – receives much attention from policy-makers internationally (Kochan et al., 2012). This VET not only is associated with low levels of youth unemployment but also supports firms' innovative activities (Wolter and Ryan, 2011).

Our empirical strategy follows a three-step process. For the first step, we use fuzzy set Qualitative Comparative Analysis (fsQCA) (Ragin, 2008) to identify innovation systems. For the second step, we use t-tests to explore the regional and sectoral boundaries of innovation systems. For the third step, we use seemingly unrelated regression analysis (SUR) (Zellner, 1962), a method in common use in applied research (e.g. Fraser et al., 2005; Piva et al. 2005), to measure the propensity of innovation systems for generating radical, incremental or organisational innovation. This empirical strategy takes into account the systems perspective that is central to the innovation system approach (Lundvall, 2007), and is also theory-driven and unbiased as to the results of the analysis.

The paper is structured as follows. Section 2 reviews the conceptual dimensions of the innovation system approach. Section 3 describes our new approach for examining innovation systems. Section 4 introduces the empirical study. Section 5 leads step-wise through the analysis and reports our findings. Section 6 concludes with implications, limitations and directions for future research.

2. The innovation system approach

The innovation system approach, which emerged during the 1980s, received widespread attention in both the academic and the policy-making realms (Sharif, 2006). Its main objectives lie in identifying existing innovation systems and in understanding how such differently organised systems generate different innovation types (Edquist, 2005b; Lundvall, 2007). Research on innovation systems provides valuable recommendations to policy-makers designing country- or regional-level innovation policies and to managers implementing those organisational structures, processes and practices that are necessary for innovation (Sharif, 2006).

Seminal contributions to the innovation system literature define innovation systems as 'the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge' (Lundvall 1992, p. 2) or as 'a set of institutions whose interactions determine the innovative performance [...] of national firms' (Nelson and Rosenberg 1993, p. 3). The conceptual nature of innovation systems thus lies in a system's approach, which focuses on key elements, non-linear interactions and a particular outcome of interest (Carlsson et al., 2002).

2.1. Key characteristics of innovation systems

The two key elements of an innovation system are institutional arrangements, such as the public policies or the education and training system, and organisations, amongst which private firms are considered the most essential agents (Edquist, 2005b; Nelson and Rosenberg, 1993). Although researchers have focused selectively on different agents and institutions, most agree that the configuration of institutional and organisational elements determines the learning modes inherent in, and the innovation types generated by, an innovation system. For example, to contrast 'the role of formal processes of R&D [...] with those focusing on the learning from informal interaction within and between organisations', Jensen et al. (2007, p. 680) distinguish between the 'Science, Technology and Innovation' (STI) and the 'Doing, Using and Interacting' (DUI) modes of learning. As they show, different institutional and organisational constellations facilitate these two ideal-type learning modes.

Different innovation systems may then also be suited for generating different innovation types. Whilst earlier research has largely focused on technological innovations, drawing on the exploration-exploitation dichotomy (March, 1991) to explain radical or incremental types of technological changes, more recent research has highlighted the importance of non-technological or 'organisational' innovation (Evangelista and Vezzani, 2010; Lam, 2005). Organisational innovation, which refers to the development of new practices, processes or structures, may not only increase the managerial efficiency of firms and improve the quality of products and services (Evangelista and Vezzani, 2010) but also alter the structure of entire industries (Damanpour and Aravind, 2011). Yet despite the importance of organisational innovation, only few studies have explored the institutional and organisational elements for organisational innovation (see, however, Castellacci, 2008).

2.2. National, regional and sectoral innovation systems

Although the innovation system approach originated from research on national innovation systems (e.g. Freeman, 1987; Lundvall, 1992; Nelson and Rosenberg, 1993), researchers soon began conceptualising innovation systems at the regional (e.g. Cooke et al. 1997) and sectoral levels (e.g. Malerba, 2004). To investigate individual innovation systems, many researchers have conducted in-depth case studies, analysing for example the (national) innovation system of the United States (US) (Mowery, 1992) and Thailand (Chaminade et al., 2012), the (regional) innovation systems of the Emilia-Romagna in Italy (Cooke et al., 1997) and Silicon Valley in the US (Saxenian, 1991), or the (sectoral) innovation systems of the biotechnology (Pisano, 1991) and the computer game (Storz, 2008) industries. The main advantage of in-depth case studies lies in their focus on the idiosyncrasies of individual innovation systems, including their historical origins – particularly actors and institutions.

Other researchers have used comparative studies to systematically examine multiple innovation systems (Carlsson et al., 2002). Nelson and Rosenberg (1993) compared 15 national innovation systems, Asheim and Coenen (2005) analysed five regional innovation systems, and Malerba (2004) focused on six sectors in Europe, including pharmaceuticals, services and telecommunications equipment. Comparative studies caution against the postulation of 'best-practice' innovation systems (Tödtling and Trippl, 2005), identify commonalities and differences between innovation systems, and promise to reveal hidden institutional and organisational elements of relevance for innovation.

In addition, scholars have developed various typologies of innovation systems, in particular for regional and sectoral systems. For example, Asheim and Coenen (2005) propose three types of regional innovation systems: i) 'territorially embedded' regional innovation system characterised by localised innovation through informal firm networks, ii) 'regionally networked' innovation systems combining clusters of firms with a regional supporting infrastructure including regional public policies, iii) 'regionalised national' innovation systems strongly supported by national innovation policy and that feature stronger international links.

In contrast, Castellacci (2008) develops a taxonomy of sectoral patterns of innovation for the manufacturing and the services sectors. Juxtaposing the functional value of products and services with their technological content, he identifies four sectoral innovation systems: i) 'advanced knowledge providers' with substantive technological capabilities and the abilities to manage complex technological trajectories, ii) 'mass production goods' with production capabilities for final and intermediate products in other production stages, iii) 'infrastructural services' supporting the production processes of producers of consumer goods through incremental innovations increasing the efficiency and quality of services, and iv) 'personal goods and services' with lower innovative capabilities predominantly concerned with increasing the efficiency and quality of their own final goods and services. The main advantages of innovation system typologies lies in their ability to provide an overview of both different innovation systems and indications of overlapping amongst innovation systems.

2.3. Integrating co-existing innovation systems

In sum, most innovation system research examines such systems at different analytical levels and through different approaches. The dominant approaches also consider the co-existence of multiple innovation systems at the same level of analysis. For example, by highlighting the idiosyncratic elements of individual innovation systems, in-depth case studies at least implicitly suggest that alternative institutional and organisational configurations exist.

Similarly, both comparative analyses (by analysing multiple innovation systems) and typology-driven theorising (by proposing multiple, differently structured ideal type innovation systems) explicitly acknowledge the co-existence of innovation systems.

Extending the idea of co-existing innovation systems, some researchers have suggested that they may integrate not only at the same but also across different analytical levels. For example, Asheim and Coenen's (2005) 'regionalised national' innovation system relies on national governmental support, international networks and 'epistemic' rather than local communities. Similarly, Cooke et al. (1997) argue that the criteria determining the boundaries of regional innovation systems may, for example be cultural (e.g. the Basque region) or administrative (e.g. Austrian *Laender*), thereby suggesting that regional innovation systems may cross national boundaries.

The literature on sectoral innovation systems even more strongly emphasises differences in the knowledge base, the heterogeneity of agents, and the variety of organisations involved in sectoral innovation systems (e.g. Castellacci, 2008). This focus on specific sectoral characteristics leads scholars to suggest that sectoral innovation systems are characterised by the interactions between agents and institutions at *various* geographical levels (Carlsson et al., 2002; Malerba, 2004). Thus research on regional and sectoral innovation systems in particular appears open to debate on the permeability of the boundaries of innovation systems and on potential overlaps that may exist between innovation systems across analytical levels.

Finally, researchers argue that, through the internationalisation of firms and markets, MNCs increasingly shape the development of innovation systems (Sharif, 2006; Whitley, 2007). Through international acquisitions or hires, MNCs establish global R&D networks, thereby facilitating cross-border knowledge transfers. Nonetheless, by implementing protectionist mechanisms (de Faria and Sofka, 2010), MNCs also prevent knowledge spill-overs beyond their 'corporate' innovation systems. Thus MNCs, by increasingly dominating innovation systems, appear to bypass the national, regional and sectoral boundaries of innovation systems.

Hence research integrating co-existing innovation systems is urgently needed. With changing institutional conditions such as the harmonization of supra-national governance, the increasingly performance-oriented monitoring of public research, and the internationalisation of firms and markets, researchers increasingly – and more generally – question the delimiting criteria of innovation systems (Coombs, 2001; Sharif, 2006). As early as 1992 Lundvall (1992, p. 1) suggested that the 'role of the nation states in supporting learning processes is now challenged by the process of internationalisation', pointing toward the erosion of the conceptual boundaries of, at the least, the national innovation system. Thus the idea of a solitary, isolated innovation system will become less relevant, and the plurality of innovation systems will matter more.

The ramifications of integrating co-existing innovation systems promise theoretical insights and valuable policy guidance. Dependencies between innovation systems with regard to their organisational and institutional base may provide insights into points of convergences. Moreover, as Edquist (2005b, p. 5), for example notes, 'the same activity may be organised differently in different' innovation systems', theorising on the equifinality of innovation systems concerning their productive capabilities. Thus beyond necessarily differing with regard to their innovation output, different innovation systems may indeed be suited for generating the same innovation type.

Moreover, some innovation systems may adopt a more fundamental role in multiple innovation systems, whereas others may be specific to certain regions and sectors. For example, Sleuwaegen and Boiardi (2014, p. 11) argue that 'authorities recognise the wider systemic role of cultural and creative industries', implying that some innovation systems may be generic to a broader innovation system, whereas others – once a critical mass has been reached – may be better characterised by their regional or sectoral specificity. This view suggests that depending on the context-specificity of innovation systems, certain innovation systems may co-exist across different layers of a broader one.

In sum, research on innovation systems needs to not only consider the co-existence of innovation systems but also develop a more substantive understanding of integrated innovation systems. Such a perspective will allow researchers to identify points of intersections between innovation systems, to specify similarities and differences in the innovative capabilities of co-existing innovation systems, and to determine the function of individual innovation systems in a broader innovation system.

3. A new approach for examining innovation systems

In this paper we examine how co-existing innovation systems integrate by designing an approach that departs from previous approaches in two ways. First, to define the conceptual framework for our analysis and to guide our selection of variables, we use a model of innovation systems that explicitly refrains from defining innovation systems based on national, regional or sectoral boundaries (Whitley, 2007). Second, to design an empirical strategy unbiased as to the results of the analysis, we introduce a configurational method, fuzzy set Qualitative Comparative Analysis (fsQCA), new to this line of research, and integrate fsQCA with econometric analyses. Our empirical strategy therefore allows us to identify innovation systems and to deal with situations of complex causality whilst handling a large number of observations.

3.1. Conceptual framework

We use Whitley's (2007) model of innovation systems to define the conceptual framework for our analysis and to guide our selection of outcome and explanatory variables. This model defines innovation system as independent of national, regional or sectoral boundaries. Most research on innovation systems has focused on an idiosyncratic description of individual innovation systems or, when examining innovation systems in a more comparative fashion, avoided specifying the precise nature and the key components of innovation systems (Carlsson et al., 2002; Edquist, 2005a). In contrast, Whitley's (2007) model defines three dimensions of innovation systems *in general*. For our purposes such a unifying model of innovation systems is indispensable. Because Whitley's (2007) model theorises on the nature of innovation systems irrespective of their national, regional or sectoral boundaries, it ensures that our findings are not influenced by predefined conceptions of particular innovation systems. Moreover, the model allows us to describe and compare innovation systems along a range of comparable dimensions, a precondition for identifying layers of and points of convergence amongst innovation systems.

Whitley (2007) posits three key characteristics of innovation systems: i) authority-sharing and organisational-learning mechanisms within firms, ii) firms' involvement in public sciences, and iii) the extent of authoritative inter-firm coordination.

'Organisational-learning and authority-sharing mechanisms' concern firms' joint problem-solving capabilities, and education and training activities. These mechanisms allow the rapid codification, diffusion and application of skills throughout the organisation (Whitley, 2003, 2007). 'Firms' involvement in public sciences' refers to their cooperation with universities and research institutions, either by directly funding projects of interest or by drawing on fundamental knowledge. The public sciences include organisations such as universities and public research institutions that compete to make significant contributions to collective knowledge. 'The extent of authoritative inter-firm coordination' describes how knowledge production, transfer and use is coordinated, through either *ad hoc* transactions or more continuous and cooperative relations (between economic) actors governed by common authority commitments.

Following the tenets of Whitley's (2007) model, we argue that the interdependencies amongst these three key characteristics explain the different nature and innovation-generating propensities of innovation systems. Thus, in contrast to studies that define innovation systems either by using methods such as cluster or factor analysis (e.g. Jensen et al., 2007), which are vulnerable to the researcher's judgement (Hollenstein, 2003), or by applying inductive approaches (Asheim and Coenen, 2005; Iammarino, 2005), our approach builds ex ante on a conceptual framework that encompasses elements of innovation systems around which some consensus in the literature has emerged (Malerba, 2004; Whitley, 2007). We use the three key characteristics for defining and operationalising the dimensions of our conceptual framework, which in turn allows us to identify and examine innovation systems.

3.2. Empirical strategy: A three-step process

Our empirical strategy consists of a three-step process. For the first step we use fsQCA to identify patterns of institutional and organisational elements associated with innovation, i.e. innovation systems. In fsQCA all logically possible combinations of absent and present measures are organised in a truth table. One reduces this truth table by considering the coverage and the consistency of each configuration. The coverage indicates the number of empirically observed cases for each configuration, whilst the consistency displays the share of firms consistent with our outcome measure, overall innovativeness. A value of 1 indicates high consistency; a value of 0.5, low consistency. For our analysis, we included only those configurations with more than three cases and only if they have consistency scores higher than 0.93. Setting such stringent thresholds, substantially higher than the commonly recommended minimum of between 0.75 (e.g. Ragin, 2008) and 0.80 (e.g. Fiss, 2011), allows us to identify prevalent innovation systems.

To analyse all possible combinations of elements in a conceptual vector space, fsQCA uses Boolean algebra. fsQCA then reduces the complexity of systemic phenomena to a minimum set of essential, peripheral and irrelevant characteristics, thereby allowing the identification of complex interactions that go beyond two- or three-way interactions (Fiss, 2011). Moreover, fsQCA is capable of dealing with equifinality, the idea that there may be various combinations of conceptual factors that, amongst other things, enable innovation. The ability of fsQCA to account for equifinality and complex interactions reflects the system-oriented perspective of the innovation system approach (Sharif, 2006).

For the second step, we extend the configurational analysis and use t-tests to examine the extent to which the regional and sectoral distribution of the firms participating in an innovation system differs from those of the population at large. This step serves to determine whether an innovation system supersedes regional and sectoral boundaries.

For the third step we examine the propensity of an innovation system for generating radical, incremental or organisational innovation. Because previous research has shown that firms may simultaneously generate different types of innovation (Evangelista and Vezzani, 2010; Tether and Tajar, 2008), we require an analytical method capable of capturing the effects of such innovation 'interdependencies'. We therefore turn to an econometric method: seemingly unrelated regression analysis (SUR) (Zellner, 1962).

SUR, which consists of several regression equations, is appropriate when one expects correlations amongst the errors terms of different equations. In our case an innovation system suited for generating one innovation type may also generate another innovation type. Thus we expect the error terms in the three equations to correlate. Because standard multi-equation models cannot capture these correlational effects, SUR is advantageous for our purposes. Our SUR model estimates the following three equations:

$$\mathrm{Rad}_i = \beta_0 + \sum_{k=1}^{K} \beta_k \, \mathrm{innosystem}_{ik} + \sum_{j=K+1}^{J} \beta_j \, x_{ij} + v_i \qquad \text{(I)}$$

$$\mathrm{Incr}_i = \gamma_0 + \sum_{k=1}^{K} \gamma_k \, \mathrm{innosystem}_{ik} + \sum_{j=K+1}^{J} \gamma_j \, x_{ij} + e_i \qquad \text{(II)}$$

$$\mathrm{Org}_i = \delta_0 + \sum_{k=1}^{K} \delta_k \, \mathrm{innosystem}_{ik} + \sum_{j=K+1}^{J} \delta_j \, x_{ij} + w_i \qquad \text{(III)}$$

We use firms' membership scores in the K innovation systems (innosystem_{ik}), which we identify in the first step of our analysis as explanatory variables for the three innovation types: radical innovation (Rad_i), incremental innovation ($Incr_i$) and organisational innovation (Org_i). To reduce biases that might result from differences in firm characteristics in the estimated associations between innovation types and innovation systems, we also include a vector of control variables x_{ij}.

Overall, our new empirical approach for examining innovation systems is theory-driven and unbiased as to the results of the analysis. The integration of fsQCA with econometric analyses, increasingly advocated in the literature (Fiss et al., 2013), allows us to incorporate the considerations of equifinality and conjunctural causation so fundamental to the innovation system approach (Sharif, 2006), to define delimiting criteria of an innovation system, and to account for the possibility of interdependencies amongst different innovation types.

4. Empirical study

For our analysis we use data from the 2005 Innovation Survey of the Swiss Economic Institute (KOF), a survey conducted triennially since 1990. Each wave, containing two to three thousand firms, constitutes a representative sample of the Swiss economy. Firms answer questions on their demographic and structural characteristics, their business environment and their workforce composition. The KOF Innovation Survey, an important database for economic and policy analysis in Switzerland, is frequently used in economic and political science research. Whilst the data has been used for analysing innovation modes in the Swiss services sector (e.g. Hollenstein, 2003), it has not yet been used in studies considering non-technological innovation and analysing innovation systems with a methodological approach similar to ours.

After eliminating observations with missing values in more than 50% of our items of interest, we obtain a sample of 384 firms.[1] Table 1 provides descriptive statistics of the firms in our analysis.

Insert Table 1 about here

Firms employed on average 274 employees, the smallest with a workforce of eight and the largest with 6,980 employees. These firms were between one and 348 years old, reflecting a particular feature of the Swiss economy: the mix of very old, traditional firms with a large number of young, highly innovative firms. In our sample 30.99% of the firms are classified as 'traditional manufacturing' firms, 39.06% as 'high-tech manufacturing', 15.36% as 'traditional services', 10.16% as 'modern services' and 4.43% as belonging to the 'construction' sector.[2] Most are located in Eastern Switzerland (21.88%), Zurich (21.09%) and the Espace Mitteland (20.57%), which includes Berne and its surrounding cantons.[3]

4.1. Outcome and dependent variables

For identifying innovation systems we develop a single aggregate outcome indicator for overall innovativeness by combining three calibrated measures for radical, incremental and organisational innovation. In fsQCA, variables are conceptualised as membership scores within pre-defined sets. For example a firm will have a certain set membership score in the set of 'firms generating organisational innovation'. This fuzzy set membership score ranges from

1 For understanding the implications of our elimination strategy, we conduct t-tests comparing means between the full sample and the subsample of firms retained in the analysis (see appendix B, table B.1). We find no significant differences in terms of age, size and research intensity. However, we find manufacturing firms and firms in Eastern Switzerland significantly overrepresented, and services and construction firms and firms located in the Lake Geneva Region significantly underrepresented, in our sample of firms. For the remaining industries and regions the results are unbiased. These differences in regional and sectoral distribution may prevent us from identifying innovation systems specific to the underrepresented sectors, i.e. services and construction, and regions, i.e. the Lake Geneva region. However, these differences will not challenge the innovation systems that we may identify. Overall the sample restrictions will not undermine the substantive contributions of our study.

2 Table A.1 in Appendix A provides information on the sectoral classification.

3 Table A.2 in Appendix A provides information on the regional classification.

0 (non-membership) to 1 (full membership). Researchers obtain these set-membership scores through calibration (Ragin, 2008), a measurement approach that differs from the purely numerical use of variables, by defining meaningful floors, ceilings and anchors.[4]

We measure radical and incremental innovations by the sales share of new and improved products, respectively, a common measure in the innovation literature (e.g. Hollenstein, 2003; Tether and Tajar, 2008). In accordance with Fiss (2011) we use the direct method of calibration for the two sets, setting the non-membership point at the 10th percentile, the cut-off point at the 50th percentile and the full membership point at the 90th percentile.

Furthermore, to measure organisational innovation that comprises changes in the organisational structure caused, for example by outsourcing or takeovers, we follow Evangelista and Vezzani (2010) and use the following three items: i) major changes to the distribution of competencies between employers and employees (binary), ii) major changes to the organisation of the company, e.g. mergers, diversification or outsourcing (binary), and iii) the share of workers that switched functions or departments. We apply indirect calibration to the first two binary measures and direct calibration to the third, setting the non-membership point at the 10th percentile, the cut-off point at the 50th percentile and the full membership point at the 90th percentile. We then summarise all three scales and normalise this measure to range from 0 to 1.

In the second step of our analysis, in which we employ t-tests, we use a firm's membership score as an identifier to group firms into innovation systems. fsQCA allows the measuring, in the form of set-membership scores, of the extent to which firms belong to an innovation system. The set-theoretic foundation of fsQCA therefore allows us to uniquely assign firms to the identified innovation systems and to compare the background characteristics between the firms of a particular innovation system and the firms in the entire sample.

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4 For more information on calibration see Ragin (2008) or Fiss (2011).

In the third step, using SUR to measure the possibly varying propensities of innovation systems for generating different innovation types, we disaggregate our indicator for overall innovativeness into its three sub-scales of radical, incremental and organisational innovation, and use three separate dependent variables in the SUR.

4.2. Explanatory and independent variables

For the fsQCA analysis, our explanatory variables contain indicators for each of the three key characteristics of innovation systems proposed by Whitley (2007), indicators common in the innovation literature.[5] First, we include four indicators for the authority-sharing and organisational-learning mechanisms: i) the degree of a workforce's specialisation (Damanpour, 1991); ii) the degree to which employees enjoy decision-making autonomy (five-item measure with adequate reliability, $\alpha = 60\%$) (Damanpour, 1991); iii) the implementation of organisational-learning mechanisms such as teamwork, job-rotation and formal training (Castellacci, 2008); and iv) participation in VET (Asheim and Coenen, 2005).

Second, we include two indicators for a firm's participation in the public sciences system: i) the use of public innovation funds (Chaminade et al., 2012) and ii) cooperation with public research organisations such as universities or other public science institutions (Castellacci, 2008; Tether and Tajar, 2008).

Third, we include two indicators reflecting the nature of authoritative inter-firm coordination, where the sharing of knowledge and collaborating for innovation is easier and less risky when inter-firm coordination is authoritative. Our two indicators measure i) the importance of intellectual property (IP) protection and patenting ($\alpha = 76\%$) (Chaminade et al., 2012) and ii) the relevance of publicly available information ($\alpha = 70\%$) for a firm's innovative activities (Cassiman and Veugelers, 2006).

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5 Table A.3 in Appendix A provides a detailed description of the measures in our three-step analysis.

To test whether the explanatory variables we select for the fsQCA reflect the three dimensions proposed by Whitley (2007), we conduct a confirmatory factor analysis. Table 2 reports the results. The differences between the loadings on the first, second and third factors are sizeable, therefore showing that the variables we selected reflect the three dimensions.

Insert Table 2 about here

To develop sets for each explanatory variable, we use items from the KOF questionnaire. For items available on a continuous scale, we use the direct method of calibration, setting the non-membership point at the 10th percentile, the cut-off point at the 50th percentile and the full membership point at the 90th percentile. For binary items or those available on Likert scales, we use the indirect method of calibration. This method, based on substantive reasons (Ragin, 2008), groups cases according to their membership degree in the target set.

Table 3 provides descriptive statistics and the correlation matrix for the calibrated outcome and explanatory variables included in the fsQCA analysis.

Insert Table 3 about here

For the second step of our analysis we include variables that allow us to examine the sub-population of firms that belong to a certain innovation system. We include five binary industry variables indicating whether firms operate in i) traditional manufacturing, ii) high-tech manufacturing, iii) construction, iv) traditional services or v) modern services. Moreover, we include seven binary regional variables indicating whether firms are located in i) the Lake Geneva Region, ii) Espace Mittelland, iii) Northwestern Switzerland, iv) Zurich, v) Eastern Switzerland, vi) Central Switzerland or vii) Ticino.

For the third step, in which we run SUR to measure the propensity of innovation systems for generating radical, incremental or organisational innovations, our independent variables are a firm's membership score in the innovation systems that we identified using fsQCA during the first step of the analysis.

Additionally, with fewer limitations for the number of variables, we include a series of control variables to better single out an innovation system's propensity for generating radical, incremental or organisational innovation. We include a firm's age because both older and younger firms are often associated with higher levels of innovativeness (Damanpour, 1991). We also include the firm size, measured as the logarithm of the number of employees, because firm size picks up a number of other firm characteristics that relate to innovation in firms (Camisón et al., 2004). Moreover, we control for the research intensity of a firm, measured by the R&D expenditures over sales, because formalised internal R&D influences the innovative activities of firms (De Marchi, 2012). Last, we include sectoral control variables.

Table 4 provides descriptive statistics and the correlation matrix of the contextual variables included in the second and third steps of our analysis.

Insert Table 4 about here

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5. Results

We first present the result of our three analytical steps and then describe and explain the identified innovation systems in the following subsections. Figure 1 illustrates the results of our fsQCA analysis.

Insert Figure 1 about here

In this configuration chart the top row labels the innovation systems to which innovative firms in the Swiss economy most frequently and consistently belong. The left-hand column lists the explanatory variables of an innovation system. The large circles in the configuration chart indicate core conditions, those essential for explaining high innovativeness in the innovation system. The smaller circles constitute contributing elements, those supporting a system's function in being innovative. Filled circles indicate that elements should be present; crossed circles indicate that the absence of an element is necessary if the system is to achieve innovation. Empty cells indicate that the element is not relevant in this particular innovation system.

The configuration chart in Figure 1 shows five distinct innovation systems that co-exist in the Swiss economy. The overall solution consistency lies at 0.93, above the levels of 0.80 recommended for fsQCA results (e.g. Fiss, 2011; Ragin, 2008). The overall solution coverage lies at 0.19, similar to the levels reported in other studies (e.g. Fiss, 2011, reports 0.37; Misangyi and Acharya, 2014, report 0.16).

Having identified successful innovation systems in Switzerland, we seek in a second step to explore whether these systems show specific sectoral or regional boundaries. Table 5 shows the results of our t-tests.[6]

Insert Table 5 about here

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[6] The use of one-sample t-tests ensures the comparability of our findings across different innovation systems and allows us to examine whether Swiss innovation systems show any particular sectoral or regional specificities.

In Table 5, the top row lists the five innovation systems corresponding to Figure 1. The left-hand column contains the sectoral and regional variables. The following three columns provide information on the sample mean, minimum and maximum. The remaining five columns show the differences in means between the entire sample and the groups of firms that belong to one of the five innovation systems.

In a third step, we measure the propensity of an innovation system for generating different innovation types. Table 6 shows the coefficients and standard errors of the SUR for radical, incremental and organisational innovation.[7] To compare the explanatory power amongst the three equations, we report the R^2 for each equation and the significance levels of differences between the R^2. Our findings show that our model best explains incremental innovation (R^2=0.225) and somewhat well explains radical innovation (R^2=0.158). More importantly, the power of the model for explaining organisational innovation is not only relatively low (R^2=0.061) but also significantly lower than its power for explaining incremental or radical innovation.

Insert Table 6 about here

We begin interpreting the results by discussing the configuration of each innovation system itself, followed by discussions of the t-test of the firms' background characteristics and the SUR of innovation type outcomes.

7 We report p values at the 15% level because the configurations in our study contain complex and non-linear interactions of conditions. Thus, whereas configurations are not necessarily linked to the outcome in a linear fashion, the regression results show a positive association of the configuration with the outcome not only for cases with a membership score above 0.5 but also for cases with membership scores below 0.5. Given the novelty of our methodological approach and the lack of standards for such models, we also report significance levels at the 15% level (see also Walsh et al., 2007).

5.1. The autarkic innovation system

As Figure 1 indicates, the key characteristics of the first innovation system are the presence of specialisation and the absence of organisational-learning practices and VET. Supporting characteristics are the absence of the following: decentralisation, reliance on public innovation funding, cooperation with public research institutions and IP protection. Provision of public knowledge is irrelevant in this system. Given these features, we label this system the *autarkic* innovation system, i.e. economically independent and self-reliant.

Learning appears to take place between senior managers and research officers. Collaboration beyond the firm's boundaries is limited, as is authority-sharing. Thus the generative mechanism entailed in this innovation system relies on the uninterrupted work of specialists. The results from the t-test in Table 4 show that the firms participating in the autarkic innovation system do not differ from the population at large, i.e. this system is not specific to any sector or region. Moreover, as Table 5 demonstrates, the SUR shows that the autarkic system is not significantly related to any innovation type.

Overall, the autarkic system appears to be a 'generic' innovation system that functions across sectoral and regional boundaries. It exhibits an equal propensity for generating radical, technological and organisational innovation. At the same time our findings suggest that the autarkic system, similar to Jensen et al.'s (2007) STI mode of learning, entails the production of codified scientific or technical knowledge. However, in contrast to their STI mode, we show that the autarkic system relies less on cooperation with public universities and research institutes and more on the internal knowledge generated by in-house personnel, possibly through internal R&D.

5.2. The public sciences innovation system

The key characteristics of the second innovation system include cooperation with public research institutions and the absence of organisational learning practices. This system's ability to innovate is supported by the presence of specialisation and participation in VET and by the absence of decentralisation, provision of public knowledge and importance of IP protection. Firms in this system may or may not rely on public innovation funding. The activities that take place in this innovation system thus rely on a specialised workforce, the inclusion of VET and intense cooperation with public research institutions. Innovation in this system thrives in environments in which governments refrain from regulating public knowledge provision and IP protection, indicating *ad hoc* and short-term authoritative inter-firm coordination (Whitley, 2007). We label this the *public sciences* innovation system, indicating that these firms engage in more generic research.

The results from the t-tests and the SUR confirm this interpretation. The public sciences system is significantly more suited for innovation in the high-tech manufacturing sector (MD = 32.79, $p < 0.01$) but significantly less so in the traditional (MD = -12.24, $p < 0.01$) and the modern (MD = -7.04, $p < 0.05$) services sectors. Moreover, firms participating in this system are significantly less frequently located in Central Switzerland (MD = -7.30, $p < 0.05$), a region that hosts no federal and only one cantonal university and few research institutes. Moreover, the public sciences system is not significantly related to any innovation type, in line with its suitability for generating collective rather than firm-specific knowledge.

The public sciences innovation system hosts organisations that largely compete for making significant contributions to collective, non-firm-specific knowledge. Researchers in the public sciences – encouraged to focus on theoretically significant problems – generate fundamental knowledge, a prerequisite for generic research within firms. Learning in the public sciences system takes place in close cooperation with the full complex of research institutes and academic institutes of higher learning (Hicks, 2012). The public sciences innovation system somewhat resembles Castellacci's (2008) 'mass production goods system', characterised by innovations relevant to science-based manufacturing and scale-intensive manufacturing. Characteristic of organisations in the public sciences system are their considerable capabilities for developing new products whereby the creation of knowledge takes place in close connection with scientific advancements in universities and public research institutes.

5.3. The knowledge-internalisation innovation system

The third innovation system is characterised by the presence of cooperation with public research institutions and provision of public knowledge. Contributing to this system's ability to innovate is the presence of organisational learning practices and the participation in VET, and the absence of specialisation, decentralisation, public innovation funding and importance of IP protection. Learning takes place amongst less specialised employees with a larger breadth of knowledge and access to external knowledge sources through either external cooperation or the availability of public knowledge. In this system innovation is generated by the combination of a variety of knowledge sources through organisational learning practices. Given these features, we label this system the *knowledge-internalisation* innovation system.

The knowledge-internalisation system shows neither regional nor sectoral specificity. As the SUR results indicate, this innovation system is best at generating organisational innovations (0.380, $p < 0.1$) and somewhat suited for generating incremental innovation (0.364, $p < 0.15$). Our results also reveal that the knowledge-internalisation system is particularly unsuited for generating radical innovation (-0.430, $p < 0.15$). Thus, like the autarkic system, the knowledge-internalisation system entails 'generic' learning mechanisms that transcend sectoral and regional boundaries. However, the knowledge-internalisation system differs from the autarkic by showing particularly strong specificities regarding the generated innovation.

Overall, learning in the knowledge-internalisation systems appears to take place in the DUI mode (Jensen et al., 2007). Innovation developed in the knowledge-internalisation system serves more applied purposes, for example for improving existing products and increasing the efficiency of firm processes. Corroborating research showing how organisational innovation requires substantive interaction between internal and external agents (Birkinshaw et al., 2008; Lam, 2005). The knowledge-internalisation system combines multiple sources of innovation through linkages beyond the firm's boundaries.

5.4. The protected hierarchy innovation system

The fourth innovation system is characterised by the presence of cooperation with public research institutions, the importance of IP protection and the absence of public innovation funding. Contributing conditions are the presence of specialisation, organisational learning practices and participation in VET, and the absence of decentralisation and provision of public knowledge. The distinguishing feature of this innovation system is the importance of IP protection and a designed involvement in the public sciences. For these features, we label it the *protected hierarchy* innovation system.

As the t-tests indicate, the protected hierarchy is a regional innovation system with participating firms concentrated in Eastern Switzerland (MD = 40.62, $p < 0.05$). As our SUR results show, the protected hierarchy systems is less suited for generating radical technological innovation (-0.454, $p < 0.15$) and more for generating organisational innovation (0.369, $p < 0.15$).

Eastern Switzerland, located at the tri-junction of Austria, Germany and Switzerland, is populated predominantly by small- and medium-sized capital goods manufacturers operating in industries such as machine engineering, electricity and precision mechanics – industries to which patenting is particularly important. Moreover, the more rural cantons of Eastern Switzerland host large agricultural production important for the Swiss food industry. Through the Bodensee-Chambers of Commerce, an association of six chambers of commerce in the three neighbouring countries, the local business structures are instrumental in initiating cooperation both between firms and across national boundaries. However, except for the

University of St. Gallen, with its substantive expertise in management and legal education, the public R&D system in Eastern Switzerland is rather weak.

As a regional innovation system, the protected hierarchy system closely resembles Cooke's (1998) 'grassroots' or Asheim and Coenen's (2005) 'territorially embedded' regional innovation system. Learning in these regions is characterised by the development of industrial districts and agricultural production, patterns we also find in Eastern Switzerland. Innovation in this regional system relies on localised institutions and business structures, such local chambers of commerce and funding through local banks. Overall, as a regional innovation system, this system relies on positive links between the innovative capabilities of firms amongst sectors within the same region. Thus in the protected hierarchy system those innovations needed for enhancing the efficiency of organisational processes or for improving the quality of products and processes are more important than radically new technological innovations.

5.5. The organised learning innovation system

The fifth innovation system features the presence of decentralisation and cooperation with public research institutions. The presence of specialisation, organisational learning practices and VET, and the absence of reliance on public research funding, IP protection and provision of public knowledge contribute to innovation in this system. For the strong presence of authority sharing and organisational learning conditions, we label this the *organised learning* innovation system.

As the t-tests results indicate, the organised learning system is specific to the modern services sector ($MD = 34.28$, $p < 0.05$) and rather 'hostile' to the traditional manufacturing sector ($MD = -19.88$, $p < 0.1$). Moreover, we find no regional specificity for this system. Thus, next to the public sciences system, the organised learning system is a sectoral innovation system. The results of the SUR model show a strong association of this system with radical innovation (0.56, $p < 0.05$).

Learning in the organised learning system closely follows the DUI mode (Jensen et al., 2007) and relies on analytical knowledge. This system is particularly important for the modern services sector, which includes financial services, computer-related business activities, and the post and telecommunication industries. That the organised learning system is highly suited for generating radical technological innovation indicates that – similar to Castellacci's (2008) 'advanced knowledge providers' sectoral innovation systems – the organised learning system hosts sophisticated innovators with substantive technological capacities that explore ground-breaking technologies.

Insert Table 7 about here

Table 7 summarises the five innovation systems we identify and compares them with similar innovation systems discussed in the literature.

6. Layers of co-existing innovation systems

Overall, we identify five co-existing innovation systems, each characterised by different interdependencies between authority-sharing and organisational-learning mechanisms, firms' involvement in the public sciences, and the nature of the authoritative inter-firm coordination. As our econometric results show, whilst innovation systems may generate some innovation types, they may also prove particularly unsuited for generating other innovation types.

6.1. Generic versus context-specific innovation systems

Figure 2 illustrates the five innovation systems in the form of spider charts that highlight the similarities and differences in their institutional and organisational elements.

Insert Figure 2 about here

The charts at the top of Figure 2 picture the two generic innovation systems (grey filled with black outline). Whereas the autarkic system relies heavily on specialisation, the knowledge-internalisation system relies on a combination of participation in VET and cooperation with public research institutions. Moreover, the learning modes inherent in the two generic innovation systems are fundamentally different, closely corresponding to two ideal type modes of learning, the STI and the DUI modes (Jensen et al., 2007). Similarly, the two generic innovation systems are structurally different and appear to exist independently of one another.

The charts at the bottom of Figure 2 picture the three context-specific innovation systems: the protected hierarchy, the public sciences and the organised learning systems (all outlined with long dashes). In the same three charts we highlight how each specific innovation system overlaps with the two generic ones (grey filled, no outline). Both generic innovation systems appear to constitute the basis for the regional system in Eastern Switzerland and for the two sectoral systems in the high-tech manufacturing and modern services sectors. Thus innovation in the regional and sectoral innovation systems integrates the learning modes inherent in generic innovation systems.

The charts also reveal the idiosyncratic elements of the context-specific innovation systems. Innovation in the protected hierarchy system, a regional system that generates organisational innovation, uniquely relies on the protection of IP. The public sciences system, specific to the high-tech manufacturing system, distinctly uses public innovation funding for innovating. The organised learning system uniquely uses a mix of decentralisation and organisational learning practices for generating radical technological innovations in the modern services sector. Hence, in addition to their reliance on generic innovation systems, context-specific innovation systems clearly combine these fundamental elements with an idiosyncratic one.

Whilst each idiosyncratic element complements the learning modes inherent to generic innovation systems, thereby enabling innovation in a context-specific innovation system, the idiosyncratic elements themselves entail substantially different logics. For example, the protected hierarchy system is uniquely based on IP protection, i.e. mechanisms *constraining* knowledge flows. Innovation in this system will require considerable investment on the part of the firm, e.g. for implementing organisational structures and processes that help to protect IP or monitor the patenting activities of competitors. In contrast, the organised learning system uses organisational learning practices, i.e. mechanisms *facilitating* knowledge flows. Innovation in the organised learning system will require considerable investment, e.g. for implementing teamwork and job rotation or the appropriate training programmes. We argue that these 'sunk costs' not only explain the persistence of regional or sectoral innovation systems but also may provide important leverage points for policy-makers to trigger the development of new regional or sectoral innovation systems.

However, in contrast to the (independently co-existing) generic innovation systems, our findings suggest that regional and sectoral innovation systems may intersect at certain points. For example both the regional protected hierarchy system and the sectoral organised learning system rely on the autarkic system (STI learning) and the knowledge-internalisation system (DUI learning). In Eastern Switzerland's modern services sector, where these two innovation systems intersect, their co-existence leads to interferences, because both require highly educated employees, apprentices and cooperation partners. These findings suggest that at these points of convergence regional and sectoral innovation systems *compete* for the fundamental institutional and organisational resources necessary for innovation. Our results also cast doubt on the view that organisational innovation dominates the services sector (e.g. Gallouj and Weinstein, 1997; Tether and Tajar, 2008). We find that organisational innovation is specific to neither the services nor the manufacturing sector. Thus the cost reduction and efficiency enhancements of organisational innovation are equally important to both sectors, not specific to the services only. This finding corroborates recent research on the sectoral specificity of organisational innovation (e.g. Camisón and Villar-López, 2014; Evangelista and Vezzani, 2010).

Finally, our results qualify the view that technological innovation dominates the manufacturing sector (Lundvall, 2007). We find no association of radical technological innovation with an innovation system specific to the manufacturing sector. Instead, our findings reveal that radical technological innovation is almost exclusively generated in the modern services sector, a segment dominated by highly specialised and knowledge-intensive products, e.g. financial services and IT-based R&D for business activities. This finding indicates that the STI mode of learning is more important in this segment of the services sector than in manufacturing, and suggests that the innovation literature overemphasises the relevance of technological innovation for the manufacturing sector.

6.2. Generation of different innovation types

Our results also provide insights into how an innovation system may be suited for generating different types of innovation, results that complement research on the interdependencies amongst different types of innovation (Camisón and Villar-López, 2014). For example the protected hierarchy systems is suited for generating organisational innovation but unsuited for generating radical technological innovation. This innovation system, with its core reliance on IP protection, encourages learning that improves the efficiency of organisational processes surrounding protected technologies. Yet the protected hierarchy system also discourages learning that requires risky investments into uncertain search processes. Thus the learning modes for generating radical technological and organisational innovations appear fundamentally different.

In contrast, the knowledge-internalisation system is suited for generating both incremental technological and organisational innovations but unsuited for generating radical technological innovation. This innovation system, with its reliance on the DUI mode of learning, facilitates the generation of rather directly applicable innovations for more efficient ways of organising work. Thus, because the learning modes for generating incremental and organisational innovation either are similar or even reinforce one another, these two innovation types may more easily be generated simultaneously. Overall, by identifying substantive innovation interdependencies amongst both generic and context-specific innovation systems, our analysis exposes the importance of contextual conditions for theories on innovation interdependencies.

6.3. The 'central' and 'surface' layers of innovation systems

Overall, the perspective that we develop in this paper provides insights into how co-existing innovation systems integrate within a larger economic area. The five innovation systems do not simply co-exist independently, nor are they spatially or functionally nested, as some scholars have suggested (Chung, 2002). Instead, we posit that an overarching innovation system exhibits two layers: the 'central' layer and the 'surface' layer. The central layer hosts two distinct and independent generic innovation systems, the DUI mode and the STI mode of learning. By demonstrating that these two ideal types matter for successful innovation not only at the firm level but also at the (macro) level of entire systems, we extend Jensen et al.'s (2007) argument of the importance of these two modes of learning.

The surface layer hosts context-specific regional and sectoral innovation systems. Whilst we find no intersections amongst the generic innovation systems, each innovation system at the surface layer overlaps with the entire central layer. At the surface layer we also identify points of convergence amongst regional and sectoral innovation systems. At these intersections context-specific innovation systems appear to compete for the fundamental institutional and organisational resources necessary for innovation. Thus, whereas Jensen et al. (2007, p. 685) argue that 'the DUI mode when combined with the STI-mode serves to improve innovative performance', we posit that only the combination of these two ideal types with an idiosyncratic element effectively nurtures innovation.

The distinction between the central and the surface layers has important implications for existing conceptual boundaries of innovation systems. The generic innovation systems at the central layer appear to exist *unbounded*, thus functioning irrespective of national, regional or sectoral boundaries. Therefore, the conceptual boundaries, as currently defined in the literature, restrict innovation systems only at the surface layer. This view also suggests that most research on innovation systems has, however unintentionally, analysed innovation systems merely at the surface layer. Thus, particularly, when seeking to understand systemic failures of innovation systems, future research should more strongly focus on understanding how the STI mode and the DUI mode of learning function at the macro-level. Moreover, a better understanding of the mechanisms that drive learning at the central layer also promises important insights into how the generic innovation systems interact with context-specific innovation systems at the surface layer.

Given the functional role that we identify for the two generic innovation systems, and given that they clearly entail the two ideal modes of learning, we expect successful (national) innovation systems to exhibit a similar central layer comprising innovation systems akin to the autarkic and the knowledge-internalisation ones. This argument should hold for all successful innovation systems, irrespective of the size of an economy or the specific resource endowments of a country.

In contrast, the surface layer that hosts regional and sectoral innovation systems is highly context-specific, so that countries will differ in their surface layer of innovation systems. Innovation systems in larger and more complex economies, such as China, India or the US, will contain a larger variety of context-specific innovation systems than smaller countries with less complex economies such as Estonia, New Zealand or Singapore. In turn, this interpretation implies that systemic problems in national innovation systems (Chaminade et al., 2012) will predominantly arise when policy-makers fail to maintain the generic innovation systems at the central layer.

7. Concluding remarks

Our study is limited in at least three ways that provide direction for further research. First, we have analysed firm-level data from a national survey in a static fashion. This empirical approach does not allow us to determine the extent to which national boundaries play a role in the co-existence of integrated innovation systems, or to provide insights into the stability of integrated innovation systems over time. As the intuitional conditions continue to change, future research should investigate the permeability of national boundaries and the dynamics of change of innovation systems.

Second, the comparatively low level of explained variance for organisational innovation in the SUR points to related areas of future research. We argue that existing theories of innovation systems are more suited for explaining technological forms of innovation, thereby reinforcing the call for more autonomous theorising on what drives organisational innovation. Furthermore, given that prominent innovation surveys such as the European 'Community Innovation Survey' (CIS) or the KOF Innovation Survey have only recently included questions on organisational innovation, and given that these questions remain relatively crude measures for organisational innovation (Armbruster et al., 2008), our findings reinforce calls for the development of more refined and accurate measurements for organisational innovation (e.g. Jensen et al., 2007).

Third, our results show that innovation systems exhibit propensities for generating multiple types of innovation. This finding, complementing recent arguments in the innovation literature (Camisón and Villar-López, 2014; Damanpour et al., 2009), highlights interdependencies that exist amongst different types of innovation. In this paper we reveal two patterns of innovation interdependencies. Yet future research may seek to improve scholarly understanding of the theoretical mechanisms underlying these innovation interdependencies.

In sum, in contrast to most research on innovation systems, we show that multiple innovation systems may co-exist across and within sectoral and regional boundaries, and that these systems entail pronounced idiosyncratic combinations of structural elements. Integrating co-existing innovation systems carries important policy implications. We show that adjustments of one particular innovation system element may nurture one innovation system but suppress another. For example investing in IP protection will facilitate innovation in the protected hierarchy system but may stifle innovation in all other innovation systems through raising barriers to knowledge transfer. As an indirect consequence, such policy changes may lead to fewer organisational innovations. Similarly, only the public sciences system would benefit from an increase in innovation funding. Yet by increasing the attractiveness of innovation in the public sciences system, such a policy might lead to a crowding out effect, to the detriment of other innovation systems such as the protected hierarchy or the organised learning system.

At the same time, by identifying two generic innovation systems, our results also provide policy implications that reveal opportunities for mutually beneficial policy interventions. For example, both investments in higher education and the development of a system of collective skill formation (such as the Swiss VET system), accompanied by incentives for university-industry knowledge transfers, appear supportive across all innovation systems. Overall, policy-makers need to carefully balance relatively simple and more complex adjustments and, for the more complex, to understand the ramifications of policy interventions on a variety of innovation systems.

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Tables

Table 1
Descriptive statistics of firms (n=384) included in the analysis

	mean	std.dev.	min	max
Firm characteristics				
Age (in years)	64.87	47.33	1	348
Number of employees	274.39	627.52	8	6980
R&D expenses over sales	0.02	0.04	0	0.34
Sectors (in %)				
Traditional manufacturing	30.99	46.31	0	1
High-tech manufacturing	39.06	48.85	0	1
Construction	4.43	20.60	0	1
Traditional services	15.36	36.11	0	1
Modern services	10.16	30.25	0	1
Regions (in %)				
Lake Geneva Region	5.73	23.27	0	1
Espace Mittelland	20.57	40.48	0	1
Northwestern Switzerland	16.41	37.08	0	1
Zurich	21.09	40.85	0	1
Eastern Switzerland	21.88	41.39	0	1
Central Switzerland	10.42	30.59	0	1
Ticino	3.91	19.40	0	1

Table 2
Principal factor analysis

		Factor 1	Factor 2	Factor 3
Authority sharing and org. learning				
1	*Specialisation*	**0.586**	0.117	0.002
2	*Decentralisation (α = 60%)*	**0.527**	-0.115	0.099
3	*Organisational learning practices*	**0.596**	-0.124	0.373
4	*Vocational education and training*	**0.606**	0.337	-0.217
Involvement in public science system				
5	*Reliance on public innovation funding*	-0.075	**0.836**	0.092
6	*Cooperation with public research institutions*	0.228	**0.721**	0.153
Authoritative inter-firm coordination				
7	*Provision of public knowledge (α = 76%)*	0.137	0.111	**0.729**
8	*Importance of IP protection (α = 70%)*	-0.092	0.176	**0.720**
	Eigenvalues	1.427	1.417	1.278
	Proportion of variance	0.178	0.177	0.160

Table 3
Descriptive statistics and correlation matrix on outcome and explanatory variables

		Mean	Std. dev	1	2	3	4	5	6	7	8
1	Innovativeness	0.48	0.23	1.00							
2	Specialisation	0.51	0.34	0.14***	1.00						
3	Decentralisation	0.33	0.15	0.11**	0.10*	1.00					
4	Organisational-learning practices	0.51	0.26	0.10*	0.11**	0.15***	1.00				
5	Vocational education and training	0.78	0.41	-0.04	0.20***	0.08†	0.16***	1.00			
6	Reliance on public innovation funds	0.13	0.34	0.12**	0.06	0.02	-0.03	0.11**	1.00		
7	Cooperation with public research institutions	0.18	0.39	0.20***	0.11**	0.08†	0.18***	0.18***	0.37***	1.00	
8	Provision of public knowledge	0.40	0.23	0.19***	0.16***	0.04	0.17***	0.03	0.15***	0.14***	1.00
9	Importance of IP protection	0.37	0.26	0.07†	0.01	0.03	0.09*	0.03	0.13***	0.15***	0.22***

Notes: † $p < 0.15$; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. All variables are calibrated set-membership values that range from 0 to 1.

Table 4
Descriptive statistics and correlation matrix of variables included in the second and third steps of the analysis

		Mean	Std. dev	1	2	3	4	5	6	7	8	9
1	Organisational innovation	0.46	0.26									
2	Radical innovation	0.47	0.35	-0.01								
3	Incremental innovation	0.49	0.34	0.08†	0.36***							
4	Autarkic	0.04	0.12	-0.06	0.09*	0.03						
5	Public science	0.03	0.10	0.08†	0.10**	0.15***	-0.13**					
6	Knowledge-internalising	0.02	0.08	0.13***	-0.05	0.06	-0.10*	0.40***				
7	Protected hierarchy	0.02	0.08	0.14***	0.02	0.05	-0.10*	0.46***	0.49***			
8	Organised learning	0.03	0.09	0.1**	0.07	0.07	-0.10*	0.50***	0.53***	0.73***		
9	Age (in years)	64.87	47.33	0.08†	-0.07	-0.16***	-0.11**	0.02	0.04	0.05	0.04	
10	Size (number of employees)	274.39	627.52	0.13***	-0.06	-0.01	-0.10**	0.12**	0.01	0.11**	0.08†	0.11**
11	R&D expenses over sales	0.02	0.04	0.01	0.24***	0.30***	0.00	0.25***	0.05	0.08†	0.12**	-0.07
12	Traditional manufacturing	0.31	0.46	-0.09*	0.02	-0.11***	-0.03	-0.03	0.04	-0.02	-0.06	0.17***
13	High-tech manufacturing	0.39	0.49	0.03	0.19***	0.36***	0.07†	0.09*	-0.03	0.08	0.05	-0.18***
14	Construction	0.04	0.21	-0.02	-0.17***	-0.16***	-0.05	-0.06	0.00	-0.05	-0.05	0.00
15	Traditional services	0.15	0.36	0.06	-0.06	-0.15***	0.01	-0.11*	-0.05	-0.11**	-0.08†	0.04
16	Modern services	0.10	0.30	0.04	-0.14***	-0.13**	-0.06	0.06	0.05	0.07	0.15***	-0.01
17	Lake Geneva Region	0.06	0.23	0	0.02	0.01	-0.00	0.04	0.01	0.01	-0.02	-0.07
18	Espace Mittelland	0.21	0.40	-0.01	-0.04	0.01	0.10*	0.00	0.05	-0.03	-0.01	0.01
19	Northwestern Switzerland	0.16	0.37	0.02	-0.04	-0.07	0.03	0.02	0.04	0.01	-0.01	-0.04
20	Zurich	0.21	0.41	0.03	0.01	-0.03	-0.02	0.05	-0.03	-0.00	0.06	0.00
21	Eastern Switzerland	0.22	0.41	0.01	0.09*	0.05	-0.05	-0.01	-0.03	0.07	-0.00	-0.00
22	Central Switzerland	0.10	0.31	-0.04	-0.01	-0.01	-0.05	-0.10*	-0.04	-0.05	-0.04	0.12**
23	Ticino	0.04	0.19	-0.05	-0.05	0.06	-0.01	-0.03	0.00	-0.04	-0.01	-0.05

Notes: † $p < 0.15$; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. All variables are calibrated set-membership values that range from 0 to 1.

Table 4 (continued)
Descriptive statistics and correlation matrix of contextual variables included in the second and third steps of the analysis

		10	11	12	13	14	15	16	17	18	19	20	21	22
10	Number of employees													
11	R&D expenditures over sales	0.01												
12	Traditional manufacturing	-0.07	-0.19***											
13	High-tech manufacturing	-0.01	0.35***	-0.54***										
14	Construction	0.00	-0.11**	-0.14***	-0.17***									
15	Traditional services	0.02	-0.21**	-0.29***	-0.34***	-0.09*								
16	Modern services	0.11**	0.06	-0.23***	-0.27***	-0.07	-0.14***							
17	Lake Geneva Region	-0.01	0.07	0.08†	0.01	-0.05	-0.01	-0.08†						
18	Espace Mittelland	0.01	0.03	0.08†	-0.01	-0.08†	-0.06	0.02	-0.13**					
19	Northwestern Switzerland	0.15**	-0.05	-0.07	0.02	0.01	0.05	0.01	-0.11**	-0.23***				
20	Zurich	-0.02	0.02	-0.17***	-0.03	0.14***	0.05	0.16***	-0.13**	-0.26***	-0.23***			
21	Eastern Switzerland	-0.08†	-0.02	0.12**	0.00	-0.05	-0.05	-0.09*	-0.13**	-0.27***	-0.23***	-0.27***		
22	Central Switzerland	-0.03	-0.04	-0.03	0.04	0.01	0.04	-0.09*	-0.08†	-0.17***	-0.15***	-0.18***	-0.18***	
23	Ticino	-0.03	0.02	0.01	-0.02	0.02	-0.01	0.02	-0.05	-0.10**	-0.09*	-0.10**	-0.11**	-0.07

Notes: † $p < 0.15$; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. All variables are calibrated set-membership values that range from 0 to 1.

Table 5
Results of one-sample t-tests on contextual factors of Swiss innovation systems

				1	2	3	4	5
Innovation system				*Autarkic*	*Public sciences*	*Knowledge-internalisation*	*Protected hierarchy*	*Organised learning*
No. of cases with MS > .5				*71*	*32*	*11*	*8*	*9*
	Sample descriptives			*Differences in means*				
	mean	*min*	*max*					
Sectors (in %)								
Traditional manufacturing	30.99	0	1	-1.41	-9.12†	5.37	6.51	-19.88*
High-tech manufacturing	39.06	0	1	-2.44	32.79***	-2.69	10.94	5.38
Construction	4.43	0	1	-1.61	(-4.43)§	4.66	(-4.43)§	(-4.43)§
Traditional services	15.36	0	1	4.36	-12.24***	-6.27	(-15.36)§	(-15.36)§
Modern services	10.16	0	1	1.11	-7.04**	-1.07	2.34	34.28**
Regions (in %)								
Lake Geneva Region	5.73	0	1	1.31	0.52	3.36	6.77	(-5.73)§
Espace Mittelland	20.57	0	1	0.56	1.31	-2.39	-8.07	12.76
Northwestern Switzerland	16.41	0	1	3.31	2.34	10.86	-3.91	(-16.41)§
Zurich	21.09	0	1	-2.78	7.04	-2.91	(-21.09)§	23.35†
Eastern Switzerland	21.88	0	1	-2.16	-3.13	-3.70	40.62**	-10.77
Central Switzerland	10.42	0	1	-0.56	-7.30**	-1.33	(-10.42)§	0.69
Ticino	3.91	0	1	0.31	-0.79	(-3.91)§	(-3.91)§	(-3.91)§

Notes: † $p < 0.15$; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. § Variables with no variance.

Table 6
Results from SUR

		Radical innovation	Incremental innovation	Organisational innovation
Set-membership scores in innovation system				
1	*Autarkic*	.144 (.153)	-.031 (.144)	-.084 (.123)
2	*Public sciences*	.224 (.195)	.250 (.183)	-.021 (.157)
3	*Knowledge-internalisation*	-.430† (.266)	.364† (.250)	.380* (.213)
4	*Protected hierarchy*	-.435† (.302)	-.392 (.284)	.369† (.242)
5	*Organised learning*	.560** (.284)	.068 (.267)	-.177 (.228)
Controls included for				
	Firm-level variables	YES	YES	YES
	Sectoral variables	YES	YES	YES
	Regional variables	NO	NO	NO
R^2		0.158	0.225	0.061
Chi^2 test (p-value)		0.000	0.000	0.074
Differences in R^2				
	Radical innovation		-0.067†	-0.097**
	Incremental innovation			-0.164***
	Organisational innovation			

Notes: n=384. All variables are calibrated set-membership values that range from 0 to 1. Controls for firm characteristics are i) firm age (in log years), ii) number of employees (in logs) and iii) R&D expenses over sales. Controls for the educational composition of firms' workforce (in percentages) are i) employees with university degrees, ii) professional education and training degrees, iii) VET degrees, iv) degrees lower than VET and v) apprentices (reference category). Sectoral control variables are i) traditional manufacturing, ii) construction, iii) traditional services, iv) modern services and v) high-technology (reference category). The chi^2 test is equivalent to an F test that tests the joint significance of all covariates. To test the significance between the differences in R^2 of the three innovation types we applied a bootstrap method with 500 iterations to identify the distribution of R^2 for each equation. We use Wald-Test to test differences. † $p < 0.15$; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 7
Generic and context-specific innovation systems in Switzerland

		Key features	Similarities with
'Central' layer - The generic innovation systems			
1	Autarkic	• Specialisation • No organisational learning • No VET	• Jensen et al.'s (2007) 'Science, Technology and Innovation' (STI)
2	Knowledge internalisation	• Cooperation with public research institutes • Provision of public knowledge	• Jensen et al.'s (2007) 'Doing, Using and Interacting' (DUI)
'Surface' layer - The context-specific innovation systems			
3	Public science	• Cooperation with public research institutes • No organisational learning • *Important for high-tech manufacturing*	• Castellacci's (2008) Mass production goods system
4	Protected hierarchy	• Cooperation with public research institutes • Reliance on IP protection • *Regional concentration in Eastern Switzerland*	• Cooke's (1998) Grassroots system • Asheim & Coenen's (2005) Territorially embedded system
5	Organised learning	• Decentralisation • Cooperation with public research institutes • *Important for modern services sector*	• Castellacci's (2008) Advanced knowledge providers

Figures

Innovation system	*1* *Autarkic*	*2* *Public sciences*	*3* *Knowledge-internalisation*	*4* *Protected hierarchy*	*5* *Organised learning*
Authority sharing & org. learning					
Specialisation	●	•	⊗	•	•
Decentralisation	⊗	⊗	⊗	⊗	●
Organizational learning practices	⨂	⨂	•	•	•
Vocational education and training	⨂	•	•	•	•
Involvement in public science system					
Reliance on public innovation funding	⊗		⊗	⨂	⊗
Cooperation with public research institutions	⊗	●	●	●	●
Authoritative inter-firm coordination					
Provision of public knowledge		⊗	●	⊗	⊗
Importance of IP protection	⊗	⊗	⊗	●	⊗
No. of prototypical firms	71	32	11	8	9
Model coefficients					
Consistency	0.93	0.96	0.94	0.95	0.94
Raw Coverage	0.08	0.07	0.04	0.04	0.05
Unique Coverage	0.08	0.04	0.01	0.01	0.01
Overall Solution Consistency	**0.93**				
Overall Solution Coverage	**0.19**				

Notes: Large circles represent core conditions; small circles, peripheral conditions. Crossed-out circles denote that the absence of a condition is important for an innovation system. Empty cells indicate that a condition is irrelevant, i.e. neither its presence nor its absence is associated with overall innovativeness. MS = membership score.

Fig. 1: Configuration chart of innovation systems in the Swiss economy

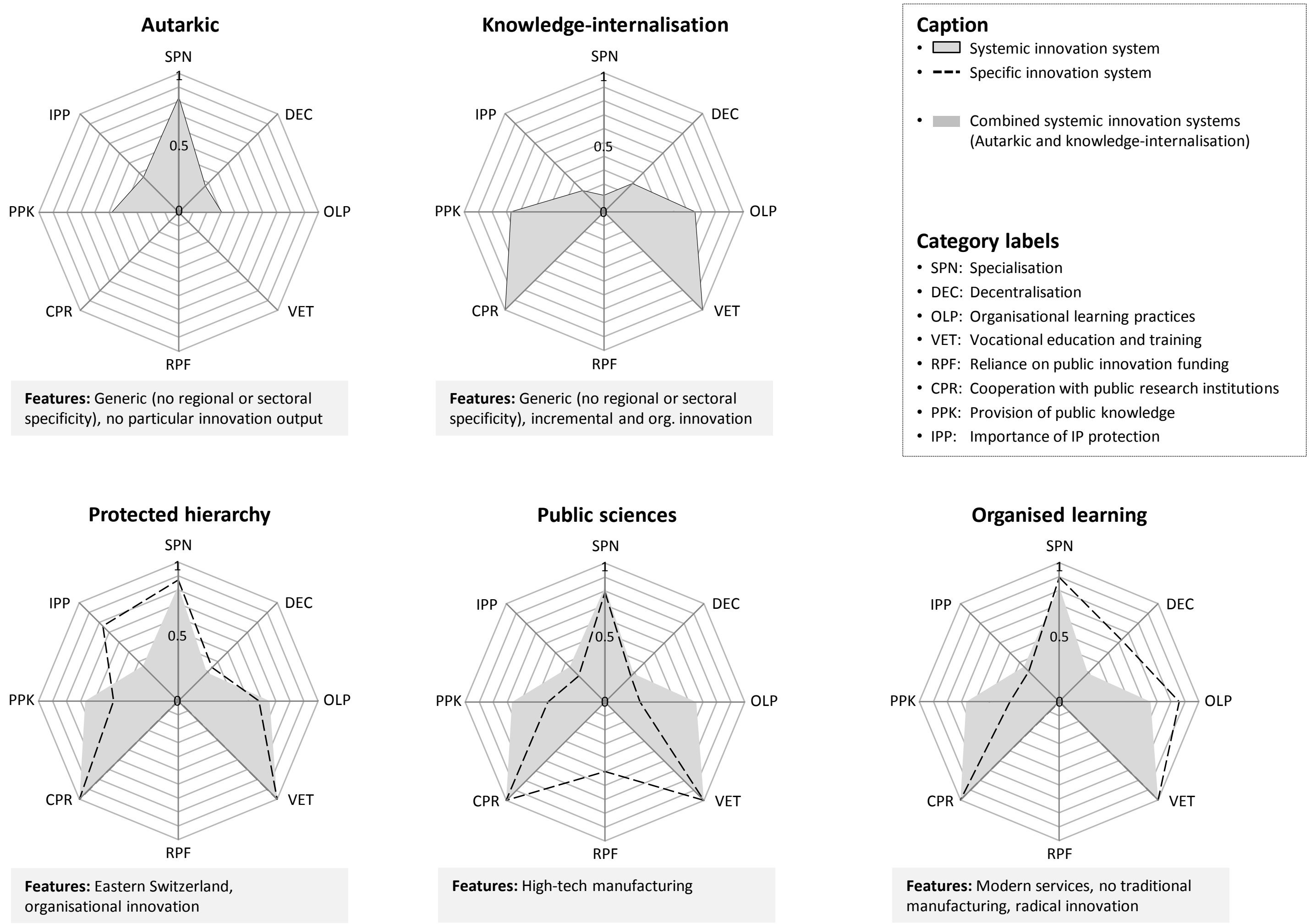

Fig. 2: Spider charts of generic and specific innovation systems

Appendix A. Sectoral and regional classifications, measurement specification

Table A.1
Official sectoral classification of the Swiss Federal Statistical Office.

Sector	Description
Traditional manufacturing	Manufacture of food products, beverages and tobacco; manufacture of textiles and textile products; manufacture of wearing apparel; dressing and dyeing of fur and manufacture of leather and leather products; manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and painting materials; manufacture of pulp, paper and paper products; publishing, printing and reproduction of recorded media; manufacture of other non-metallic mineral products; manufacture of basic metals; manufacture of fabricated metal products, except machinery and equipment; manufacture of watches and clocks; manufacture of furniture, jewellery, musical instruments, sports goods, games and toys and other goods, recycling; electricity, gas and water supply
Traditional services	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel and wholesale trade and commission trade, except of motor vehicles and motorcycles, Hotels and restaurants, Land transport; transport via pipelines, Water transport, air transport and supporting transport activities; activities of travel agencies, Real estate activities and Renting of machinery and equipment without operator and of personal and household goods, Other service activities
High tech manufacturing	Manufacture of coke, refined petroleum products and nuclear fuel and manufacture of chemicals and chemical products, Manufacture of rubber and plastic products, Manufacture of machinery and equipment n.e.c., Manufacture of electrical machinery and apparatus n.e.c., Manufacture of office machinery, data processing devices, Manufacture of radio, television and communication equipment and apparatus, manufacture of medical and surgical equipment and orthopedic appliances, manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, manufacture of industrial process control equipment and manufacture of optical instruments and photographic equipment, Manufacture of transport equipment
Modern services	Financial intermediation; insurance (excluding compulsory social security); computer related activities and research and development; other business activities; post and telecommunications
Construction	Construction

Table A.2
Regional classification of the Swiss Federal Statistical Office.

Region	Cantons
Lake Geneva Region	Geneva, Vaud, Valais
Espace Mittelland	Berne, Fribourg, Solothurn, Neuchâtel, Jura
Northwestern Switzerland	Basel-Stadt, Basel-Landschaft, Aargau
Zurich	Zurich
Eastern Switzerland	Glarus, Schaffhausen, Appenzell A. Rh, Appenzell I. Rh, St. Gallen, Grison, Thurgau
Central Switzerland	Lucerne, Uri, Schwyz, Obwalden, Nidwalden, Zug
Ticino	Ticino

Table A.3
Measurement definitions used in the analysis.

Indicator	fsQCA	SUR	Calibration/ measurement	Description
Innovativeness	Outcome		d. calibration	Aggregate of calibrated innovation measures for radical, incremental and organisational innovation.
Radical innovation		DV	d. calibration	Sales percentage of newly introduced products.
Incremental innovation		DV	d. calibration	Sales percentage of substantially improved products.
Organisational innovation		DV	d. calibration	Count measure considering major changes to i) the distribution of competences between employer and employees; ii) the distribution of tasks; iii) the overall organisation of the company (e.g. mergers, new cooperation, outsourcing).
Specialisation	EV		d. calibration	Blau's index of types of educational degrees of a firm's workforce (employees with university degrees, professional education and training degrees, vocational education and training degrees, apprentices and degrees lower that vocational education and training).
Decentralisation	EV		d. calibration	Scale from five items asking whether employer or employees has decision-making power; ranges from 0 (centralised) to 1 (decentralised); α = 60%.
Organisational-learning practices	EV		d. calibration	Count measure of binary indicators considering implementation of i) teamwork; ii) job rotation, iii) continued training activities.
Vocational Education and Training	EV		ind. calibration	Binary variable, 1 if the firm participates in the VET, 0 otherwise.
Reliance on public innovation funds	EV		ind. calibration	Binary variable, 1 if the firm makes use of public innovation funds, 0 otherwise.
Cooperation with public research institutions	EV		ind. calibration	Binary variable, 1 if the firm cooperates with public research organisations, 0 otherwise.
Provision of public knowledge.	EV		d. calibration	Four-items scale on relevance of publicly available information (e.g. patents, science fairs, scientific meetings); ranges from 0 (not relevant) to 1 (very relevant); α = 70%.
Importance of IP protection	EV		ind. calibration	Five-point Likert-scale question dependence of firm's competitive advantage on IP protection, ranges from 0 (no dependence) to 1 (high dependence); α = 76%.
Autarkic IS		EV	fuzzy set score	Fuzzy set membership score computed from results of first-step analysis.
Public sciences IS		EV	fuzzy set score	Fuzzy set membership score computed from results of first-step analysis.
Knowledge-internalisation IS		EV	fuzzy set score	Fuzzy set membership score computed from results of first-step analysis.
Protected hierarchy IS		EV	fuzzy set score	Fuzzy set membership score computed from results of first-step analysis.
Organised learning IS		EV	fuzzy set score	Fuzzy set membership score computed from results of first-step analysis.
Age		CV	uncalibrated	In years since founding (in log years).
Size		CV	uncalibrated	Number of employees (in logs).
R&D intensity		CV	uncalibrated	R&D expenses over sales.
Sector		CV	uncalibrated	Categorical variables: 1 = Traditional manufacturing; 2 = High-tech manufacturing; 3 = Construction; 4 = Traditional services; 5 = Modern services (Source: Swiss Federal Statistical Office).
Region		CV	uncalibrated	Categorical variables: 1 = Lake Geneva Region; 2 = Espace Mittelland; 3 = Northwestern Switzerland; 4 = Zurich; 5 = Eastern Switzerland; 6 = Central Switzerland; 7 = Ticino (Source: Swiss Federal Statistical Office).

DV = Dependent variable; EV = Explanatory variable; CV = Control variable; VET = Vocational education and training; IS = Innovation system; CHF = Swiss Francs; IP = Intellectual property; R&D = Research and development; d. calibration = direct method of calibration; ind. calibration = indirect method of calibration.

Appendix B. Results robustness and measurement reliability

We conducted several tests to ensure the robustness of our results. First, to understand the implications of the elimination strategy for defining our sample, we used one-sample t-tests to compare means between the full sample (n= 2552) and the group of firms retained in the analysis (n=384). As Table B.1 shows, firms in the analysis are on average older (M = 64.9 versus M = 63.2) and larger (M = 274.4 versus M = 255.8), and have a lower share of employees in R&D (M = 5.9 versus M = 6.3). None of the differences are statistically significant.

Insert Table B.1 about here

However, we find statistically significant differences in the sectoral and regional distribution between the firms in the analysis and the full sample. Manufacturing firms and firms located in Eastern Switzerland are significantly overrepresented in our sample. These differences will not change the substantive contribution of our study because those innovation systems that we identify for overrepresented sectors and regions will exist in their own right, i.e. irrespective of sampling differences. However, we also find service and construction firms and firms in the Lake Geneva Region to be significantly under-represented in our sample. These differences may hinder the identification of additional innovation systems specific to under-represented sectors and regions.

Previewing our results, we argue that the very high consistency scores for the individual innovation systems that we actually identify in our study mitigate concerns that over- or under-representation might change our results. Our main concern then pertains to the risk of not identifying innovation systems specific to under-represented sectors and regions. Given that for one of these under-represented sectors, the modern services, we identify a specific innovation system (despite the sector's being under-represented), the differences might change our results by identifying innovation systems specific to the construction or traditional service industry or the Lake Geneva Region. Thus, overall, we argue that these differences – although statistically significant – will not alter the substantive contribution of our study.

Second, we have developed our measures closely in line with the innovation literature and have used Cronbach's Alphas to examine the reliability of our multi-item measures. The results for all measures indicate acceptable reliability. Additionally, we explore how our performance-oriented innovation measures relate to alternative intention-oriented measures, e.g. patenting, the number of patents and the introduction of new or improved products and R&D expenditures. Table B.2 shows that our aggregate innovation measure correlates significantly with all three independent innovation-type measures but not with any of the alternative ones. This finding indicates that our innovation measures adequately capture a system's success at innovating, rather than merely at fostering intentions to innovate.

Insert Table B.2 about here

Third, to ensure that our results are not biased by SUR's inability to account for censored outcome variables, we examine the minimum and the maximum of all three innovation types and estimate both a three-equation Tobit model and a three-equation OLS model. Tables B.3 and B.4 show the results of the two models, respectively. None of the values touches the upper or lower censoring limit (0 or 1), and in both models, coefficients, standard errors and the goodness of fit measures remain stable. As expected, neither the results of the Tobit model nor the results of the OLS model differ substantively from those of the SUR analysis.

Insert Table B.3 and Table B.4 about here

Fourth, following recent studies using fsQCA (e.g. Fiss, 2011; Crilly et al., 2014), we assess the extent to which our results of the fsQCA analysis are sensitive to different calibrations. We do so by varying the crossover points by up to +/- 2.5 % for those explanatory variables that we had calibrated via the direct method, because these variables appear most likely to be sensitive to alternative thresholds. Figure B.1 shows the fsQCA results for an increase of 2.5% of the crossover point; Figure B.2, the results for a decrease of 2.5% of the crossover point.

Insert Figure B.1 and Figure B.2 about here

Further, by increasing and decreasing the consistency cut-off by .01, we examine the extent to which the fsQCA results are robust to different specifications of frequency and consistency cut-offs. Figures B.3 and B.4 show the results of these analyses, respectively.

Insert Figure B.3 and Figure B.4 about here

Moreover, we examine the robustness of our results by increasing and decreasing the frequency cut-off by 1. Figures B.5 and B.6 show the results of these analyses, respectively.

Insert Figure B.5 and Figure B.6 about here

Table B.5 summarises the results of the robustness tests. We find the autarkic and the protected hierarchy innovation systems to be highly robust across all tests. The public science and the knowledge internalisation innovation systems are most sensitive to an increase of the frequency cut-off. The organised learning innovation system is sensitive to an increase in the consistency cut-off. Nonetheless, the substantive implications of our study remain unaffected by these changes.

Insert Table B.5 about here

Appendix B. Tables

Table B.1
Results from one-sample t-tests comparing differences in means between full sample and sample of firms in the analysis

Organisational characteristics	Full sample Mean (n=2,552)	Sample in analysis Mean (n=384)	*Mean Difference*
Age (in years)	63.20	64.87	*1.67*
R&D expenses over sales	0.02	0.02	*-0.00*
Number of employees	255.77	274.39	*18.62*
Share of employees in R&D (in %)	6.28	5.92	*-0.36*
Sectors (in %)			
Traditional manufacturing	25.47	30.99	*5.52***
High-tech manufacturing	23.98	39.06	*15.08****
Construction	10.12	4.43	*-5.69***
Traditional services	24.69	15.36	*-9.33****
Modern services	15.67	10.16	*-5.51****
Regions (in %)			
Lake Geneva Region	12.93	5.73	*-7.20****
Espace Mittelland	21.94	20.57	*-1.37*
Northwestern Switzerland	14.50	16.41	*1.91*
Zurich	19.20	21.09	*1.89*
Eastern Switzerland	17.05	21.88	*4.83***
Central Switzerland	9.52	10.42	*0.90*
Ticino	4.86	3.91	*-0.95*

Note: † $p < 0.15$; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table B.2
Correlations amongst innovation measures

		1	2	3	4	5	6	7	8
1	Overall innovativeness								
2	Organisational innovation	0.450***							
3	Radical innovation: Sales share of newly introduced products	0.737***	-0.013						
4	Incremental innovation: Sales share of improved products	0.767***	0.077†	0.365***					
5	Use of patenting (binary)	0.247***	-0.004	0.207***	0.254***				
6	Number of registered patents 2006-2008	0.177***	0.062	0.137***	0.143***	0.409***			
7	Newly introduced products (binary)	0.218***	0.046	0.170***	0.198***	0.123**	0.073		
8	Newly introduced processes (binary)	0.120**	0.049	0.071	0.114**	-0.039	0.021	-0.114**	
9	R&D expenditures	0.159***	0.116**	0.082†	0.123**	0.189***	0.548***	0.066	0.048

Note: † p < 0.15; * p < 0.1; ** p < 0.05; *** p < 0.01.

Table B.3
Results of three-equation Tobit model

		Radical innovation	Incremental innovation	Organisational innovation
1	Autarkic	0.144 (0.153)	-0.031 (0.144)	-0.084 (0.123)
2	*Public sciences*	0.224 (0.195)	0.250 (0.184)	-0.021 (0.157)
3	*Knowledge-internalisation*	-0.430† (0.266)	0.364† (0.250)	0.380* (0.214)
4	*Protected hierarchy*	-0.435 (0.302)	-0.392 (0.284)	0.369† (0.242)
5	*Organised learning*	0.560** (0.284)	0.068 (0.267)	-0.177 (0.228)
Controls included for				
	Firm-level variables	YES	YES	YES
	Sectoral variables	YES	YES	YES
	Regional variables	NO	NO	NO
Pseudo-R^2		*0.241*	*0.378*	*0.378*

Notes: n=384. All variables are calibrated set-membership values that range from 0 to 1. Controls for firm characteristics are i) firm age (in log years), ii) number of employees (in logs) and iii) R&D expenses over sales. Controls for the educational composition of firms' workforce (in percentages) are i) employees with university degrees, ii) professional education and training degrees, iii) VET degrees, iv) degrees lower than VET and v) apprentices (reference category). Sectoral control variables are i) traditional manufacturing, ii) construction, iii) traditional services, iv) modern services and v) high-technology (reference category). † $p < 0.15$; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table B.4
Results of three-equation OLS-model

		Radical innovation	Incremental innovation	Organisational innovation
1	Autarkic	0.144 (0.157)	-0.031 (0.147)	-0.084 (0.126)
2	*Public sciences*	0.224 (0.200)	0.250 (0.188)	-0.021 (0.160)
3	*Knowledge-internalisation*	-0.430† (0.272)	0.364 (0.256)	0.380* (0.219)
4	*Protected hierarchy*	-0.435 (0.309)	-0.392 (0.290)	0.369† (0.248)
5	*Organised learning*	0.560* (0.290)	0.068 (0.273)	-0.177 (0.233)
Controls included for				
	Firm-level variables	YES	YES	YES
	Sectoral variables	YES	YES	YES
	Regional variables	NO	NO	NO
R^2		*0.158*	*0.225*	*0.061*

Notes: n=384. All variables are calibrated set-membership values that range from 0 to 1. Controls for firm characteristics are i) firm age (in log years), ii) number of employees (in logs) and iii) R&D expenses over sales. Controls for the educational composition of firms' workforce (in percentages) are i) employees with university degrees, ii) professional education and training degrees, iii) VET degrees, iv) degrees lower than VET and v) apprentices (reference category). Sectoral control variables are i) traditional manufacturing, ii) construction, iii) traditional services, iv) modern services and v) high-technology (reference category). † $p < 0.15$; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table B.5
Summary of fsQCA robustness test

	1 Autarkic	2 Public sciences	3 Knowledge internalisation	4 Protected hierarchy	5 Organised learning
ROBUSTNESS TESTS					
Crossover point = 50th percentile (+2.5%)	A: Identical	B: Similar	C: Identical	D: Similar	E: Identical
Crossover point = 50th percentile (-2.5%)	A: Somewhat Similar	C: Similar	B: Similar	D: Identical	E: Identical
Consistency cut-off = 0.95 (+.01)	A: Similar	C: Similar	B: Identical	D. Similar	Does not appear
Consistency cut-off = 0.93 (-.01)	A1 & A2: Similar	B: Identical	C: Identical	D: Identical	E: Identical
Frequency cut-off = 4 (+1)	A: Identical	Does not appear	Does not appear	B: Similar	C: Identical
Frequency cut-off = 2 (-1)	A1 & A2: Very Similar	B: Similar	C: Similar	F: Similar	H: Similar

Notes: In comparing the results reported in the paper with the six robustness tests we coded innovation systems as *identical* when there is no change in either core or contribution condition; *very similar* if no directional change in core condition; *similar* if directional change in core condition; *somewhat similar* if most core conditions remain stable but other core and contributing conditions change. Innovation systems that were not shown in the robustness test were coded as '*does not appear'*. Capital letters (e.g. A, B, C) refer to innovation systems identified in the robustness tests.

Appendix B. Figures

Frequency cut-off: 3 ***Consistency cut-off: 0.93***	*Robustness test No. 1* ***Crossover point +2.5 percentage points***				
Permutation	*A*	*B*	*C*	*D*	*E*
Corresponding innovation system in reported results	*1*	*2*	*3*	*4*	*5*
Authority sharing & org. learning					
Specialisation	⬤	•	⊗	⬤	•
Decentralisation	⊗	⊗	⊗	⊗	⬤
Organizational learning practices	⨂	⨂	•	•	•
Vocational education and training	⨂	•	•	•	•
Involvement in public science system					
Reliance on public innovation funding	⊗	⨂	⊗	⊗	⊗
Cooperation with public research institutions	⊗	⬤	⬤	⬤	⬤
Authoritative inter-firm coordination					
Provision of public knowledge		⊗	⬤	⊗	⊗
Importance of IP protection	⊗	⊗	⊗	⬤	⊗
Model coefficients					
Consistency	0.93	0.94	0.94	0.95	0.94
Raw Coverage	0.08	0.04	0.04	0.04	0.05
Unique Coverage	0.08	0.01	0.01	0.01	0.01
Overall Solution Consistency	**0.92**				
Overall Solution Coverage	**0.16**				

Fig. B.1 Robustness Test No. 1 - Crossover point +2.5%

Frequency cut-off: 3 ***Consistency cut-off: 0.93***	*Robustness test No. 2* ***Crossover point -2.5 percentage points***					
Permutation	*A*	*B*	*C*	*D*	*E*	*F*
Corresponding innovation system in reported results	*1*	*3*	*2*	*4*	*5*	*new*
Authority sharing & org. learning						
Specialisation	⬤	⊗	•	•	•	•
Decentralisation	⊗	⊗	⊗	⊗	⬤	⊗
Organizational learning practices		•	⨂	•	•	•
Vocational education and training	⨂	•	•	•	•	•
Involvement in public science system						
Reliance on public innovation funding	⊗	⨂	•	⨂	⊗	⬤
Cooperation with public research institutions	⊗	⬤	⬤	⬤	⬤	⊗
Authoritative inter-firm coordination						
Provision of public knowledge	⬤	⬤	⊗	⊗	⊗	⬤
Importance of IP protection	⊗	⊗	⊗	⬤	⊗	⬤
Model coefficients						
Consistency	0.93	0.94	0.98	0.94	0.93	0.94
Raw Coverage	0.08	0.04	0.03	0.04	0.05	0.02
Unique Coverage	0.08	0.01	0.03	0.01	0.01	0.02
Overall Solution Consistency	**0.93**					
Overall Solution Coverage	**0.20**					

Fig. B.2 Robustness Test No. 2 - Crossover point -2.5%

Frequency cut-off: 3 ***Consistency cut-off: 0.94***	*Robustness test No. 3* ***Consistency cut-off = 0.94(+0.01)***			
Permutation	*A*	*B*	*C*	*D*
Corresponding innovation system in reported results	*1*	*3*	*2*	*4*
Authority sharing & org. learning				
Specialisation	●	⊗	•	•
Decentralisation	⊗	⊗	⊗	⊗
Organizational learning practices	⊗	•	⨂	•
Vocational education and training	⨂	•	•	•
Involvement in public science system				
Reliance on public innovation funding	⊗	⊗	●	⨂
Cooperation with public research institutions	⊗	●	●	●
Authoritative inter-firm coordination				
Provision of public knowledge	●	●	⊗	⨂
Importance of IP protection	⊗	⊗	⊗	•
Model coefficients				
Consistency	0.94	0.94	0.99	0.95
Raw Coverage	0.07	0.04	0.03	0.04
Unique Coverage	0.07	0.02	0.03	0.02
Overall Solution Consistency	**0.95**			
Overall Solution Coverage	**0.16**			

Fig. B.3 Robustness Test No. 3 - Consistency cut-off = 0.94 (+0.01)

Frequency cut-off: 3 ***Consistency cut-off: 0.92***	*Robustness test No. 4* ***Consistency cut-off = 0.92(-0.01)***					
Permutation	*A1*	*A2*	*B*	*C*	*D*	*E*
Corresponding innovation system in reported results	*1*	*1*	*2*	*3*	*4*	*5*
Authority sharing & org. learning						
Specialisation	●	●	•	⊗	•	•
Decentralisation	⊗	⊗	⊗	⊗	⊗	●
Organizational learning practices	⊗		⨂	•	•	•
Vocational education and training	⨂	⨂	•	•	•	•
Involvement in public science system						
Reliance on public innovation funding	⊗	⊗		⊗	⨂	⊗
Cooperation with public research institutions	⊗	⊗	●	●	●	●
Authoritative inter-firm coordination						
Provision of public knowledge		⊗	⊗	●	⊗	⊗
Importance of IP protection	⊗	⊗	⊗	⊗	●	⊗
Model coefficients						
Consistency	0.93	0.90	0.96	0.94	0.95	0.94
Raw Coverage	0.08	0.08	0.07	0.04	0.04	0.05
Unique Coverage	0.01	0.01	0.04	0.01	0.01	0.01
Overall Solution Consistency	**0.92**					
Overall Solution Coverage	**0.20**					

Fig. B.4 Robustness Test No. 4 - Consistency cut-off = 0.92 (-0.01)

Frequency cut-off: 4 ***Consistency cut-off: 0.93***	*Robustness test No. 5* ***Frequency cut-off*** *= 4(+1)*		
Permutation	*A*	*B*	*C*
Corresponding innovation system in reported results	*1*	*4*	*5*
Authority sharing & org. learning			
Specialisation	●	•	•
Decentralisation	⊗	⊗	●
Organizational learning practices	⨂	•	•
Vocational education and training	⨂	•	•
Involvement in public science system			
Reliance on public innovation funding	⊗	⊗	⊗
Cooperation with public research institutions	⊗	●	●
Authoritative inter-firm coordination			
Provision of public knowledge		⊗	⊗
Importance of IP protection	⊗	●	⊗
Model coefficients			
Consistency	0.93	0.95	0.94
Raw Coverage	0.08	0.04	0.05
Unique Coverage	0.08	0.01	0.02
Overall Solution Consistency	**0.93**		
Overall Solution Coverage	**0.14**		

Fig. B.5 Robustness Test No. 5 - Frequency cut-off = 4 (+1)

Frequency cut-off: 2 ***Consistency cut-off: 0.93***					*Robustness test No. 6* ***Frequency cut-off*** *= 2(-1)*					
Permutation	*A1*	*A2*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*
Corresponding innovation system in reported results	*1*	*1*	*2*	*3*	*new*	*new*	*4*	*new*	*5*	*new*
Authority sharing & org. learning										
Specialisation	●	●	●		⊗	●	●	•	●	•
Decentralisation	⊗		⊗	⊗	⊗	⨂	⊗	●	●	⊗
Organizational learning practices	⨂	⨂	⨂	•	⨂	⊗	•	⊗	•	•
Vocational education and training	⨂	⨂	•	•	•	⨂	•	●	•	•
Involvement in public science system										
Reliance on public innovation funding	⊗	⊗		⨂	•	•	⨂	⊗	⊗	●
Cooperation with public research institutions	⊗	⊗	●	●	●	•	●	⊗	●	⊗
Authoritative inter-firm coordination										
Provision of public knowledge		•	⊗	●	●	●	⊗	●	⊗	●
Importance of IP protection	⊗	⊗	⊗	⊗	⊗	⊗	●	•	⊗	●
Model coefficients										
Consistency	0.93	0.93	0.96	0.95	0.97	1.00	0.95	0.93	0.94	0.95
Raw Coverage	0.08	0.08	0.07	0.07	0.02	0.01	0.04	0.15	0.05	0.02
Unique Coverage	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.15	0.01	0.02
Overall Solution Consistency	**0.93**									
Overall Solution Coverage	**0.40**									

Fig. B.6 Robustness Test No. 6 - Frequency cut-off = 2 (-1)