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Idiosyncrasies within and Interdependencies between Innovation Systems: A mixed method approach

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Abstract

The innovation system approach has not only taken a prominent position in the academic literature but has also influenced policymakers around the globe. Most studies in this literature have analysed single innovation systems from a country-level perspective, following a 'technological imperative'. Yet recent findings on regional and sectoral innovation systems, the internationalization of firms and markets and improved understandings of the role of non-technological innovations require a re-examination of the innovation system approach. This paper identifies co-existing innovation systems that depend on different institutional and organizational arrangements and seeks to understand the propensity of these systems to generate technological and non-technological types of innovation. We analyse a sample of 384 Swiss firms and use three methodological steps: first, fsQCA for identifying innovation systems; second, t-tests for examining whether innovation systems are constrained by organizational, sectoral or regional boundaries; and third, regression analysis to show which innovation systems are more suited for generating radical, incremental or organizational innovations. We identify four co-existing innovation systems in the Swiss economy: the autarkic, the knowledge-internalisation, the corporate and the public science innovation system. These innovation systems exist across and within sectoral and regional boundaries and entail substantively different propensities to innovate. Our results indicate that, because of their idiosyncrasies, studying innovation systems in isolation risks neglecting important interdependencies across co-existing innovation systems.

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Keywords

Innovation systems; technological and organizational 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 innovation can be facilitated by policymakers (Edquist, 2005; Sharif, 2006; Von Hippel, 1988; Zaltman et al., 1973). 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 configurations of institutional arrangements and organizations leading to technological change (Carlsson et al., 2002; Lundvall, 2007).

Most research on innovation systems is conducted at the country level examining - in the form of single or comparative case studies (e.g., Dantas and Bell, 2009; Hart, 2009; Hung and Whittington, 2011) - how the innovation systems of different nations, regions or sectors (Breschi and Malerba, 1997; Buesa et al., 2010; Malerba, 2004) facilitate the generation of radical or incremental innovations. More recently, however, some scholars in this field have asked for a re-evaluation of the innovation system approach for two reasons (Sharif, 2006).

Changes in institutional conditions suggest that the relevance of boundary criteria, such as national, regional or sectoral constraints, of innovation systems is diminishing (Sharif, 2006; Whitley, 2007). Additionally, recent contributions to the general innovation literature have highlighted the major role of *non*-technological types of innovation, such as new organizational structures, processes or practices, in the innovative activities of firms (Evangelista and Vezzani, 2010; Lam, 2005; Sanidas, 2005; Tether and Tajar, 2008; Whittington et al., 1999); findings that ask for the innovation system approach to reduce its current 'technological imperative' (Damanpour and Aravind, 2011: 2) in favour of a broadened scope to include organizational innovations.

In this paper we argue that for the substantive changes in the institutional conditions of innovation systems and for the economic relevance of non-technological types of innovation, current research risks neglecting essential interdependencies within and across co-existing innovation systems. We therefore aim to answer three interrelated questions. To which innovation systems do innovative firms most frequently and most consistently belong? Are those innovation systems specific to regions or sectors? Finally, what types of innovation, considering technological and organizational innovation, are associated with different innovation systems?

Our empirical approach builds on a conceptual model proposed by Whitley (2007), who argues that innovation systems share three key characteristics: authority-sharing and organizational-learning mechanisms within firms (Whitley, 2007); 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. We use the three key characteristics of Whitley's (2007) framework to define the conceptual dimensions of our empirical analysis.

In the empirical analysis, we examine a sample of 384 firms in Switzerland. Switzerland is highly successful in promoting innovation, a success 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 Commision, 2013). In particular, during the recent economic crisis, the Swiss dual-track Vocational Education and Training system (VET) - which trains apprentices simultaneously in classrooms and in firms - received much attention from policymakers internationally (Guo et al., 2013; Kochan et al., 2012). This VET not only is associated with low levels of youth unemployment (Wolter and Ryan, 2011) but has also been shown to support firms' innovative activities.

Our empirical strategy follows a three-step process. For the first step, we use fuzzy set Qualitative Comparative Analysis (fsQCA) (Ragin, 1987) to identify those innovation systems in which innovative firms most frequently and consistently participate. For the second step, we use t-tests to explore the contextual boundaries of successful innovation systems. For the third step, we use a Seemingly Unrelated Regression Analysis (SUR) (Zellner, 1962) a method that has found considerable use in applied research (e.g., Chiang, 2009; Fraser et al., 2005; Piva et al. 2005), to show which innovation systems are more suited for generating radical, incremental or organizational innovations. This three-step strategy not only adequately acknowledges the systems perspective central to the innovation system approach but is theory-driven and unbiased as to the results of the analysis.

We contribute to the innovation system literature by identifying four different innovation systems that co-exist within an economic area and therefore are not restricted by regional or sectoral boundaries. Our findings point towards complex complementarities (Edquist, 2005) amongst a firm's learning mechanisms, a firm's involvement in the public sciences and the authoritative inter-firm coordination mechanisms institutionalized by regional and national governments. Additionally, by showing that innovation systems entail varying propensities for developing different innovation types, we provide grounds for theorizing on the generative mechanisms that facilitate radical, incremental and organizational innovation (Bergek et al., 2008; Crossan and Apaydin, 2010). Most importantly, by identifying the multi-dimensional structure of innovation systems and by measuring their propensities to innovate, we highlight important interdependencies across co-existing innovation systems.

The paper is structured as follows. Section 2 reviews the conceptual dimensions of innovation system approach. Section 3 describes our approach for examining innovation systems. Section 4 introduces the empirical study. Section 5 leads step-wise through the analysis. In Section 6 we report our findings. Section 7 concludes with implications, limitations and directions for future research.

2. The innovation system approach and its conceptual dimensions

The innovation system approach which emerged during the 1980s (Edquist, 1997; Freeman, 1987; Lundvall, 1992; Nelson, 1993) received widespread attention in both the academic and the policymaking realms (Sharif, 2006). Its main objectives lie in identifying existing innovation systems and understanding the constellations of institutional regime and firm behaviours and the processes that determine how such differently organized systems generate different innovation types (Edquist, 2005; Lundvall, 2007). Contributions from research on innovation systems provide valuable recommendations to policymakers designing country- or regional-level policies fostering innovation and to managers implementing those organizational structures, processes and practices 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) or as 'a set of institutions whose interactions determine the innovative performance of national firms' (Nelson, 1993). The largely agreed-upon conceptual nature of innovation systems thus lies in a system's approach (Bertalanffy, 1968) that focuses on key components, non-linear interactions and a particular outcome of interest (Carlsson et al., 2002; Edquist, 2005), rather than examining individual associations between variables.

Additionally, the innovation system approach has adopted a comparative perspective (e.g., Godinho and Ferreira, 2012; Guan and Chen, 2012), examining how multiple elements combine into different patterns of production (Lundvall, 2007). Thus, the innovation system approach at least implicitly considers the possibility of multiple, co-existing innovation systems.

The literature regularly debates three conceptual aspects of the innovation system approach: the nature and necessary specificity of key characteristics of an innovation system, the types of innovations generated by innovation systems and the contextual boundaries innovation systems (Lundvall, 2007; Sharif, 2006). We now briefly discuss each conceptual factor.

2.1. Key characteristics of innovation systems

The two key characteristics of an innovation system are institutional arrangements and organizations. Amongst organization, private firms are considered the most essential agents (Edquist, 2005). However, beyond these two fundamental characteristics, researchers have focused selectively on different agents, factors and institutions that may be characteristic for an innovation system.

Some scholars resist further specifying key characteristics. They argue that the traditional focus should remain on country-specific case studies of 'national' innovation systems (Edquist and Hommen, 2008; Klochikhin, 2012). The innovation system approach needs to be able to account for idiosyncrasies entailed in the institutional arrangements and the organizational features of specific market economies. Therefore, to make best use of the approach, proponents of this position find the lack of a theoretical framework desirable (Sharif, 2006).

Others counter that the absence of a unifying framework with a clear set of key characteristics compromises the comparability of the innovation system approach, whether between and within countries, sectors, or regions. Edquist and Hommen (2008), for example, argue for a unified framework for systematically comparing national innovation systems and

Whitley (2007) reasons that a coherent set of components is necessary for specifying the combinations of key characteristics constituting an innovation system.

2.2. Innovation types generated by innovation systems

The second conceptual element in the innovation system literature pertains to its focus on innovation outcomes. In the past, research has largely focused on technological innovations and drawn on the exploration-exploitation dichotomy (March, 1991) to explain radical or incremental types of technological changes (Gustafsson and Autio, 2011). Exploration refers to the discovery of new possibilities and entails long-term, risky and uncertain search processes. Exploration is commonly associated with radical innovation. In contrast, exploitation refers to the refinement of current products or services, relatively short-term process with immediate and certain payoffs. Consequently, exploitation is commonly associated with incremental innovation.

Scholars, such as Whitley (2007) and Maula (2006) have either replaced or extended the focus on exploration and exploitation by distinguishing, for example, between systemic and autonomous innovations. Whilst autonomous innovations affect only individual elements of a product or a service, systemic innovations require significant adjustment in other parts of the product or service, thereby affecting the entire business model of an organization. Systemic innovation requires stronger collaborative business models for coordinating with producers, suppliers and customers. Thus, innovation systems suited for the generation of systemic innovations are structured differently than systems suited for the generation of autonomous innovations.

Both dichotomies, exploration versus exploitation and systemic versus autonomous, consider technological types of innovation. However, more recent research has highlighted the importance of non-technological innovations; innovations that have also been referred to as organizational (Lam, 2005; Sanidas, 2005) innovation. Organizational innovation refers to the development and implementation of new practices, processes or structures and recent research has shown that organizational innovation not only leads to efficiency-enhancing changes in the management of firms (Hamel, 2006; Teece, 2007), but may also alter the structure of entire industries (Damanpour and Aravind, 2011). Tether and Tajar (2008), studying European service firms, find the organization-cooperation mode, the most prevalent one, to be most strongly associated with non-technological innovation. Others, such as Lam (2005) or Damanpour and Arvind (2011) suggest that organizational innovation plays a significant role in interactions with radical and incremental innovations.

2.3. Boundary criteria of innovation systems

Early research in the innovation system literature frequently examined specific national innovation systems (e.g. Freeman, 1987; Nelson, 1993). Yet disagreement over the boundary criterion of the concept of an innovation system has triggered a shift in the analytical focus of innovation system research. Consequently, more recent research has focused on alternative delimiting criteria, arguing for regional (Buesa et al., 2010), sectoral (Hollenstein, 2003; Malerba, 2004) or technological (Carlsson, 1994) innovation systems.

More recently, with changing institutional conditions (such as the internationalization of firms, markets, value chains and capital markets), the weakening of the developmental state and the increasingly performance-oriented monitoring of public research orientations, researchers have questioned such delimiting criteria more generally (Coombs, 2001; Sharif, 2006; Whitley, 2003a). Rather, these researchers argue that important characteristics of 'modern' innovation systems, such as international research and development (R&D) networks or global patenting rights, increasingly bypass national boundaries. To them, for the innovation system approach to remain valid and useful, it needs to focus more systematically on economic domains rather than nation-state, regional or sectoral boundaries.

In sum, previous contributions have provided important theoretical insights into the functioning of innovations systems and the role of individual factors influencing their efficiency. More recently however, research has highlighted the possibility of multiple co-existing innovation systems and changes in institutional conditions suggest that the relevance of national boundaries as a contextual boundary of innovation systems is diminishing (Sharif, 2006). Furthermore, much of the innovation system literature has followed a bias towards considering innovation as connected to R&D departments and technology-intensive industries, therefore focusing on explanations of radical and incremental technological change (Gustafsson and Autio, 2011).

We argue that recent findings on regional and sectoral innovation systems, changing institutional conditions and the importance of organizational innovations for the innovative activities of both manufacturing and service firms call for a new evaluation of the innovation system approach.

3. A new approach for examining innovation systems

In this paper we design an approach for holistically examining innovation systems that departs from previous approaches in two important ways.

We build on a conceptual model of innovation systems proposed by Whitley (2007) that centres on the firm as the dominant actor and, without restricting innovation systems to national, sectoral or regional boundaries, proposes three conceptual dimensions of innovation systems. We use this model to define the conceptual framework for our analysis and to guide our selection of outcome and explanatory variables. Thus, in contrast to previous studies that have used cluster or factor analysis, methods vulnerable to the judgement of the researcher

(Hollenstein, 2003; Whittington et al., 1999; Wiggins and Ruefli, 1995), and that have rather inductively identified innovation systems, our approach builds *ex ante* on a theoretical framework for capturing the variety of innovation systems that may co-exist next to each other.

In our empirical strategy we combine configurational with statistical analysis to identify the variety of innovation systems in which innovative firms in Switzerland most frequently participate, to examine whether Swiss innovation systems appear more frequently within particular organizational, sector or regional boundaries, and to measure the propensity of innovation systems to generate radical, incremental or organizational innovations. In the following we introduce our approach in more detail.

3.1. Conceptual framework

Whitley (2007) posits three key characteristics of innovation systems: authority-sharing and organizational-learning mechanisms within firms, firms' involvement in public sciences and the extent of authoritative inter-firm coordination. Organizational-learning and authority-sharing mechanisms, concern firms' education and training activities and joint problem-solving capabilities. These allow learning from formal knowledge production for skills to be codified, diffused and applied rapidly throughout the organization (Whitley, 2003b, 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 organizations that complete to make significant contributions to collective knowledge, a prerequisite for generic research within firms. The innovation system literature regularly discusses the significant role of universities and other public research institutions (Gruber et al., 2012; Hicks, 2012; Sharif, 2006).

The extent of authoritative inter-firm coordination describes how knowledge production, transfer and use is coordinated, either through *ad hoc* transactions or through more continuous and cooperative relations between economic actors governed by common authority commitments.

Following the tenets of Whitley's (2007) innovation system approach, we argue that the interdependencies amongst these three key characteristics explain the different nature and innovation-generating propensities of innovation systems. We use the three key characteristics for defining and for operationalising the conceptual dimensions of our analytical frame that allows us to identify and examine successful 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 a configurational method, fsQCA, a Boolean-algebraic method that has gained considerable popularity in the management literature as indicated by the increasing number of high-impact publications (e.g. Crilly et al., 2012; Fiss, 2007, 2011). fsQCA builds on a conceptual vector space that allows analysing all possible combination of conceptual factors. Thereby, fsQCA is capable of dealing with equifinality, the idea that there may be various combinations of conceptual factors that enable, for example, innovation. At the same time, fsQCA 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.

The ability of fsQCA to account for equifinality and complex interactions reflects the system-oriented perspective of the innovation system approach (Sharif, 2006). Integrating the conceptual key characteristics of innovation systems with fsQCA allows us to deal with situations of complex causality whilst handling a large number of observations and to identify the varieties of innovation systems in which innovative firms in Switzerland most frequently and consistently participate.

For the second step, we seek to understand the extent to which different innovation systems are specific to particular organizational, sectoral or regional conditions. fsQCA allows identifying and holistically describing different innovation systems present in the Swiss economy. To determine whether these patterns follow the literature we extend the configurational analysis and use t-test to examine the extent to which background characteristics of the firms participating in an innovation system differ from those of the population at large. This step serves to demonstrate that the variety of innovation systems determined through fsQCA analysis supersedes regional and sectoral boundaries.

For the third step, with organizational, regional or sectoral specificities of innovation systems established, we turn to examining the propensities of the various innovation systems themselves to generate different types of innovation. As previous research has shown that firms' structure may generate different types of innovation simultaneously (Damanpour et al., 2009; Evangelista and Vezzani, 2010; Hollenstein, 2003; Tether and Tajar, 2008), we require an analytical method that is able of capturing the effects of such innovation interdependencies. We therefore turn to an econometric method, SUR (Zellner, 1962), for measuring the propensity of innovation systems to generate radical, incremental or organizational innovations.

SUR consists of several regression equations and is appropriate when one expects correlations amongst errors terms of different estimation equations. As in our case, when examining different types of innovations simultaneously we assume that the generative mechanisms of an innovation systems to generate one type of innovation may also foster the generation of another type of innovation. Hence, we expect error terms to correlate. Standard multi-equation models would be unable to capture these effects because they do not link the variance-covariance matrices of all equations and therefore cannot produce efficiency gains and correct standard errors. Thus, for our purposes, SUR is advantageous to conventional multi-equation OLS models.

In sum, our empirical approach is theory-driven and unbiased as to the results of the analysis. The novel combination of fsQCA with statistical methods is increasingly advocated in the literature (Chuang et al., 2012; Fiss et al., 2013; Greckhamer et al., 2008). It allows us to adequately incorporate considerations of equifinality and conjunctural causation so fundamental to the innovation system approach (Fiss, 2007; Sharif, 2006), to define delimiting criteria of innovation systems 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 contains two to three thousand firms and constitutes a representative sample of the Swiss economy. Firms answer questions on their demographic and structural characteristics, their business environment and the composition of their workforce. The KOF Innovation Survey, an important database for economic and policy analysis in Switzerland, is used frequently in economic and political science research (KOF, 2013). The data has been used to analyse innovation modes in the Swiss service sector (Hollenstein, 2003) but has not yet been used in studies that consider non-technological forms of innovation and analyse innovation systems using 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. Table 1 provides descriptive statistics of the firms included in our analysis.

Insert Table 1 about here

The turnover of the 384 firms ranged between 1.1 million CHF and 4.1 billion CHF. Firms aged between 1 and 348 years, reflecting one of the particular features of the Swiss economy; hosting some very old, traditional firms but also a large number of young, highly innovative firms. 30.99% of the firms in our sample 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% of firms as belonging to the 'construction' sector. Firms employed, on average, 274 employees, the smallest with a workforce of eight and the largest with 6,980 employees. Those firms participating in the Swiss VET employed an average of six apprentices.

4.1. Outcome and dependent variables

For our three-step analysis, we define one outcome variable for the fsQCA analysis and, based on the results of the fsQCA analysis, the variables for the t-tests and regression analysis.

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 organizational innovation'. This fuzzy set membership score ranges from 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.[1]

In the first step analysis using fsQCA, in which we aim to identify the innovation systems most prevalent amongst innovative firms, we develop a single aggregate outcome

[1] For more information on calibration we refer to Ragin (2008) or Fiss (2011).

indicator for overall innovativeness by combining three calibrated measures for radical, incremental and organizational innovation.

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 setting the non-membership point at the 10^{th} percentile, the cut-off point at the 50^{th} percentile and the full membership point at the 90^{th} percentile to develop the two sets.

Furthermore, to measure organizational innovation which comprises changes in the organizational structure caused, for example, by outsourcing or takeovers, we follow Evangelista and Vezzani (2010) and use the following items: i) major changes to the distribution of competencies between employers and employees (binary), ii) major changes to the organization 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 measure, setting the non-membership point at the 10^{th} percentile, the cut-off point at the 50^{th} percentile and the full membership point at the 90^{th} percentile. Second, we summarize all three scales normalize the measure to range from 0 to 1.

The results of the fsQCA analysis will identify different innovation systems and will allow measuring, in the form of set-membership scores, the extent to which firms belong to each of these types. As before, these set-membership scores range from full non-membership (0) to full membership (1), where firms above 0.5 are more members than not. By definition, a firm can have a membership score of above 0.5 in only one innovation system. The set-theoretic foundation of fsQCA therefore enables us to uniquely group and assign firms to the identified innovation systems. We will use these membership scores in the subsequent analysis.

In the second step of our analysis, in which we employ t-tests, we use firms' membership score as an identifier to group firms into innovation systems. Our dependent variables for the t-tests are therefore binary variables that indicate whether a firm participates in an innovation system or not. This allows us to compare the background characteristics between those firms belonging to a particular innovation system and those firms in the entire sample.

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

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). First, we include four indicators for the authority-sharing and organizational-learning mechanisms: i) the degree of a workforce's specialization, ii) the degree to which employees enjoy decision-making autonomy (five item measure with adequate reliability, $\alpha = 60\%$), iii) the implementation of organizational-learning mechanisms such as teamwork, job-rotation and formal training and iv) participation in VET.

Second, we include two indicators for a firm's participation in the public science system: i) the use of public innovation funds and ii) cooperation with public research organizations such as universities or other public science institutions.

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 ($\alpha = 76\%$) and ii) the relevance of publicly available information ($\alpha = 70\%$) for a firm's innovative activities.

Fourth, we include an indicator of product differentiation (percentage of R &D expenditure over sales), a standard measure in the innovation literature for capturing industry effects that might influence the configuration of successful innovation systems (Datta et al., 2005; Hambrick and Lei, 1985).

To develop sets for each of the outcome and 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 which, based on substantive reasons sets thresholds or groups cases according to their membership degree in the target set (Ragin, 2008).

Table 2 provides descriptive statistics and a correlation matrix for the calibrated outcome and explanatory variables included in the fsQCA analysis.

Insert Table 2 about here

For the second step of our analysis, we include uncalibrated organizational, sectoral and regional measures that have been considered important in previous literature. We consider a firm's turnover in million of Swiss Francs, then its age and size, measured by its number of full-time employees. We also consider the number of apprentices, the share of employees in

R&D and whether a firm participates in VET. Furthermore, we consider the educational background of a firm's workforce, distinguishing between employees with a university degree, those with a degree higher than VET (e.g., degrees from universities of applied science or professional education and training), those with VET degrees and employees with degrees lower than VET.

We also include five categorical industry variables indicating whether a firm operates in i) traditional manufacturing, ii) high-tech manufacturing, iii) construction, iv) traditional services, or v) modern services. Last, we include seven categorical regional variables that indicate 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 association of innovation systems with radical, incremental or organizational innovations, our independent variables are a firm's membership scores in the innovation systems that we identify during the first step of the analysis using fsQCA. These variables work as follows: a set-membership score of 1 indicates that a firm's structure entirely corresponds to such an ideal type; a set-membership score of 0 indicates a firm's absolute non-resemblance to that form; and a set-membership score above 0.5 indicates that a firm resembles this innovation system more than another one.

The set-membership score that a firm receives in any innovation system approximate the degree to which the firm's structure is consistent with the system. Additionally, with fewer limitations for the number of variables, we include a wide range of control variables to better single out the propensity of an innovation system above and beyond the influence exerted by firm, sectoral or regional characteristics. Table A.1 in the Appendix provides a detailed description of the measures in our three-step analysis.

Table 3 provides descriptive statistics and the correlation matrix of the contextual variables included in the second and third step of our analysis.

Insert Table 3 about here

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5. Analysis

5.1. First step: fsQCA for identifying co-existing innovation systems

In fsQCA all logically possible combinations of absent and present measures are organized in a truth table. One minimizes 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 and a value of 0.5 a low consistency. For our analysis, we set the consistency threshold at 0.94, substantially higher than the commonly recommended minimum of between 0.75 (e.g. Ragin, 2006) and 0.80 (e.g. Fiss, 2011), and the coverage threshold at three cases. Setting such stringent thresholds allows us to identify innovation systems prevalent in the Swiss economy. Figure 1 presents the results of our set-theoretical analysis.

Insert Figure 1 about here

In this configuration chart (Fiss and Ragin, 2008) 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 elements, those essential for explaining high innovativeness in the innovation system. The smaller circles constitute contributing elements, 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.

The configuration chart in Figure 1 shows four distinct innovation systems that co-exist in the Swiss economy. Three of the innovation systems are distinct whilst the systems numbered 3a and 3b represent two permutations of the same basic structure, instances in which the same combination of core elements is surrounded by different contributing elements. The overall solution consistency lies at 0.94 and the overall solution coverage at 0.29. Both values are above the generally recommended consistency levels for reliable fsQCA results (Ragin, 2006). In the lower segment of the configuration chart we provide additional descriptive information on the number of firms that participate in each innovation system.

5.2. Second step: One-sample t-test for contextualizing innovation systems

Having identified successful innovation systems in Switzerland, we seek, in a second step, to explore whether these innovation systems are specific to particular organizational, sectoral or regional boundaries. We therefore conduct one sample t-tests comparing mean differences (MD) to examine how extensively the firms that participate in each innovation system differ in their contextual characteristics from all firms in the sample. The use of one-sample t-tests ensures the comparability of our findings across different innovation systems and allows examining whether Swiss innovation systems show any particular organizational, sectoral or regional specificities.

Table 4 shows the results of our t-tests.

Insert Table 4 about here

In Table 4, the top row lists the four innovation systems corresponding to Figure 1. The left-hand column contains the organizational, sectoral and regional context 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 four innovation systems.

5.3. Third step: SUR for exploring the innovation propensities of innovation systems

After contextualizing those innovation systems to which Swiss firms most often belong, we now seek to better understand the associations of innovation systems with the three innovation types: radical, incremental or organizational innovation.

As we expect the error terms in the regression equations to be correlated we turn to an advanced econometric method: SUR (Zellner, 1962). SUR consists of several regression equations and is the most appropriate analytical approach in situations where correlation is expected amongst error terms. We estimate the following three equations with the SUR model using three dependent variables for each of the three equations measuring a firm's success at radically, incrementally or organizationally innovating:

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

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

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

We use firms' membership scores in the K innovation systems ($\mathrm{innosystem}_{ik}$) that 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 organizational innovation (Org_i). to reduce bias that might result from differences in firm characteristics in the estimated associations between innovation types and innovation systems we furthermore include a vector of control variables x_{ij}.

Table 5 shows the coefficients and standard errors of the SUR for radical, incremental and organizational innovation. We report the R^2 for each equation. This information serves to compare the explanatory power between the three equations. It indicates that our model best explains the occurrence of incremental innovations (R^2=0.172) and somewhat well their occurrence radical innovations (R^2=0.094). The capacity of the model for explaining the occurrence of organizational innovation is relatively low (R^2=0.048).

Insert Table 5 about here

The results demonstrate that different innovation systems are correlated with different types of innovation and provide additional important insights into the propensity of innovation systems to successfully generate radical, incremental or organizational innovation.. This analysis represents an important extension of the fsQCA results by providing additional indication to the defining specificities of innovation systems and their propensities to generate different types of innovation.

6. Results

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.

6.1. The autarkic innovation system

The key characteristics of the first innovation system are the presence of specialization, and the absence of organizational-learning mechanisms and VET. Supporting characteristics are the absence of decentralization, involvement in public science system and authoritative inter-firm coordination. The 71 firms participating in this innovation system, are - as the results of the t-test indicate - significantly younger (MD = -12.60, $p < 0.01$) but otherwise do not differ from the population at large. The SUR shows that this innovation system is most suited for radical innovation (with a coefficient of 0.429, $p < 0.1$). The generative mechanism entailed in this innovation system relies on the uninterrupted work of specialists and closely resembles an *autarkic* innovation system.

6.2. The knowledge-internalisation innovation system

The second innovation system is characterized by the absence of specialization and the presence of organizational-learning practices and of public knowledge. Contributing to this system's ability to innovate are low levels of decentralization, the participation in VET, abstained involvement from public sciences and the absence of IP protection. We identify 62 firms that belong to this system. These firms are significantly smaller (MD = -103.54, $p < 0.01$) and employ fewer apprentices (MD = -3.90, $p < 0.05$). The fact that the firms participating in this innovation system have fewer employees with a university degree (MD = -2.26, $p < 0.1$) or a degree higher than VET (MD = -2.34, $p < 0.1$) explains the absence of specialization.

This innovation system is specific to the traditional manufacturing sector (MD = 9.33, $p < 0.01$) and, as the SUR results show, is best at generating organizational innovations (with a coefficient of 0.228, $p < 0.1$). Given these features, we label this innovation system a *knowledge-internalisation* one. Less specialized employees with a larger breadth of knowledge and access to external knowledge sources improve the processes, practices and structure of firms'; a type of innovation that is particularly important in a sector in which technological innovations seem less critical to a firm's success.

6.3. The corporate innovation system: autarkic or internalising

The third innovation system exists in two permutation. Both permutations share specialization, IP protection and the absence of cooperation with public research institutions as key characteristics. Participating in the Swiss VET and avoiding to implement decentralized organizations facilitates innovation. This combination of a specialized workforce avoiding cooperation with public science institutions and requiring the protection of IP resembles a *corporate* innovation system. Yet the two permutations differ in their combinations of two contributing elements and thus allow identifying two alternative forms of the corporate innovation system.

The first permutation relies on the absence of organizational-learning mechanisms and of public knowledge. We identify 36 firms that participate in this innovation system. These firms are significantly smaller ($MD = -62.03$, $p < 0.1$) and have fewer employees with a university degree ($MD = -2.03$, $p < 0.05$) and with a VET degree ($MD = -3.84$, $p < 0.1$). This innovation system is particularly unsuited for the traditional service sector ($MD = -7.03$, $p < 0.1$) and more frequently apparent in the Lake Geneva Region ($MD = -8.16$, $p < 0.1$). The SUR results provide important additional insights: this innovation system seems highly destructive for generating organizational innovations (with a coefficient of -0.336, $p < 0.05$) and also otherwise shows no particular propensity to generate radical or incremental innovation. Absent learning mechanisms and external knowledge sources indicate that this *corporate* innovation system operates in an *autarkic* manner.

Instead, the second neutral permutation of the corporate innovation system features additional organizational-learning mechanisms and public knowledge provision as contributing elements. Only 19 small firms participate in this permutation of the corporate innovation system. These firms are, again, significantly smaller ($MD = -62.92$, $p < 0.1$) and have significantly more employees in R&D ($MD = 7.71$, $p < 0.1$) and with a university degree ($MD = 1.96$, $p < 0.1$). The sectoral specificity of this innovation system is pronounced as participating firms operate less frequently in the traditional manufacturing sector ($MD = -15.20$, $p < 0.05$) and more frequently in the high-tech manufacturing sector ($MD = 45.15$, $p < 0.01$). Regionally, the area around Zurich seems to be least suited for this innovation system ($MD = -15.83$, $p < 0.01$). As the SUR results show, this innovation system shows no particular propensity to generate any of the three innovation types. Given this system's reliance on internal organizational-learning practices and external provision of public knowledge, we label this the *corporate internalising* innovation system.

6.4. The public science innovation system

The key characteristics of the fourth innovation system include the reliance on public innovation funding, the cooperation with public research institutions and the absence of public knowledge provision. This system's ability to innovate is supported under the presence of specialization and participation in VET and under the absence of decentralization, organizational-learning mechanism and IP protection. Contrary to firms participating in all other innovation systems, the ones in this system are significantly larger ($MD = 358.53$, $p < 0.05$), employ more apprentices ($MD = 16.18$, $p < 0.1$) and more employees in R&D ($MD = 6.94$, $p < 0.05$). The educational background of these firms' workforce contains more employees with university degrees ($MD = 3.33$, $p < 0.1$) and VET degrees ($MD = 6.43$, $p < 0.01$), but significantly fewer employees with degrees lower than VET ($MD = -10.92$, $p < 0.01$). The particular mix of educational degrees thus seems to play a particularly important role in this innovation system.

As in the case of the corporate internalising innovation system, this one is significantly more suited for innovation in the high-tech manufacturing sector ($MD = 37.86$, $p < 0.01$). Firms participating in this innovation system are less frequently located in Central Switzerland ($MD = -6.57$, $p < 0.05$). The SUR indicates that this innovation system is most suited for radical innovation (with a coefficient of 0.597, $p < 0.05$) and somewhat suited for incremental innovation (with a coefficient of 0.475, $p < 0.1$). Given these features, this innovation system resembles the classic *public science* innovation system.

6.5. Results robustness and measurement reliability

We conducted several tests to ensure the reliability of our measures and the robustness of our results. First, we have developed our measures closely in line with the innovation literature and have examined the reliability of our multi-item measures using Cronbach's Alphas. The results for all measures indicate adequate 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. We find our aggregate innovation measure to correlate 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 fostering intentions to innovate.

Second, to understand 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. We find no significant differences in terms of age, size, turnover or share of employees in R&D. However, firms in the analysis employ more apprentices on average and more frequently offer VET, indicating that firms that are more strongly embedded in the Swiss institutional environment are more willing to complete questionnaires. In sum, however, these differences are neither surprising nor problematic.

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 a three-equation Tobit model and a three-equation OLS-model.

None of the values touches the upper or lower censoring limit (0 or 1). As expected, neither the results of the Tobit model nor the results of the OLS model differ substantively from those of the SUR analysis.

Fourth, following recent publication using fsQCA (e.g., Fiss, 2011; Crilly et al., 2012) we assess the extent to which our results of the fsQCA analysis are sensitive to different calibrations by varying the crossover points by up to +/- 2.5 percentage points for those explanatory variables that we had calibrated using the direct method. These variables appear most likely to be sensitive to alternative thresholds. Further, we examine the extent to which the fsQCA results are robust to different specifications of frequency and consistency cut-offs by increasing and decreasing the consistency threshold by .01 and by increasing and decreasing the frequency threshold by 1. We find the *autarkic*, the *knowledge-internalisation* and the *corporate autarkic* innovation system to be highly robust across all tests. The *corporate internalising* innovation systems is most sensitive to changes in the crossover point and to an increase of the frequency cut-off. The *public science* system is somewhat sensitive to an increase in the crossover point and in the frequency. However, the substantive implications of our study remain unaffected by these changes.

7. Conclusion

In most contributions to the innovation system literature, innovation systems are conceptualized and depicted as singular phenomena (e.g. Hung and Whittington, 2011) or, as in the case of comparative national innovation systems, are thought to exist relatively independently from one another (Lundvall, 2007). In contrast, our findings show that different innovation system can co-exist within one country. For Switzerland we identify four innovation systems that exist side by side and that entail important interdependencies amongst individual elements and across innovation systems.

Past research has also suggested that innovation systems exist only in specific national, regional or sectoral context. Yet in Switzerland's highly successful innovation economy, we find three sectoral innovation systems. The *knowledge-internalisation* system drives organizational innovation in the traditional manufacturing sectors. The *corporate internalising* and the *public science* system are characteristic for the high-tech manufacturing sectors although only the latter proves suited for generating radical and incremental innovation. Additionally, we find one regional system, the *corporate autarkic* system, that is specific to the Lake Geneva Region.

However, whilst these findings provide some evidence for sectoral and regional limits of innovation system, we also identify one generic innovation system, unbounded by regional or sectoral restrictions: the *autarkic* system, particularly effective at generating radical innovations. Hence, the delimiting criteria of innovation systems do not necessarily appear to be regional or sectoral.

Furthermore, we neither find sectoral innovation systems specific to the traditional or modern service sector, or to construction, nor additional regional innovation systems. Instead, and arguably more important, two innovation systems appear particularly *hostile* to certain sectors: the *corporate autarkic* system for traditional services and the *corporate internalising* one for traditional manufacturing. These findings imply that in some contexts larger coordination efforts may have a negative rather than an unambiguous positive influence on innovation and that innovation systems may prove to be particularly unsuited to certain sectors.

Across all innovation systems we identify important idiosyncratic interdependencies between authority-sharing regimes and organizational-learning mechanisms, the firms' involvement in the public sciences and the nature of the authoritative inter-firm coordination. That all three conceptual dimensions are necessary - either in their presence or absence - for every innovation systems may be interpreted as an indicator of theoretical saturation in favour of the rich literature on innovation systems that succeeded in identifying and defining the important conceptual dimensions of innovation systems.

Yet, neither are all conceptual dimensions of equal importance nor does their presence necessarily facilitate innovation. In fact, our findings show that all innovation systems rely strongly on the presence of one element and the absence of another element. The *corporate* systems facilitate kinds of innovations by specialists but forbear cooperation with public research institutions and strongly rely on IP protection. In contrast, *public science* innovation system requires intense cooperation with research institutions and extensive use of public innovation funds. Yet it also essentially abstains from using additional public knowledge. Thus, the generative mechanisms entailed in innovation systems rely at least as much on the presence as on the absence of factors. The implication from these findings is that a proper assessment of successful innovation systems not only requires defining what a system is good at doing but also what a system is good at doing *not*.

Additionally, the econometric results reported here show that innovation systems have different propensities to innovate. *Autarkic* innovation systems are best at generating radical innovations; *public science* at radical and incremental innovations. Only the *knowledge-internalisation* innovation system shows a strong propensity to generate organizational innovations, evidence that corresponds to recent findings on the organizational cooperation mode of innovation (Tether and Tajar, 2008).

Yet arguably most interesting are our findings for the two *corporate* innovation systems. Whereas the *corporate internalising* innovation system shows no particular propensity to generate innovation, the corporate *autarkic* system even impedes the generation of organizational innovation. This finding may partially be attributable to the belief that especially organizational innovation requires the inclusion of both internal and external knowledge sources for identifying shortcoming in organizational processes, practices and structures, and that high degrees of specialization and protective coordination mechanisms are harmful to the generative mechanisms leading to organizational innovation.

With the exception of the *autarkic* innovation system, we find VET, particular to the Swiss economy, to be highly conducive to the innovation-generating propensities of firms. IP protection, as a regulatory coordination mechanism, is important only for coordinated innovation systems. In all other innovation systems, the protection of IP hinders rather than encourages innovation. Our findings therefore corroborate criticism of IP protection and suggest that the regulation of property rights, whilst important for appropriating the added value of past innovations, seem to discourage the generation of new innovation.

In sum, contrary to most research on innovation systems, we show that multiple innovation systems may coexist across and within sectoral and regional boundaries and that these reflect pronounced idiosyncratic combinations of structural elements. Their co-existence carries important policy implications. Adjustments in one area may nurture one innovation system but suppress another. For example, investments into higher education or stricter enforcement of IP protection will support *corporate* innovation systems but may stifle the *knowledge-internalisation* innovation system by training too many specialists. As an indirect consequence such policy changes may lead to fewer organizational innovations. In contrast, other policy implications seem problematic. For example, the development of a VET system is supportive almost across all innovation systems. Thus, policymakers need to distinguish between relatively simple and more complex adjustments and, in the latter case, to understand the ramifications of policy changes on a variety of innovation systems.

Our findings point to at least three important avenues of future research. First, fewer attention should be paid to *corporate* innovation systems, which have been in the focus for much of the past three decades of innovation system research. Rather, more emphasis should be laid on understanding the *autarkic* and the *knowledge-internalisation* innovation system which are important for smaller organizations and significant drivers for radical and organizational innovation respectively. In particular, given mounting evidence on the economic relevance of organizational innovation (e.g. Evangelista and Vezzani, 2010; Tether and Tajar, 2008), our results clearly recommend focusing on the *autarkic* innovation systems.

Second, the comparatively low level of explained variance for organizational innovation in the SUR points to two related areas of future research. We reason that existing theories of innovation systems are more suited for explaining technological forms of innovation, thereby reinforcing the call for more autonomous theorizations on what drives organizational innovation. Simultaneously, given that prominent innovation surveys such as the European 'Community Innovation Survey' (CIS) or the KOF Innovation Survey have only recently included questions on organizational innovation and given that these questions remain relatively crude measures for organizational innovation (Armbruster et al., 2008), our finding calls for the development of more refined and accurate measurements for organizational innovation. More refined measures may, for example enquire into whether organizational innovations lead to changes in the structures, boundaries or processes of the adopting firm, Whittington et al.'s (1999) classification that resonates strongly with recent empirical investigations on non-technological forms of innovation (e.g. Mol and Birkinshaw, 2009; Meuer, 2014).

Third, our results show that innovation systems exhibit propensities for generating multiple types of innovation. This finding, complementing recent arguments in the innovation literature, highlights interdependencies that exist amongst different types of innovation (Camisón and Villar-López, forthcoming; Damanpour et al., 2009). Further research may thus specify the kinds of interdependencies amongst innovation types or examine their effects on the overall performance of firms or innovation systems.

Figures and tables

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

	mean	std.dev.	min	max
Firm characteristics				
Turnover (in mil. CHF)	130.00	417.00	1.10	4,070.00
Age (in years)	64.87	47.33	1	348
Number of employees	274.39	627.52	8	6980
Number of apprentices	12.55	30.38	0	352
Share of employees in R&D (in %)	5.92	7.93	0	55
Firms with VET	0.78	0.41	0	1
Workforces' educational background (in %)				
University degree	6.20	10.55	0	90
Degree higher than VET	14.57	11.24	0	65
VET degree	46.15	19.71	0	97
Degree lower than VET	28.30	23.52	0	94
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
Descriptive statistics and correlation matrix on outcome and explanatory variables

		1	2	3	4	5	6	7	8	9	10	11	12
1	Innovativeness	1.00											
2	Organizational innovation	0.45***	1.00										
3	Radical innovation	0.74***	-0.01	1.00									
4	Incremental innovation	0.77***	0.08	0.36***	1.00								
5	Specialization	0.14***	0.05	0.09*	0.12**	1.00							
6	Decentralization	0.11**	0.15***	0.04	0.05	0.10*	1.00						
7	Organizational-learning	0.10*	0.24***	-0.07	0.07	0.11**	0.15***	1.00					
8	VET	-0.04	0.06	-0.13**	0.01	0.20***	0.08	0.16***	1.00				
9	Public innovation funds	0.12**	0.00	0.10*	0.12**	0.06	0.02	-0.03	0.11**	1.00			
10	Research cooperation	0.20***	0.11**	0.10*	0.19***	0.11**	0.08	0.18***	0.18***	0.37***	1.00		
11	Knowledge provision	0.19***	0.15***	0.08	0.16***	0.16***	0.04	0.17***	0.03	0.15***	0.14***	1.00	
12	IP Protection	0.07	0.02	0.08	0.05	0.01	0.03	0.09*	0.03	0.13***	0.15***	0.22***	1.00
13	Product differentiation	0.32***	0.01	0.26***	0.32***	0.20***	0.07	0.05	0.06	0.23***	0.25***	0.30***	0.17***

* Statistically significant at the 0.1 level; ** at the 0.05 level; *** at the 0.01 level.

Table 3
Descriptive statistics and correlation matrix of contextual variables included in the second and third step of the analysis

		1	2	3	4	5	6	7	8	9	10	11	12
1	Organizational innovation	1.00											
2	Radical innovation	-0.01	1.00										
3	Incremental innovation	0.08	0.36***	1.00									
4	Autarkic	-0.05	0.10**	0.07	1.00								
5	Knowledge-internalisation	0.05	-0.02	0.04	-0.21***	1.00							
6	Corporate autarkic	-0.07	-0.02	0.06	-0.21***	0.44***	1.00						
7	Public science	0.01	0.14***	0.14***	-0.07	-0.13**	-0.13**	1.00					
8	Corporate internalising	0.00	0.02	0.07	-0.21***	0.55***	0.74***	-0.13**	1.00				
9	Turnover (in mil. CHF)	0.16***	-0.05	0.01	-0.06	-0.09*	-0.09*	0.04	-0.08	1.00			
10	Age (in years)	0.08	-0.07	-0.16***	-0.07	-0.05	0.03	0.02	0.03	0.10*	1.00		
11	Number of employees	0.13***	-0.06	-0.01	-0.08	-0.08	-0.06	0.04	-0.06	0.81***	0.11**	1.00	
12	Number of apprentices	0.12**	-0.07	-0.02	-0.14***	-0.05	0.03	0.05	-0.01	0.53***	0.15***	0.57***	1.00
13	Share of employees in R&D (in %)	0.06	-0.13**	0.01	-0.63***	0.33***	0.33***	0.11**	0.33***	0.06	0.14***	0.09*	0.22***
14	Firms with VET	0.06	0.19***	0.32***	0.09*	0.04	0.03	0.21***	0.11**	0.01	-0.10*	0.00	0.03
15	University degree	0.01	0.03	0.06	0.05	-0.14**	-0.06	0.04	-0.05	0.17***	-0.10**	0.11**	0.08
16	Degree higher than VET	0.09*	0.07	0.22***	0.11**	-0.01	0.09*	0.01	0.07	0.04	-0.05	0.00	0.03
17	VET degree	0.05	-0.18***	-0.09*	-0.04	0.01	0.01	0.01	0.01	0.08	0.01	0.09*	0.08
18	Degree lower than VET	-0.08*	0.12**	-0.06	0.02	0.03	-0.08	-0.04	-0.06	-0.16***	0.05	-0.12**	-0.19***
19	Lake Geneva Region	0.00	0.02	0.01	0.04	-0.05	-0.07	0.09*	-0.08	0.02	-0.07	-0.01	-0.03
20	Espace Mittelland	-0.01	-0.04	0.01	0.09*	0.03	-0.01	0.02	-0.01	-0.04	0.01	0.01	-0.04
21	Northwestern Switzerland	0.02	-0.04	-0.07	-0.01	-0.07	-0.10**	-0.06	-0.04	0.19***	-0.04	0.15***	0.06
22	Zurich	0.03	0.01	-0.03	-0.06	-0.05	-0.01	0.06	-0.06	-0.02	0.00	-0.02	0.07
23	Eastern Switzerland	0.01	0.09**	0.05	-0.02	0.12**	0.10**	-0.02	0.11**	-0.08	0.00	-0.08	-0.06
24	Central Switzerland	-0.04	-0.01	-0.01	-0.03	-0.04	-0.01	-0.06	0.00	-0.04	0.12**	-0.03	0.03
25	Ticino	-0.05	-0.05	0.06	0.00	0.04	0.10**	-0.04	0.07	-0.04	-0.05	-0.03	-0.07
26	Traditional manufacturing	-0.09*	0.02	-0.11**	-0.02	0.00	-0.04	0.00	-0.08	-0.05	0.17***	-0.07	-0.08
27	High-tech manufacturing	0.03	0.19***	0.36***	0.11**	0.03	0.09*	0.12**	0.19***	-0.02	-0.18***	-0.01	0.03
28	Construction	-0.02	-0.17***	-0.16***	-0.05	0.02	0.03	-0.04	-0.02	-0.04	0.00	0.00	0.16***
29	Traditional services	0.06	-0.06	-0.15***	-0.06	-0.05	-0.10*	-0.09*	-0.11**	0.05	0.04	0.02	-0.05
30	Modern services	0.04	-0.14***	-0.13**	-0.04	-0.01	0.00	-0.07	-0.04	0.08	-0.01	0.1125**	0.03

* Statistically significant at the 0.1 level; ** at the 0.05 level; *** at the 0.01 level.

Table 3 (continued)
Descriptive statistics and correlation matrix of contextual variables included in the second and third step of the analysis

		13	14	15	16	17	18	19	20	21	22	23	24
13	Share of employees in R&D (in %)	1.00											
14	Firms with VET	0.05	1.00										
15	University degree	-0.06	0.21	1.00									
16	Degree higher than VET	-0.01	0.30***	0.13**	1.00								
17	VET degree	0.06	-0.09*	-0.18***	-0.15***	1.00							
18	Degree lower than VET	-0.13**	-0.17***	-0.34***	-0.42***	-0.71***	1.00						
19	Lake Geneva Region	-0.01	-0.01	-0.01	-0.02	-0.02	0.03	1.00					
20	Espace Mittelland	0.02	0.05	-0.06	0.01	0.07	-0.04	-0.13**	1.00				
21	Northwestern Switzerland	-0.02	-0.03	0.02	0.09*	0.05	-0.08	-0.11**	-0.23***	1.00			
22	Zurich	0.02	0.04	0.21***	0.03	0.01	-0.12**	-0.13**	-0.26***	-0.23***	1.00		
23	Eastern Switzerland	0.03	-0.03	-0.11**	-0.07	0.00	0.07	-0.13**	-0.27***	-0.23***	-0.27***	1.00	
24	Central Switzerland	-0.03	-0.01	-0.08	-0.02	-0.09*	0.13**	-0.08*	-0.17***	-0.15***	-0.18***	-0.18***	1.00
25	Ticino	-0.06	-0.04	0.01	-0.03	-0.09*	0.11**	-0.05	-0.10**	-0.09*	-0.10**	-0.11**	-0.07
26	Traditional manufacturing	0.00	-0.25***	-0.20***	-0.25***	-0.21***	0.39***	0.08	0.08	-0.07	-0.17***	0.12**	-0.03
27	High-tech manufacturing	0.03	0.48***	0.07	0.21***	0.03	-0.16***	0.01	-0.01	0.02	-0.03	0.00	0.04
28	Construction	0.05	-0.12**	-0.09*	0.00	-0.03	0.04	-0.05	-0.08	0.01	0.14***	-0.05	0.01
29	Traditional services	-0.07	-0.25***	-0.10**	-0.13***	0.20***	-0.05	-0.01	-0.06	0.05	0.05	-0.05	0.04
30	Modern services	0.01	-0.01	0.38***	0.21***	0.05	-0.31***	-0.08	0.02	0.01	0.16***	-0.09*	-0.09*

* Statistically significant at the 0.1 level; ** at the 0.05 level; *** at the 0.01 level.

Table 3 (continued)
Descriptive statistics and correlation matrix of contextual variables included in the second and third step of the analysis

		25	26	27	28	29
25	Ticino	1.00				
26	Traditional manufacturing	0.01	1.00			
27	High-tech manufacturing	-0.02	-0.54***	1.00		
28	Construction	0.02	-0.14***	-0.17***	1.00	
29	Traditional services	-0.01	-0.29***	-0.34***	-0.09*	1.00
30	Modern services	0.02	-0.23***	-0.27***	-0.07	-0.14***

* Statistically significant at the 0.1 level; ** at the 0.05 level; *** at the 0.01 level.

Innovation system	**1** *Autarkic*	**2** *Knowledge-internalisation*	**3a** *Corporate autarkic*	**3b** *Corporate internalising*	**4** *Public science*
Authority sharing & org. learning					
Specialization	⬤	⨂	⬤	⬤	•
Decentralization	⊗	⊗	⊗	⊗	⊗
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	⊗	⊗	⬤	⬤	⊗
Product differentiation	•	⬤	⬤	⬤	•
No. of firms	*71*	*62*	*36*	*19*	*26*
Model coefficients					
Consistency	0,95	0,94	0,94	0,95	0,99
Raw Coverage	0,05	0,15	0,14	0,15	0,03
Unique Coverage	0,05	0,05	0,02	0,02	0,03
Overall Solution Consistency	**0, 94**				
Overall Solution Coverage	**0, 29**				

Configuration chart based on Ragin & Fiss (2008). 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 "don't care's", i.e., neither their presence nor their absence is associated with overall innovativeness. MS = membership score.

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

Table 4
Results of one-sample t-tests on contextual factors of Swiss innovation systems

Innovation system				*1a Autarkic*	*2 Knowledge-internalisation*	*3a Corporate autarkic*	*3b Corporate internalising*	*4 Public science*
No. of cases with MS > .5				*71*	*62*	*36*	*19*	*26*
	Sample means			*Differences in means*				
	mean	*min*	*max*					
Firm characteristics								
Turnover (in mil. CHF)	130.00	1.1	407.000	-40.20	-61.50***	-66.90***	-52.60**	303.00*
Age (in years)	64.87	1	348	-12.60***	-5.82	-6.26	5.71	7.25
Number of employees	274.39	8	6980	-96.28	-103.54***	-62.03*	-62.92*	358.53**
Number of apprentices	12.55	0	352	-12.55†	-3.90**	1.56	-2.08	16.18*
Share of employees in R&D (in %)	5.92	0	55	-0.62	0.43	-0.85	5.71***	6.94**
Firms with VET	0.78	0	1	-0.78†	0.22†	0.22†	0.22†	0.22†
Workforces' educational background (in %)								
University degree	6.20	0	90	1.74	-2.26*	-2.03**	1.96*	3.33*
Degree higher than VET	14.57	0	65	0.50	-2.34*	2.10	1.27	0.28
VET degree	46.15	0	97	-0.14	0.59	-3.84*	-0.20	6.43**
Degree lower than VET	28.30	0	94	2.67	3.62	1.12	-4.46	-10.92***
Sectors (in %)								
Traditional manufacturing	30.99	0	1	-1.41	9.33*	-0.43	-15.20**	-7.91
High-tech manufacturing	39.06	0	1	-2.44	-5.19	5.38	45.15***	37.86***
Construction	4.43	0	1	-1.61	-1.20	3.90	-4.43†	-4.43†
Traditional services	15.36	0	1	4.36	0.77	-7.03*	-15.36†	-15.36†
Modern services	10.16	0	1	1.11	-3.71	-1.83	-10.16†	-10.16†
Regions (in %)								
Lake Geneva Region	5.73	0	1	1.31	0.72	8.16*	-5.73	1.96
Espace Mittelland	20.57	0	1	0.56	3.62	-3.90	0.48	2.51
Northwestern Switzerland	16.41	0	1	3.31	-0.28	-5.30	4.64	-1.03
Zurich	21.09	0	1	-2.78	-1.74	1.13	-15.83***	9.68
Eastern Switzerland	21.88	0	1	-2.16	0.70	3.12	9.70	-2.65
Central Switzerland	10.42	0	1	-0.56	-2.36	-4.86	5.37	-6.57**
Ticino	3.91	0	1	0.32	-0.68	1.65	1.35	-3.91†

* Statistically significant at the 0.1 level; ** at the 0.05 level; *** at the 0.01 level. † Variables with no variance.

Table 5
Results from SUR

		Radical innovation	Incremental innovation	Organizational innovation
Set-membership scores in innovation system				
1	*Autarkic*	0.429* (0.237)	0.276 (0.222)	-0.088 (0.185)
2	*Knowledge-internalisation*	-0.0167 (0.175)	0.130 (0.164)	0.228* (0.136)
3a	*Corporate autarkic*	-0.074 (0.226)	0.233 (0.212)	-0.366** (0.176)
3b	*Corporate internalising*	0.147 (0.231)	-0.126 (0.217)	0.085 (0.180)
4	*Public science*	0.597** (0.260)	0.475* (0.243)	-0.034 (0.202)
Controls included for				
	Firm-level variables	YES	YES	YES
	Workforce educ. background	YES	YES	YES
	Sectoral variables	YES	YES	YES
	Regional variables	NO	NO	NO
R^2		*0.094*	*0.172*	*0.048*

n=384; Controls for firm characteristics: Firm age (in years), number of employees, binary controls for sectors: traditional manufacturing, construction, traditional services, modern services (high-technology is reference category). * Statistically significant at the 0.1 level; ** at the 0.05 level; *** at the 0.01 level.

Appendix A

Table A.1
Measurement definitions used in the three-step analysis

Indicator	fsQCA	SUR	Calibration/ measurement	Description
Innovativeness	Outcome		d. calibration	Aggregate of calibrated innovation measures for radical, incremental and organizational innovation.
Radical innovation		DV	d. calibration	Sales percentage of newly introduced products of the firm's turnover.
Incremental innovation		DV	d. calibration	Sales percentage of substantially improved products of the firm's turnover.
Organizational innovation		DV	d. calibration	Count measure considering major changes to (a) distribution of competences between employer and employees, (b) distribution of tasks, or (c) overall organization of the company (e.g. mergers, new cooperation, outsourcing, etc.).
Specialization	EV		d. calibration	Share of employees with a PhD or higher secondary education a firm's workforce, ranges from 0 (no specialization) to 1 (full specialization).
Decentralization	EV		d. calibration	Scale from five items asking whether employer or employees has decision-making power; ranges from 0 (centralized) to 1 (decentralized); α = 60%.
Organizational-learning	EV		d. calibration	Count measure of binary indicators considering implementation of (a) teamwork, (b) job rotation, or (c) continued training activities.
VET	EV		ind. calibration	1 if the firm participates in the VET, 0 otherwise.
Public innovation funds	EV		ind. calibration	1 if the firm makes use of public innovation funds, 0 otherwise.
Public research cooperation	EV		ind. calibration	1 if the firm cooperates with public research organizations, 0 otherwise.
Public knowledge provision	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%.
Product differentiation	EV		d. calibration	Share of R&D expenditure.
Firm's membership in IS				
Autarkic 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.
Corporate (internalisation) IS		EV	fuzzy set score	fuzzy set membership score computed from results of first-step analysis.
Corporate (autarkic) IS		EV	fuzzy set score	fuzzy set membership score computed from results of first-step analysis.
Public science IS		EV	fuzzy set score	fuzzy set membership score computed from results of first-step analysis.
Turnover		CV	uncalibrated	in million CHF.
Age		CV	uncalibrated	In years since founding.
Size		CV	uncalibrated	Number of employees.
No. of apprentices		CV	uncalibrated	Number of apprentices trained.
R&D intensity		CV	uncalibrated	Share of employees in R&D.
Firm with VET		CV	uncalibrated	1 if the firm participates in the VET, 0 otherwise.
Workforces' educational background				
University degree		CV	uncalibrated	Share of employees with university degree.
Higher than VET		CV	uncalibrated	Share of employees with higher degree than VET (except university).
VET degree		CV	uncalibrated	Share of employees with VET degree.
Lower than VET		CV	uncalibrated	Share of employees with lower degree than VET (unskilled).
Sector		CV	uncalibrated	Categorical variable based on the official sectoral classification of the KOF: 1 = Traditional manufacturing; 2 = High-tech manufacturing; 3 = Construction; 4 = Traditional services; 5 = Modern services.
Region		CV	uncalibrated	Categorical variable based on the official regional classification of the Swiss Federal Statistical Office : 1 = Lake Geneva Region; 2 = Espace Mittelland; 3 = Northwestern Switzerland; 4 = Zurich; 5 = Eastern Switzerland; 6 = Central Switzerland; 7 = Ticino.

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.

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