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Disclosure statement

No potential conflict of interest was reported by the authors.

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Innovation and the Knowledge-Base for Entrepreneurship: Investigating SME Innovation across European Regions using fsQCA

Abstract

This study considers regional innovation across Europe, which is important because of the increasing role that innovative capacity plays in economic competence and competitiveness. Using a relevant 2019 data set, 236 regions across 25 European countries are investigated, focusing on four potential, interlinked, conditions of potential relevance to SME innovation, specifically measures focused on levels of human capital, internal firm innovation, innovation collaborations and broader knowledge collaborations between the public and private sector. The methodology applied uses a configurational approach to elucidate relationships, specifically fuzzy-set Qualitative Comparative Analysis (fsQCA) to evaluate how these conditions affect, at a regional level, the proportion of SMEs sales from either new-to-the-market or new-to-the-firm (NMFS) innovations. Amongst the results, in addition to the existence of the classic "core" region "innovation ecosystem" recipe having presence of three of the four conditions (in-house innovation being non-relevant), the analysis reveals that innovation policy may need to be specifically tailored in certain types of regions. For example, when education and co-production are both absent, collaboration can still create a beneficial presence of NMFS outcome, whilst when education alone is absent SME in-house innovation can still create a beneficial presence of NMFS outcome. This suggests that greater collaboration is required to overcome more extensive absence of other parts of the Regional Innovation System (RIS), whilst in-house innovation is required to overcome a lack of education alone. The main contributions of the research, therefore, are to generate a more comprehensive evaluation of the complexity of innovation at the level of the region, Graphical 'map' based elucidation of findings also contributing to the study's 'scene setting' for European regions on this SME-innovation issue.

Keywords: SMEs, Innovation, European regions, fsQCA

Introduction: Rationale, need for the work and the research questions

As regional economies develop, less innovative European regions are often actively encouraged, via EU, national and regional level policies, to close the innovation gap with their better performing counterparts (De Noni *et al.*, 2018). Innovation is also considered increasingly important in creating economic, social and environmental solutions in Europe (Tamayo-Orbegozo *et al.*, 2017), including as a way to increase regional economic resilience (Bristow and Healy, 2018). Similarly, entrepreneurship is regarded as central to this type of economic development in the European context, driving innovations to be successfully created, disseminated and utilized, particularly within the wider EU economy (McCann and Ortega-Argilés, 2016).

This study is required because, whilst there has been much research in this area, however, there is currently a gap in the literature in respect of analysis using configurational approaches able to capture the complex, interrelated, asymmetrical and nuanced nature of what drives innovation in widely differing regions. This topic is important because, as Fernández-Serrano *et al.* (2019) identified in the Spanish context, policies to support innovation will have different effects in low and high income regions, for example, because of the different ways in which individual entrepreneur characteristics interact with the different socio-economic and innovation system conditions that exist in different regions. The last 20 years has also seen a range of regional innovation policies at the EU level supporting networking among heterogeneous organizations (Caloffi *et al.*, 2015). Investigation of the effect of collaborative networks on lagging European regions' innovation performance identifies that knowledge spillovers from other regional actors (such as universities) and collaborative networks of local firms and other actors (which can compensate for the lack of spillover effects in peripheral regions) are also relevant (De Noni *et al.*, 2018). The firm's own internal innovation capacity, consistent with the concept of absorptive capacity, is also, necessary to allow exploration and exploitation of such external knowledge (Radicic *et al*., 2019), encapsulated through concepts such as social capital (Yoon *et al.* 2015) and affected differently according to the government policies pursued (Yoon *et al,* 2018)

Květoň and Kadlec (2018) identify three knowledge bases as important to a discussion of what could be termed the absorption capacity of the region more broadly, including codified analytical knowledge which includes publications. This can be combined with "synthetic knowledge" (combining existing knowledge with internal firm learning) and "symbolic" tacit knowledge consistent with local cooperation, the combinations then determining innovation outcomes for both firms and the wider region. These forms of existing research based findings support the employment of a configurational approach here, given that it is the system, as a whole (or at least conjunctional elements of it), rather than individual elements that generates outcomes in terms of the presence or absence of innovation, identifying the focus of the study.

The study's aim, therefore, is to explore the level of variability of conditions' evidence for the presence or absence of SME innovation across EU-regions (using a sales-based measure of new-to-market / new-to-firm innovations (NMFS) of SMEs as the outcome measure). Whether there are noticeably different levels of variability between the presence or absence of such SME innovation performance is also an important objective. The specific research questions are whether the conjunctional causation one would associate with a regional system of innovation exists, whether the equifinality in terms of causal combinations one would might expect in heterogeneous regions is a reality and also whether there are asymmetrical combinations causing more positive regional innovation outcomes, compared with more negative results.

A configurational approach is preferred over other conceptual and methodological frameworks for several reasons. Regression models for example, capture individual conditions in isolation, rather than identifying complex combinations (Deng et al., 2019), otherwise known as conjunctional causation, where some conditions only have an effect in conjunction with other conditions, but not on their own (Woodside, 2013). Conversely, Structural Equation Modelling is unable to account for potential equifinality, where more than one causal combination can lead to the same outcome (Fiss et al., 2013), or asymmetrical relationships between conditions and outcomes (Fiss et al., 2013), where causal configurations for presence of the innovation outcome potentially differing from causal configurations for absence of the innovation outcome. The reason for proposing this particular method is, therefore, because the technique employed in this study, fuzzy-set Qualitative Comparative Analysis (fsQCA), is able to deal with all these three possibilities, and generate nuanced, configurational, region-specific findings, creating value for academics and policymakers in providing greater detail which can assist their own future research in those regions.

Described in Ragin (2008; 2013), the use in this study of fsQCA's explicitly configurational approach to analysis, therefore generates a contribution of the work through exploring novel directions in regional innovation research. Berg-Schlosser *et al.* (2009) also acknowledge that causal asymmetry is possible with fsQCA, the presence and absence of the outcome potentially driven by different factors. Therefore, fsQCA offers a novel and relevant method of investigation, increasingly employed (see Roig-Tierno *et al*, 2017),in both entrepreneurship and innovation-focused research (Kraus *et al*., 2018), including in the area of regional development (Pickernell *et al*., 2019; Beynon *et al*., 2019a), as well as other contexts (Piñeiro-Chousa et al. 2019; Thomann and Maggetti, 2020). The scene setting nature of the study is also re-enforced by the ability to employ of graphical 'map' based elucidation of findings to enable greater comparison between regions. The proposed framework can be beneficial for academics and policymaker because it identifies where innovation policy may need to be specifically tailored in certain types of regions.

The structure of the rest of the study is as follows: Section 2 discusses the conditions of potential relevance to SME innovation and its variation, particularly across European regions, from which a framework for analysis is derived. In section 3, the conceptual configuration is outlined followed by, in section 4, a discussion of the specific European-regions data used, along with required pre-calibration of the considered data (for use with fsQCA). Section 5 undertakes initial fsQCA elucidation of the calibrated European regions SME-innovation data, including both causal recipes and graphical map-based elucidation. Section 6 discusses these resultant causal recipes and consequent graphical 'map' based elucidation. In section 7, conclusions are offered as well as directions for future research.

Background Literature Review

European Regions and Innovation

In the European context, a region's research capacity has been identified as the most important single factor in subsequent firm innovation (Sternberg and Arndt, 2001), and argued that individual firm and regional capacities were linked. Increasing the volume and value of entrepreneurial activities driving innovation is therefore a critical policy challenge (see Landabaso, 2014, Secundo et al, 2015). Existing empirical research covering the European Union typically, however, focuses on R&D and its subsidization, studies investigating the effectiveness of public support on measures of innovation and firm performance, other than R&D expenditure found to be relatively scarce (Radicic *et al*., 2016).

Radicic *et al*. (2019) identifies that technological product and process innovations, non-technological (organizational and marketing) innovations and the success of product and process innovations in the market (innovative sales) are potentially complementary. Gray (2006) identifies "absorptive capacity" as a key component in this debate, defined as including overall firm learning capacity, internally implementing and disseminating new knowledge, and using new resources and technologies. SMEs with absorptive capacity components such as higher education levels and innovation propensity, experienced improved firm performance (Gray, 2006; Hu and Hughes, 2020). Sternberg and Arndt (2001) noted that in the European context, firm-specific innovation factors have a stronger effect than region-specific or other, external, potential conditions. Radicic *et al*. (2019) highlight, however, that internal innovation capacity, consistent with the concept of absorptive capacity, is necessary to enable exploration and exploitation of external knowledge. Huang and Rice (2009) highlight that this absorptive capacity must be considered in relation to the external sources it will seek to absorb knowledge from, including through networking and collaboration activities.

In terms of supporting elements to innovation activities generally and collaborative approaches specifically, De Noni *et al*. (2018) identify measures of tertiary education (proxying for human capital more generally) as a control variable in their study of collaborations, given that they see regional innovation performance as partly dependent on human capital within the local economy.

The types of collaboration identified as of importance to positive innovation outcomes (see, for example, De Noni *et al*. (2018), in the lagging EU region context), is often, however, particularly difficult for SMEs, particularly in relation to non-firm actors such as universities (Caloffi *et al*., 2015). Regarded as important in fostering innovation within regional ecosystems (Pugh *et al*., 2019), Serbanica *et al*. (2015) identify several ways in which universities can directly transfer knowledge to local SMEs. Corral de Zubielqui *et al*. (2015) suggest that SMEs tend to use "generic" university–industry knowledge transfer, such as through published research results, instead of highly relational university–industry link types. Radicic *et al*. (2019) also highlight that SMEs searching for cooperation with higher education institutions (HEIs) or alternative public-sector knowledge actors can be perceived as following a low commercial/market risk strategy, Autant-Bernard *et al*. (2006) identifying co-publication as a measure of the interactivity of regional actors.

By contrast, Corral de Zubielqui *et al*. (2015) found SME knowledge acquisition more likely to occur from clients/customers and suppliers than government or HEIs. De Noni *et al*. (2018), identify collaborative networks of local firms as important (see Huggins and Thompson, 2015). Sternberg and Arndt (2001) suggest, however, that before setting up such relationships, the requisite human resources, as well as the firm's own internal innovation activities, are first required, suggesting greater emphasis is given to how innovative firms can overcome the disadvantages encountered in specific regional environments.

Drawing these elements together, Żelazny and Pietrucha (2017), identified feedbacks between institutions, human capital and technology conditions that facilitate creativity (a key component of innovation). Lau and Lo (2015) perceive innovation occurring within a regional innovation systems (RIS) approach where government supports through policies such as education and training, knowledge intensive supporting services and value chains assisting firms with the requisite internal absorptive capacity. Huggins *et al.'s*. (2015) identifies, however, that whilst accessing knowledge externally is important to SMEs, particularly those unable to generate the requisite innovation themselves, that complex relationships exists, where external knowledge from own-region knowledge sources (such as universities and research institutes), for example, may not be utilised by SMEs in high growth stages. Doran *et al.* (2012) find similarly, in Irish contexts, that SMEs found non-local knowledge for innovation interactions at least as valuable as local ones.

The Framework for Analysis

This discussion identifies potential combinations of different elements supporting what can be seen in combination as regional absorptive capacity, which may affect SME innovation within that region. Regional absorptive capacity can be seen to simultaneously draw on a number of overlapping concepts, including smart specialization (McCann and Ortega-Argilés, 2016), regional innovation systems, (Caloffi et al., 2015) and more recently, regional innovation ecosystems (Schaeffer and Matt, 2016) and entrepreneurial ecosystems (Dedehayir et al., 2018). Essentially, regional absorptive capacity, discussed by Miguélez, and Moreno (2015), Azagra-Caro et al (2006), Roper and Love (2006), and Caragliu and Nijkamp (2012) amongst others, incorporates a region's ability to create and absorb innovation successfully, via the interlinking of firm and regional level innovation generation activities, human capital endowments, higher education activity in innovation, and the ability of firms to utilise knowledge from public and externally conducted research, including via formal and informal networks. Regional absorptive capacity also establishes that external-to-the-region knowledge is more easily absorbed in regions in already having relatively large knowledge stock and capacity (Miguélez, and Moreno, 2015), and conversely, that regions without such capacity are likely to see the knowledge they create or attract, spilling over into surrounding regions (Caragliu and Nijkamp, 2012).

Whilst government policy needs to support both innovation and entrepreneurship in order to foster growth and sustainability (Galbraith et al., 2017), Huggins and Williams (2011) found in the UK context, that regional policy makers are often encouraged to focus on short-term over long-term results, leading to tensions in enterprise policy between regional competitiveness and economic and social disadvantage goals. This existing literature therefore also indicates areas where complementary or substitute relationships between the condition variables are possible. It must be acknowledged, however, that this previous research uses techniques that focus on identifying the effect of individual conditions. The configurational approach, by way of contrast, specifically focuses on identifying where conditions in combination are important. This both emphasizes the exploratory nature of our work, and highlights that when discussing the data used for and results obtained from the configurational approach, they will not be fully comparable with prior literature. This configurational conceptualization generates a basic theoretical framework for analysis, shown in Figure 1 below.

See Figure 1 Here

Methodological Approach

As the configurational approach is used to explain how order emerges from combinations of conditions (Meyer *et al.*, 1993), pre-specified relationships are unsuitable, due to the explorative nature of the study. Figure 1, therefore, presents a broad conceptual framework of SME innovation, where innovation outcomes result from a wide range of combinations of (presence and absence of) absorptive capacity supporting conditions. Nevertheless, broad research propositions are possible, identified as follows:-

1. The Conjunctional causation one would associate with a regional system of innovation exists,
2. Equifinality in terms of causal combinations in heterogeneous regions is a reality
3. There will be asymmetrical combinations causing more positive regional innovation outcomes, compared with more negative results.

As stated previously, a configurational approach is preferred over other conceptual and methodological frameworks and alternative options to conduct the analysis because of its ability to simultaneously overcome limitations of other methods, which are specifically problematic given the research questions in this study. Specifically, regression models capture individual conditions in isolation, rather than identifying complex combinations (Deng et al., 2019), whilst Structural Equation Modelling is unable to account for potential equifinality, or asymmetrical relationships between conditions and outcomes (Fiss et al., 2013). The main features of the technique employed in this study, fuzzy-set Qualitative Comparative Analysis (fsQCA), is its ability to deal with all these three possibilities. As identified by Misangyi et al

(2017) this also helps to move management research away from focusing on net effects and towards the important area of causal complexity.

In terms of the steps used in the methods, there is a need first to describe the data itself and the pre-preparation of it to make it suitable for fsQCA. The specific data considered came from the EU Regional Innovation Scoreboard (RIS) RIS2019 data set, which uses Eurostat and other internationally recognized data available in June 2019 (see Bristow and Healy, 2018, for a fuller discussion of the dataset). This dataset provides comparable innovation relevant data for 238[1] regions across 23 EU Member States, the (non-EU) regions of Norway, Serbia, and Switzerland, with (EU countries) data for Cyprus, Estonia, Latvia, Luxembourg, and Malta provided at country level (in these countries NUTS 1 and NUTS 2 level identical to country).

The RIS is chosen for the research here because, in addition to allowing a broad analysis of factors affecting regional innovation (Bristow and Healy, 2018), it also contains a range of variables explicitly focused on the innovation performance (and related innovation supporting indicators) of small and medium-sized enterprises (SMEs). It has been considered in previous extant research literature (see Sternberg and Arndt, 2001). In addition, Bristow and Healy (2018) utilised data from the 2012 RIS scoreboard to examine the role of innovation in the economic resilience of European regions. A description of the specifically considered European-region-innovation data, derived from the European's Regional Innovation Scoreboard (RIS) 2019 (https://interactivetool.eu/RIS/index.html), is given in Table 1, along with a justification for the use of these specific conditions and outcome.

See Table 1 here

One feature of the employment of fsQCA in this study, and in general terms, is the re-formulation of the considered data (individual conditions and outcome – see Table 1), into fuzzy-set representations (for the conditions and outcome reported in Table 1 they are index

[1] In this study two European regions had incomplete data hence were removed.

values relating 2019 data to the EU 2019 average values). Moreover, for a condition or outcome it is re-calibrated to a fuzzy set 0-1 domain, the values are membership values (measuring the truth of 'object X is a member of A' - see Verkuilen, 2005). In this study, the Direct Method is employed (Ragin, 2008), which structures the fuzzy sets (see Andrews *et al.*, 2016; Beynon *et al.*, 2016). The quantitative anchors are values across the domain of a condition (or outcome) which relate directly to the fuzzy domain values of, 0.05 (full non-membership - low threshold anchor), 0.5 (crossover point) and 0.95 (full membership - upper threshold).

Establishment of the qualitative anchors started with the acknowledgement of no prior or definitive standards for these conditions and outcome (Cooper & Glaesser, 2016, who describe this in terms of 'no obvious calibration points'). Consistent with Andrews *et al.* (2016) and Beynon *et al.* (2016), a two-stage approach was then adopted, commencing with the formulization of a probability density function (pdf) formed for each condition or outcome. From this, required qualitative anchors are identified (lower and upper thresholds and crossover point), then followed by a subjective over-consideration of the pertinence of the established qualitative anchors in the context of the constructed innovation problem (see Douglas *et al.*, 2020, for further general discussion on this re-calibration stage).

For the conditions and outcome in the EU-regions data set, the respective pdf and qualitative anchor details are shown in Figure 2, along with subsequent fuzzy set functions.

See Figure 2 Here

In Figure 2, the graphs exposit the calibration details for the four conditions (1a – 1d) and outcome (1e). In each graph, the solid line is the respective pdf, dotted vertical lines are the respective lower ($x^{\perp}$) and upper (x^{T}) thresholds and crossover ($x^{\times}$) values, the dashed line is the subsequent fuzzy set function transforming each condition and outcome European-region values onto respective fuzzy set 0-1 domain. These findings, in particular, the crossover point values found for each condition and outcome, were considered against the spread of respective European-region values, in this exploratory study the authors did not feel there was propensity for changes to the anchor points (we note in Andrews *et al*., 2019, similar propensity checks were made based on the pdf results and a change was made to one condition crossover point – this option fully available to the authors here).

Within fsQCA, strong membership of a fuzzy value (for a condition) relates to whether a fuzzy value is < 0.5 or ≥ 0.5, and so assigned 0 or 1, respectively (see Ragin, 2008). It follows, each case (European-region) is described by 0 or 1 across their conditions (not necessary for outcome), when considered in strong membership terms. With reference to this re-calibration processes, there are therefore three forms of the data values able to be considered, original, fuzzy and strong membership (for conditions only), see Table 2, for a sample of the EU-region data set expositing these.

See Table 2 Here

In Table 2, the sample of EU-regions demonstrates the different representations of the cases (EU-regions) considered in this study. The top rows show the actual condition and outcome values (over their respective scales – in this case index values), middle rows are the respective fuzzy values (over 0-1 domains) and bottom rows are strong membership values (of conditions only). Of note, within the representations, the primary role of the 'strong membership' representation (bottom rows) are in the offering of empirical evidence to understood configurations (of European-regions described by the same combination of 0 or 1 conditions in strong membership terms). The majority of the technical calculations are made using the fuzzy representation of cases (middle rows in Table 2).

In terms of the main indicators to interpret results, and research performed, prior to generating the main results, the more formal fsQCA actions are undertaken, namely, necessity and sufficiency analyses (the latter including exposition of concomitant truth table), see Ragin (2008) and Douglas *et al*. (2020) for descriptions and reflections of these actions.

The necessity analysis undertaken is to investigate whether instance of the outcome contribute a subset of the instances of the causal conditions (Ragin, 2008; Vis & Dul, 2018). A condition is necessary for an outcome if it exhibits large consistency and non-trivial coverage (Douglas *et al*., 2020). For the four conditions (con) (TERD_EDUC, SME_INHOUSE, INN_SME_COLLAB, PUB_PRIVATE_COPUB), using their fuzzy value representations, and considering their negation (not-con) forms also (e.g. membership to absence of condition rather than its presence), the respective necessity based consistency and coverage measure values are presented in Table 3, noting the NMFS and ~NMFS refer to the presence and absence of New Market Firm Sales, respectively.

See Table 3 Here

With an understood threshold of 0.9 considered (Greckhamer, 2011; Greckhamer *et al*., 2018). the descriptive statistics (bottom rows of Table 3), identifies no conditions should be individually considered necessary. The analysis next moves onto the notion of sufficiency analysis, next described. rior to the specific sufficiency analysis utilised for the results, it is pertinent first to obtain a sense of the groupings of the European-regions across the different configurations to be considered (found using the strong membership values describing each case – examples shown in Table 2). Two visualisations of the configuration details are next reported, see the truth table in Table 4 and technical graphs in Figure 3. The details in these two sources (Table 4 and Figure 3) should be considered simultaneously (contribute evidence to derivation of values for required frequency and consistency threshold values, see later discussion).

See Table 4 Here

See Figure 3 here

In Table 4, the top half of the table, in column terms, shows (in strong membership terms) the representation of the configurations for which empirical evidence exists from cases (no configuration 13 shown since no cases associated with it – hence considered a logical remainder). The 'No.' column shows the number of cases associated with the relevant configuration. In Figure 3a, complementing the previous comments, as you go left to right along the x-axis, the left hand y-axis scale associated triangle-points line shows the size of the individual group of European-regions associated with a configuration (configurations indexed in decreasing size of number of cases – see column No. in Table 4), and on the right hand y-axis associated circle-points line shows the cumulative sum of cases included in the n^{th} largest configurations (e.g. from Table 4 – largest two configurations are 45 and 42 in size (top left triangle points) which sum to 87 (second bottom left circle point) – and so on).

The top horizontal straight line in Figure 3a shows the 80% threshold signifying 80% of cases (here 189 European-regions (rounded up) also shown) are contained in the n^{th} largest configurations (Afonso *et al.*, 2018). The vertical straight line shows the number of configurations (the largest) associated with the 80% threshold of cases. The horizontal bottom line denotes the frequency threshold (on left-hand y-axis) to also achieve this, a first suggestion for a 'to be employed' frequency threshold, defining the minimum level of required empirical evidence (No. of cases) associated with a configuration for it to be further considered.

Taking inference from Figure 3a, Figure 3b considers further the balance of consistency threshold and frequency threshold (Andrews *et al.*, 2016, for discussion). The graph shows, as the frequency threshold goes up (left to right along x-axis) – the percent of cases considered in the relevant configurations, with at least that frequency of cases associated with it, goes down (since progressive configurations are not further considered due to lack of concomitant empirical evidence). However, as the frequency threshold goes up, with different numbers of configurations considered (some not considered), a reformulation of the consistency threshold is necessary (including following the criteria to have no configurations future associated with both NMFS and ~NMFS – see Andrews *et al*., 2016), hence the triangle-point line shows the newly formulated consistency threshold values, going down as frequency threshold goes up. This also influences cases still considered, since reducing the consistency threshold may mean other configurations may have an association to the presence or absence of NMFS (previously not). Hence, the percentage of case still considered may go up or down – as the circle-point line shows here. With a thought to keeping as many cases in as possible – it suggests a frequency threshold of 10 and consistency threshold of 0.833, with suggested 88.136% cases retained in the analysis (for causal recipes).

Further shown in the right-hand columns of Table 4 are the associated consistency (and PRI score) values associated with each configuration towards the presence (NMFS) and absence (~NMFS) of NEW_MARKET_FIRM_SALES. Using the identified consistency threshold of 0.833, there are eight and two configurations associated with NMFS and ~NMFS, respectively, including a total of 208 cases. These 208 cases, out of 236, is 88.136% of all cases considered (a total matching the value in Figure 2b associated with top of circle-point line in the graph), are broken down as 140 and 68 associated with NMFS and ~NMFS, respectively. Due to only frequency threshold impact, there are a total of five configurations (strikethrough' d in Table 4) with less than 10 cases associated with them (totalling 28 EU-regions), considered logical remainders (Douglas *et al*., 2020).

Results

In terms of the result. as a benchmark for the future sufficiency analyses undertaken, three maps are first generated which shade the respective European-regions depending on whether they are subsequently to be considered associated with NMFS, ~NMFS and logical remainders, see Figure 4.

See Figure 4 here

Inspection of the three maps highlights noticeable groupings of European-regions but with exceptions. Starting with those cases (in configurations) associated with the absence of NMFS (~NMFS in Figure 4b), the map shows almost blanket inclusions of the European-regions of Spain and Eastern Europe, as well some Italian and Southern European regions of other European states. This has similarities with work such as Camagni and Capello (2013), but is able to encompass a wider range of countries, and evaluate in more detail, than this previous work

In terms of presence of NMFS, in Figure 4a, there is a majority of Western (excluding Spain), Central and North European regions. This is broadly similar to the study of Lopes *et al*. (2018), but by utilising NMFS is able to focus on the outcomes of innovation for firms themselves. Excluded from two previous region groups, Figure 4c shows those European-regions associated with empirical evidence lacking configurations which are spread across Europe in geographical terms, but including Madrid, Catalonia and the North East of England. These maps will offer a reference point for the later groupings of European-regions identified in the next undertaken fsQCA 'sufficiency analysis' work (from the individual causal recipes later identified).

The subsequent main part of the sufficiency analysis next follows. Following the same approach as Andrews *et al*. (2016), complex and parsimonious solutions are generated, reported in Table 5. Before sufficiency analysis results themselves are presented, however, all potential forms of solutions are first discussed. Rihoux and Ragin (2009) define the complex solution as the minimal formula generated without using logical remainders, the parsimonious solution being the minimal formula created using all possible logical remainders. In the parsimonious solution therefore, configurations for which there is no empirical evidence (known as logical remainders), but which are possible are, after being labelled as counterfactuals, included. Between these two solutions, using the description consistent with Douglas *et al*. (2020), is the intermediate solution. This includes so-called 'easy' counterfactuals, those consistent with both existing empirical and theoretical knowledge (Ragin, 2008). Based on the exploratory nature of this study, and the opinion of the authors, no 'easy' counterfactuals were identified. The intermediate solution, therefore, effectively equates to the complex solution (Andrews *et al*., 2016; 2019; Douglas *et al*., 2020), the complex solution itself also advocated by Wagemann and Schneider (2010), and followed in more recent papers such as Beynon *et al*. (2016) and Pickernell *et al*. (2019). Details of these solutions (complex-intermediate and parsimonious) are presented in Table 5, which shows recipes related to the presence of NMFS (with the ONMFS in the title) and also the absence of NMFS (with NNMFS in the title).

See Table 5 here

The circle representation, shown across from the four considered conditions, are adapted from Ragin and Fiss (2008), though, for reasons already discussed, we consider the complex solution with parsimonious solution rather than a discernible intermediate solution and parsimonious solution, as Ragin and Fiss (2008) do. To summarize, solid and open circles denote the presence and absence of a condition (no circle 'does not matter'), respectively. Large and small sizes of the circles indicate core (in complex and parsimonious solutions) and peripheral (in complex solutions), respectively.

In Table 5, these technical details include the configurations associated with the established causal recipes (indexes relate to configuration rows in Table 4). Beyond the top row labelling, the details are roughly in two, with top showing complex solution and bottom showing parsimonious solution details. In the top section, complex solution, there are identified four (CONMFS1, CONMFS2, CONMFS3, CONMFS4) and one (CNNMFS1) causal recipes associated with the presence and absence of NMFS, respectively. In terms of parsimonious solutions, there are two (PONMFS1, PONMFS2) and one (PNNMFS1) causal recipes associated with presence and absence of NMFS, respectively.

Discussion

Comprehensive discussion of these results is provided in this section. To further aid in the discussion, European-region maps are again presented which graphically exposit the cases (European-regions) associated with each established causal recipe (respective European-regions shaded in). In Figures 5 and 6, maps with shaded European-regions are presented, describing the complex solution based causal recipes for the presence and absence of NMFS, respectively.

See Figure 5 here

See Figure 6 here

The four maps in figure 5 geographically describing the causal recipes associating to the presence of NMFS offer clear evidence on how there may be alternative pathways to the same outcome (here presence of NMFS). We acknowledge the partial overlap of cases associated with causal recipes (see for example the European-regions of Portugal each covered by CONMFS1, CONMFS2, CONMFS3). In regard to the map in figure 6 describing the single absence of NMFS causal recipes CNNMFS1, it mimics that which appeared in Figure 4b, and further evidence how amongst the considered conditions the combination of absence of SME_INHOUSE, INN_SME_COLLAB, and PUB_PRIVATE_COPUB encompasses all these European-regions.

Building on previous work, such as Huggins and Williams (2011), Huggins *et al.* (2015), Galbraith *et al.*, (2017), and Pickernell et al., (2019), Figures 5 and 6 clearly indicate both the geographic nature of SME innovation as measured by NMFS, and the consequent potential importance of policy. This is in terms both of the absence of NMFS being concentrated in the peripheral East and South of Europe, but also the different recipes that apply to the presence of NMFS. Specifically, CONMFS4, the recipe representing the fullest Industry-Government-University Innovation Ecosystem, is more concentrated in the "core" regions of Europe, whilst CONMFS1, CONMFS2 and CONMFS3 are more associated (though clearly not exclusively) with regions in the Western periphery. These results and their implications are explored further below.

In general terms, there is clear asymmetry between presence and absence of NMFS. Supporting the work of De Noni *et al.* (2018) and Radicic *et al.* (2019), SME collaboration is both consistent and most often seen, being absent for absence of NMFS and present in three of the four presence of NMFS recipes. Supporting Radicic *et al.* (2019), SME in-house innovation was consistently absent for absence of NMFS and present in two of the four presence of NMFS. Education and co-production of publications are more inconsistent, however, and generally can be regarded as more supportive than central, which is also consistent with De Noni *et al.* (2018) and Żelazny and Pietrucha (2017) in their treatment of human capital and Radicic *et al.* (2019) who found cooperation with HEIs positively affected innovation by SMEs, but not consequent sales from such innovation, suggesting a more indirect impact.

Comparing configuration-based findings with previous literature, it needs to be acknowledged, however, that direct comparability is not possible where that previous research focuses on net effects of single conditions, given that fsQCA focuses on configurational effects among conditions. Evaluating the conceptual framework presented in Figure 1 in combination with the results, however, allows us to identify five paths related to (presence and absence of)

SME innovation. As the configurational approach also seeks to generate typologies/taxonomies (Meyer *et al*., 1993), however, the results are also discussed in that context. Opportunities presented by this technique include the ability to identify and classify groups of regions that share similar (single or multiple) recipes. This then allows regions to benchmark themselves against others in similar positions, as well as identifying what is required to move to other, potentially more advantageous groups.

This also allows building on the work of studies such as Sternberg and Arndt (2001), who noted that, in the European context, policymakers need to clear about the nature and capacity of their region when designing policy (which should begin from the premise of the individual firm's capabilities), particularly where an innovation system approach is being taken. Taking such an Innovation systems approach reveals some interesting nuances. For example, Configurations 5 and 6 (covering 34 regions) are affected by recipe CONMFS1 only, this recipe perhaps best described as an industry-led innovation system. Configuration 3 (covering 11 regions) is affected by recipe CONMFS3 only, this recipe best described as a Government-led (but also likely to include University collaboration) innovation system. Configuration 15 (covering 10 regions, including Wales) is affected by recipe CONMFS2 only, this recipe best described as a basic Industry-Government RIS. Configuration 12 (covering 18 regions, including London, North West England, New Aquitane, Brittany, Amsterdam, Middle Sweden (Uppsala), and the Basque country, is affected by recipe CONMFS4 only, this recipe best described as a full Industry-Government-University Innovation Ecosystem. In addition to four clearly different recipes for presence of NMFS, some regions are affected by more than one. Specifically, configuration 7 (including Northern Ireland) is affected by three of the four presence of NMFS recipes, with configuration 8 and 16 (which includes Scotland) affected by two of the four presence of NMFS recipes.

More broadly, these results echo Fernández-Serrano *et al*. (2019) study (in a Spanish-only context), where conclusions suggested that innovation policy needs to be specifically tailored in specific types of regions. In their study in high-income regions needing to be more focused on promoting cooperation between companies as an effective mechanism to support innovation, whilst in lower income regions the policy should be on individual entrepreneurs with growth ambitions, and qualification levels. For example, recipe CONMFS3 shows that when education and co-production are both absent, collaboration can still create a beneficial presence of NMFS outcome, whilst recipe CONMFS1 illustrates that when education alone is absent that SME in-house innovation can still create a beneficial presence of NMFS outcome. Taking recipes CONMFS1 and CONMFS3 together, therefore, might suggest that greater collaboration is required to overcome more extensive absence of other parts of the RIS, whilst in-house innovation (which can still include some links with other organisations) is required to overcome a lack of education alone. Recipe CONMFS2 seems most indicative of regions where some but not all the constituents of a full RIS are in place, with in-house innovation and collaboration both present, but education and co-publication not relevant, suggesting a more basic network based system is in place. Recipe CONMFS4 seems most closely related to a classic "core" region "innovation ecosystem" recipe having presence of three of the four conditions (in-house innovation being non-relevant), and including configuration 16 which has presence of all four conditions.

However, comparing CONMFS3 with CONMFS4 suggests the need to specifically compare these regions (as education and co-production absent in CONMFS3 and present in CONMFS4, whilst collaboration is present in both, and hence no obvious consistent substitution effect identified). This might be explained by different sectoral foci. Alternatively, it could suggest a complementary relationship as opposed to a substitution role that is fundamentally different. Bristow and Healy (2018) identify, for example, that regions with weaker institutions often exhibit research and innovation systems where networking and knowledge exchange are more inhibited, locking these regions into declining sectors, using out-dated technology and with less capacity to respond to economic shocks.

Focusing on some example cases in European geographies that have been historically considered economically peripheral (Galbraith *et al.*, 2017), also suggests that the long term implications for regions with presence of NMFS, but for reasons linked to different recipes, may be fundamentally different. For Northern Ireland for example, Galbraith *et al.* (2017) identified that key weaknesses for Northern Irish SMEs had been in terms of recognizing the relevance of external knowledge, but also requiring help in searching for external knowledge, their study finding significant failings in the policy studied in this regard. This may to an extent explain Northern Ireland being affected by recipes CONMFS1, CONMFS2 and CONMFS3, none of which include the presence of wider knowledge sources as proxied by education and co-publication.

Morgan (2017), in comparing Wales and Basque country in relation to their innovation policy identified that in the Basque country there was explicit policy focus on manufacturing, endogenous innovation capability and a strong role for regional government in partnership with industry organisations, leading to a much fuller innovation system (as indicated by the fsQCA results and association with recipe CONMFS4) than in Wales, which is much more government driven. According to Morgan (2017), this is partly because Wales lacks the Basque country's strong economic network actors, which may be supported by the recipe Wales is most strongly associated with (CONMFS2) highlighting in-house innovation and collaboration being both present, but education and co-publication not relevant, suggesting a more basic network based system at work. However, given that the Welsh government has had a focus on Foreign Direct Investment, universities driving the knowledge economy, and a belief that the state needs to pro-actively drive innovation, the lack of these in the recipe (CONMFS2) would not suggest that these policies have been successful to this point. In the case of Scotland, Brown's (2016) analysis found the Scottish innovation system overly reliant on universities, and UK-wide policy. In these circumstances, it is therefore unsurprising that Scotland finds itself in the same group as most of England, affected by recipes CONMFS2 and CONMFS4. Scotland can be seen as falling between Wales and the Basque country, in terms of being affected by both CONMFS2 and CONMFS4.

Conclusions

FsQCA was used with the intention to test the multi conjunctional nature of SME innovation against a range of conditions of potential relevance, those conditions having differing requirements in terms of SMEs generating internal innovation as compared to generating it via networks and building external links. This study is important, because it extends existing knowledge on the issue using fsQCA to allow a more comprehensive evaluation of the complexity of innovation at the level of the region. The main lessons from this study are that , in the case of the presence of new-to-market and new-to-firm SME innovations, this multi conjunctional nature is evidenced through the four causal recipes (CONMFS1, CONMFS2, CONMFS3, CONMFS4), in contrast, in regard to the absence of new-to-market and new-to-firm SME innovation there is only one causal recipe identified (CNNMFS1). In numbers of causal recipe terms, this variation across the presence and absence of new-to-market and new-to-firm SME innovation is noteworthy in itself.

We have also, however, identified limitations that offer avenues for future research, including future comparison of the main findings in this study and replicability in European and other settings, through this type of empirical investigation. Limitations of the study include its cross-sectional nature, as fsQCA has been problematic to apply to longitudinal panel data (Fiss *et al.*, 2013). The stability of (a sub-set of variables at least) an fsQCA over time has, however, been examined (albeit using a different data set in the related field of entrepreneurship in a recent analysis (Beynon et al, 2019b), utilising new techniques which may also be applicable here. As such, the cross-sectional study in this study, must be regarded as an initial benchmarking analysis, upon which future longitudinal analysis can be built, considering fsQCA longitudinally offering a method to unravel the complex dynamics of SME innovation over time by identifying how configurations change as regional economies and policies develop. Thus, the field can move to more dynamic theories of SME innovation in regional contexts and practitioners will learn more about the development of conditions necessary for the most beneficial SME innovation outcomes. Such future study would also be able to help evaluate the efficacy of Piñeiro-Chousa et al's (2020) call to integrate entrepreneurial training, innovation and knowledge management to promote entrepreneurship that positively contributes to economic growth. In addition, the issue of resilience as identified in Bristow and Healy (2018) suggests that additional research is required to examine the degree to which the conditions and causal recipes discussed here are related to likely more or less longer term regional resilience-related innovation outcomes (as opposed to shorter term SME market sales related innovation outcomes).

Nevertheless, the study connects with the journal's central scope in addressing central factors in economic development, namely entrepreneurial vitality and innovation, as regional phenomena, identifying the complex regional contexts in which entrepreneurs innovate. The implications of the work, provided through the novel insights generated, will also be of interest to policy makers, highlighting groups of regions in the European context facing similar conditions, implying that policy learning and benchmarking is possible.

Incorporating the research into policy recommendations, the identification of recipes that apply to different groups of regions allows policymakers in those countries to more clearly identify where policy should be focused and, crucially, whether policy approaches may need to be broader, given that it is the combinations of conditions that are important in explaining SME innovation. This can assist policy makers in strengthening the specific conditions in their respective regions to more effectively generate beneficial SME innovation outcomes.

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List of Figures and Tables

Figure 1: Framework for Analysis

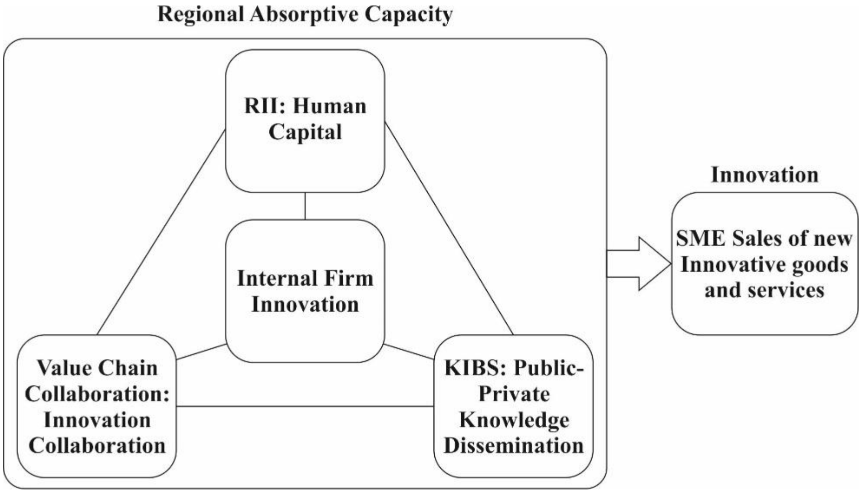

Table 1. Description of considered European-region conditions and outcome

Variable	**Description of Variable Used and Justification**
Condition	
TERD_EDUC	Index created by comparing percentage of population aged 25-34 in each region who have completed tertiary education, against the EU 2019 average for this indicator. De Noni *et al*. (2018), identifying regional innovation as partly depending on local human capital, use tertiary educational attainment as a proxy for human capital more broadly. Żelazny and Pietrucha (2017) also used similar though not identical measures as a proxy for human resources, as part of the enablers of innovation.
SME_INHOUSE	Index created by comparing SMEs innovating in-house as percentage of SMEs in each region against the EU 2019 average for this indicator. Radicic *et al*. (2019) highlight that, internal innovation capacity, consistent with the concept of absorptive capacity, is also necessary to allow exploration and exploitation of external knowledge. This variable was also used in Květoň and Kadlec (2018).
INN_SME_COLLAB	Index created by comparing innovative SMEs collaborating with others (having co-operation agreements on innovation activities with other enterprises or institutions) as a percentage of SMEs in each region against the EU 2019 average for this indicator. Recent decades have seen a range of regional innovation policies supporting networking among heterogeneous organizations, inspired by concepts such as regional innovation systems and smart specialization (Caloffi *et al*., 2015). De Noni et al. (2018) also identify collaborative networks of local firms and other actors as important, whilst Radicic *et al*. (2019) found cooperation increases firms' innovativeness and

	beneficial commercial outcomes. This variable was previously used by Květoň and Kadlec (2018).
PUB_PRIVATE_COPUB	Index created by comparing Public-private (excludes the private medical and health sector) co-publications (academic publications) per million population in each region (publications assigned to the country/countries in which the businesses or other private sector organisations are located) against the EU 2019 average for this indicator. Radicic *et al*. (2019) identify this type of cooperation as relatively low risk, whilst Autant-Bernard *et al*. (2006), use co-publications specifically as a regional interactivity measure in their study into the creation of biotech companies in France. Żelazny and Pietrucha (2017) also used the same measure as a proxy for linkages and entrepreneurship, as part of the enablers of innovation.
Outcome	
NEW_MARKET_FIRM_SALES	Index created by comparing sales of new-to-market and new-to-firm innovations as a percentage of total turnover for SMEs in each region against the EU 2019 average for this indicator. Radicic *et al*.'s (2019) empirical study identified technological (product and process) innovations, and non-technological (organisational and marketing) innovations as potentially complementary with the commercial success of product and process innovations (i.e., innovative sales). This variable was also previously used by Květoň and Kadlec (2018) and Żelazny and Pietrucha (2017).

Figure 2. Re-calibration details of variables (from index values to fuzzy values using Direct method)

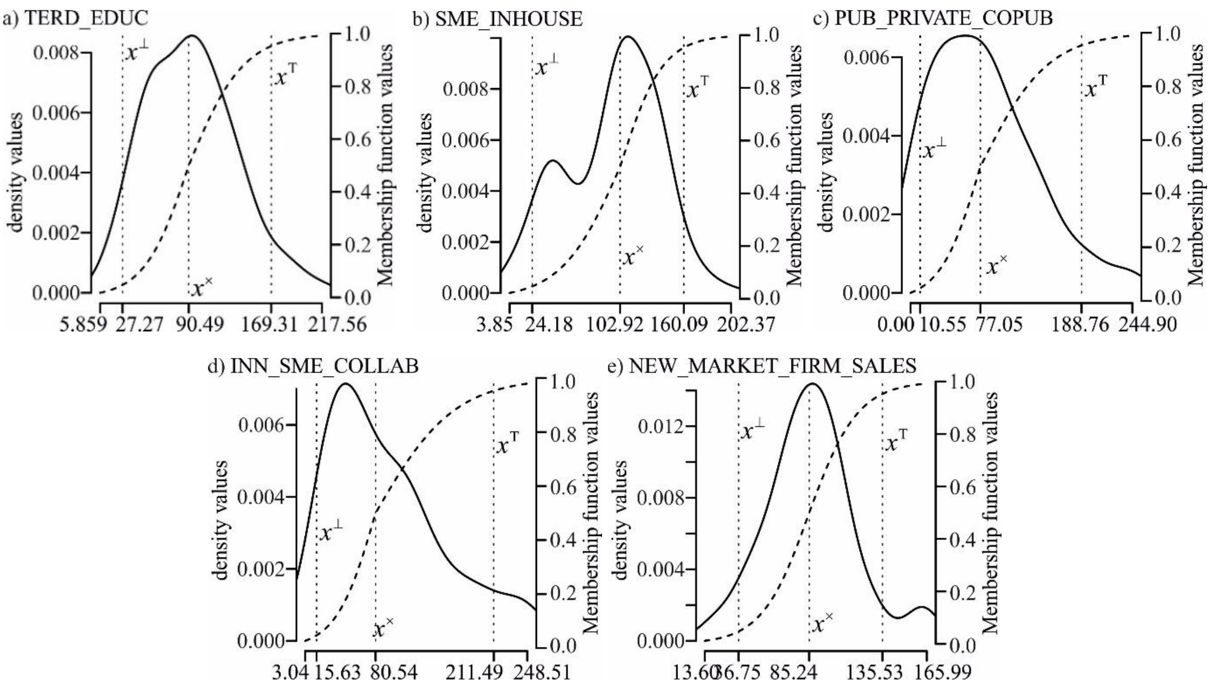

Table 2. Example of European region details (actual, fuzzy and strong membership)

NUTS	REGION	TERD_EDUC	SME_INHOUSE	INN_SME _COLLAB	PUB_PRIVATE_ COPUB	NEW_MARKET _FIRM_SALES
Original						
BE2	Vlaams Gewest	125.39	130.13	204.44	148.57	130.61
BE3	Région Wallonne	103.91	130.05	133.94	119.71	127.51
BG31	Severozapaden	17.97	49.44	17.93	14.86	88.86
BG32	Severen tsentralen	81.25	43.72	23.10	9.37	67.14
Fuzzy						
BE2	Vlaams Gewest	0.791	0.807	0.945	0.872	0.937
BE3	Région Wallonne	0.625	0.806	0.772	0.759	0.926
BG31	Severozapaden	0.031	0.115	0.052	0.057	0.554
BG32	Severen tsentralen	0.392	0.095	0.066	0.045	0.246
Strong-membership						
BE2	Vlaams Gewest	1	1	1	1	0.937
BE3	Région Wallonne	1	1	1	1	0.926
BG31	Severozapaden	0	0	0	0	0.554
BG32	Severen tsentralen	0	0	0	0	0.246

Table 3. Analysis of necessity results for New Market Firm Sales (NMFS and ~NMFS)

Condition		**New Market Firm Sales**			
		NMFS		**~NMFS**	
		Consistency	Coverage	Consistency	Coverage
TERD_EDUC	con	0.672	0.696	0.628	0.649
	not-con	0.661	0.640	0.705	0.683
SME_INHOUSE	con	0.740	0.749	0.578	0.584
	not-con	0.588	0.583	0.751	0.743
INN_SME_COLLAB	con	0.705	0.766	0.548	0.594
	not-con	0.626	0.581	0.784	0.726
PUB_PRIVATE_COPUB	con	0.644	0.720	0.557	0.621
	not-con	0.661	0.599	0.749	0.677
Descriptive Statistics	Min	0.588	0.581	0.548	0.584
	Max	0.740	0.766	0.784	0.743

Table 4. Truth table and frequency and consistency threshold implications

Cnfg	TERD _EDUC	SME _INHOUSE	INN_SME _COLLAB	PUB_PRIVATE _COPUB	No.	Consistency | PRI score			
						NMFS		~NMFS	
1	0	0	0	0	42	0.642	0.218	**0.874**	0.725
~~2~~	~~0~~	~~0~~	~~0~~	~~1~~	~~6~~	~~0.893~~	~~0.404~~	~~0.927~~	~~0.592~~
3	0	0	1	0	11	**0.891**	0.587	0.845	0.413
~~4~~	~~0~~	~~0~~	~~1~~	~~1~~	~~2~~	~~0.945~~	~~0.719~~	~~0.859~~	~~0.281~~
5	0	1	0	0	20	**0.905**	0.678	0.792	0.299
6	0	1	0	1	14	**0.91**	0.617	0.853	0.373
7	0	1	1	0	12	**0.904**	0.642	0.826	0.351
8	0	1	1	1	10	**0.919**	0.653	0.844	0.335
9	1	0	0	0	26	0.732	0.259	**0.899**	0.722
~~10~~	~~1~~	~~0~~	~~0~~	~~1~~	~~6~~	~~0.873~~	~~0.378~~	~~0.92~~	~~0.609~~
~~11~~	~~1~~	~~0~~	~~1~~	~~0~~	~~5~~	~~0.916~~	~~0.688~~	~~0.816~~	~~0.312~~
12	1	0	1	1	18	**0.928**	0.761	0.77	0.234
~~14~~	~~1~~	~~1~~	~~0~~	~~1~~	~~9~~	~~0.914~~	~~0.542~~	~~0.889~~	~~0.405~~
15	1	1	1	0	10	**0.922**	0.73	0.78	0.242
16	1	1	1	1	45	**0.858**	0.635	0.723	0.288
FsQCA details: Frequency Threshold ≥ 10, Consistency Threshold ≥ 0.853						8 (140)		2 (68)	

Figure 3. Graphical elucidation of frequency and consistency threshold impact

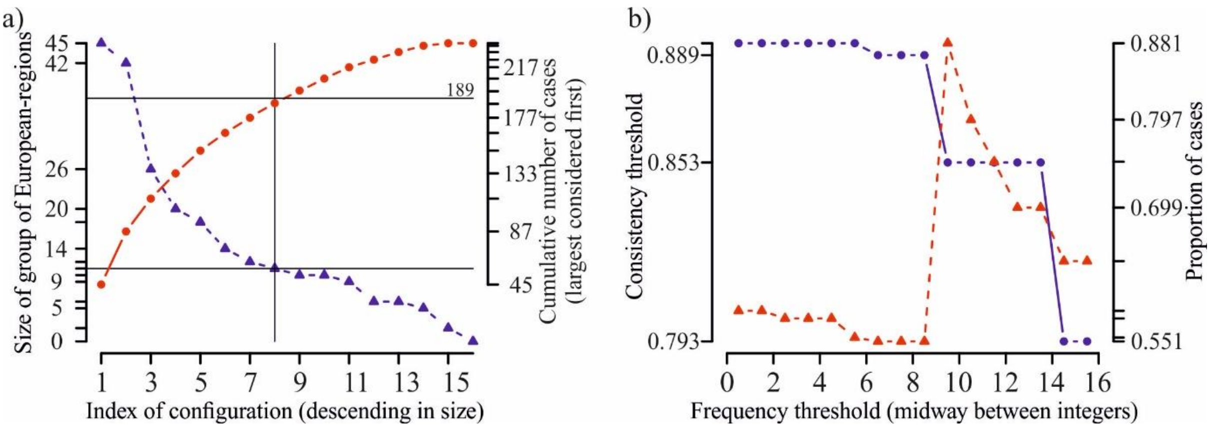

Figure 4. Map based details of summary truth table findings (regions associated with NMFS and ~NMFS, and those not considered)[2]

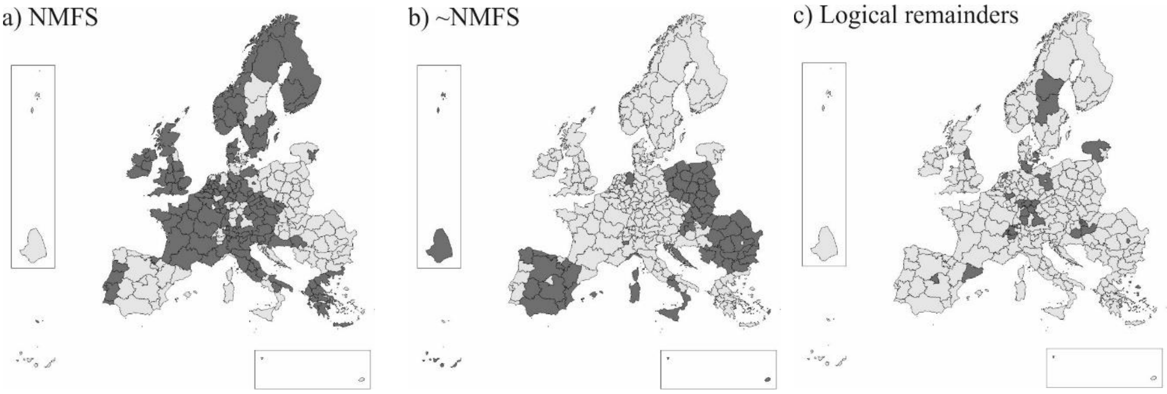

Table 5. Sufficiency analysis results from consideration of TERD_EDUC, SME_INHOUSE, INN_SME_COLLAB, and PUB_PRIVATE_COPUB conditions against the presence (NMFS) and absence (~NMFS) of SMEs' New Market Firm Sales

Conditions	SMEs' New Market Firm Sales				
	NMFS				~NMFS
Complex Solution	CONMFS1	CONMFS2	CONMFS3	CONMFS4	CNNMFS1
TERD_EDUC	⊖		⊖	•	
SME_INHOUSE	⬤	⬤			⊖
INN_SME_COLLAB		•	⬤	⬤	⊖
PUB_PRIVATE_COPUB			⊖	•	⊖
Configurations (in strong membership terms)	5, 6, 7, 8	7, 8, 15, 16	3, 7	12, 16	1, 9
Consistency*	0.847	0.801	0.882	0.847	0.837
PRIscore*	0.637	0.575	0.610	0.651	0.702
Raw Coverage*	0.536	0.584	0.385	0.486	0.595
Unique Coverage*	0.132	0.040	0.024	0.039	-
Solution Consistency, PRI score, Cov	0.784, 0.605, 0.788				-
Parsimonious Solution	PONMFS1		PONMFS2		PNNMFS 1
Configurations (in strong membership terms)	5, 6, 7, 8, 15, 16		3, 7, 8, 12, 15, 16		1, 9
Consistency*	0.749		0.766		-
PRIscore*	0.550		0.576		-
Raw Coverage*	0.740		0.705		-
Unique Coverage*	0.156		0.121		-
Solution Consistency, PRI score, COv	0.730, 0.556, 0.861				-

* The consistency and coverage values are over the whole data set of cases (not just from those configurations shown associated in strong membership terms)

[2] For compactness terms two sets of EU-regions are moved – shown in ovals.

Figure 5. Map based details of Causal recipes from complex solutions for presence of NMFS

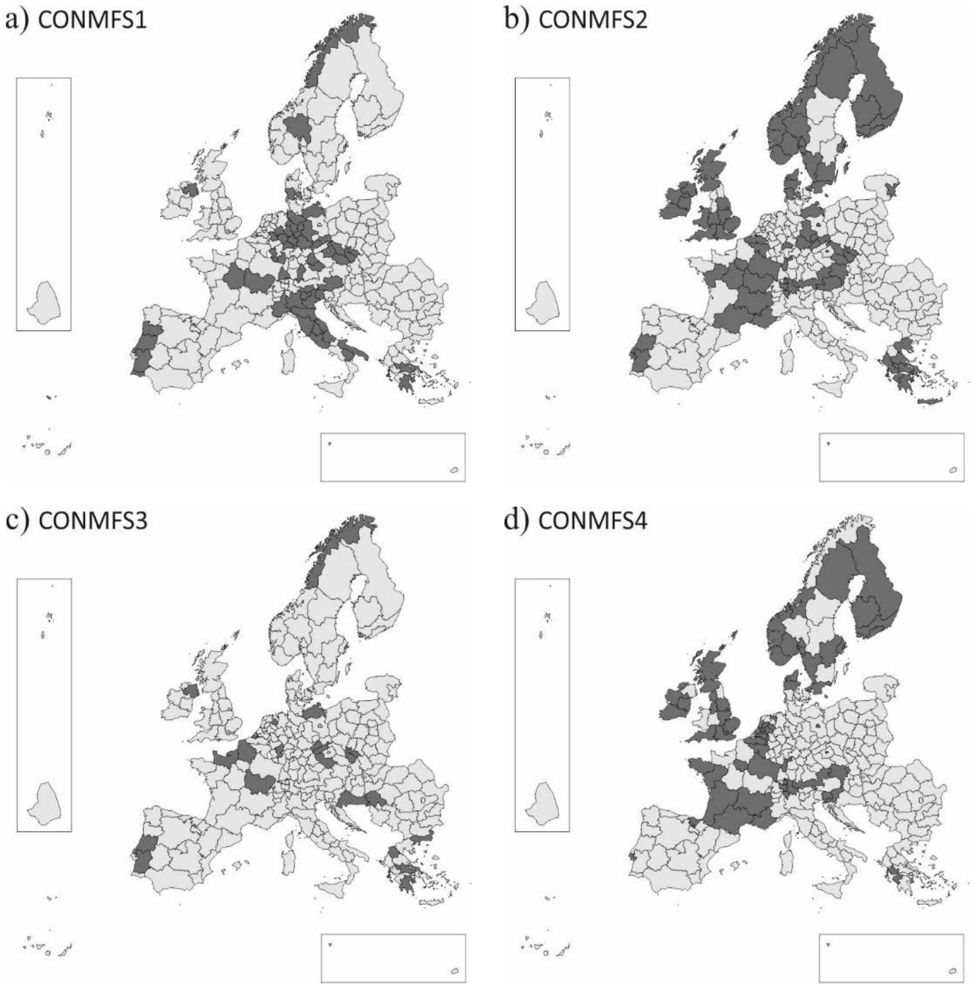

Figure 6. Map based details of Causal recipes from complex solutions for absence of NMFS