Research Policy 45 (2016) 844–856

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

Related and unrelated variety as regional drivers of enterprise productivity and innovation: A multilevel study

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ARTICLE INFO

Article history:
Received 13 February 2015
Received in revised form 7 January 2016
Accepted 19 January 2016
Available online 1 February 2016

Keywords:
Related variety
Unrelated variety
Productivity
Innovation
Specialization
Population density

ABSTRACT

We conduct multilevel analyses of Norwegian data and find that related industrial variety is a positive regional driver of enterprise innovation. Unrelated variety is a negative regional driver of enterprise productivity. This implies that regions with high levels of related variety and low levels of unrelated variety optimize enterprise performance. We argue that regional specialization is a two-dimensional construct inversely associated with related and unrelated variety. Thus, a specialized region (low in unrelated variety) is in fact a driver of enterprise productivity. In addition, we find that population density is another regional driver of enterprise productivity.

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1. Introduction

Do regional characteristics influence enterprise performance? In a review, Howells and Bessant (2012, p. 931) argue that "the geographical environment in which the firm is located can have an important effect on its growth, profit and overall development, including survival and innovative performance." Yet despite a growing number of studies on economic-geographical regions, the linkages between regional characteristics and enterprises are poorly understood or underappreciated (Christiansen and Jakobsen, 2012; Gertler, 2010). Firms or enterprises are frequently mentioned in this line of research, but they remain a vague entity (Maskell, 2001; Taylor and Oinas, 2006). Scholars acknowledge that regional characteristics matter for value creation (e.g. Krugman, 1991; Porter, 2000) and that critical resources reside beyond enterprise boundaries (Das and Teng, 2000; Dyer and Singh, 1998; Ghosh and John, 2012), but an enterprise can also be labeled a bundle of distinct resources residing within its boundaries (Barney, 1991; Barney et al., 2011). In this paper, we intend to contribute to a more nuanced understanding of the region–enterprise nexus by analyzing how geographical localization characteristics are genuinely associated with the enterprise performance measures of *productivity* and *innovation* (while controlling for enterprise and industry characteristics). Productivity is defined as output per worker (Hall and Jones, 1999), and innovation is defined as the creation of novel and useful products for enterprises "to gain a competitive edge in order to survive and grow" (Grønhaug and Kaufmann, 1988, p. 3).

Our study is grounded in the paradigm of evolutionary economic geography, which is concerned "about why regions differ in their ability to generate, imitate or apply new variety, and ... the economic and institutional structures through which a region can retain or even expand its competitive position" (Boschma and Lambooy, 1999, p. 412). Furthermore, the paradigm emphasizes how regions evolve (Martin, 2010; Martin and Sunley, 2006), the spatial dimension of innovation (Boschma and Martin, 2007; Kogler, 2015), and the cognitive, organizational, social, institutional, and geographical dimensions of proximity (Boschma, 2005). Historically, there has been a wide-ranging debate over the regional characteristics that may spur value creation, covering factors from specialization to diversity or variety (Arrow, 1962; Glaeser et al., 1992; Jacobs, 1969; Marshall, 1890; Romer, 1986), but evolutionary economic geography "has gone beyond this dichotomy to argue that the crucial point ... is encapsulated in the concept of related variety" (Hassink et al., 2014, p. 1298).

In this study, we examine the concept of related variety – in addition to unrelated variety – at a regional level. Yet in so doing, we emphasize that regional specialization is a two-dimensional construct; a low level of specialization can indicate a region with a high level of related or unrelated industrial variety. In a region

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http://dx.doi.org/10.1016/j.respol.2016.01.013
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		Related variety	
		Low	*High*
Unrelated variety	*High*	*1) Regions with a low level of related variety but a high level of unrelated variety*	*2) Regions with high levels of both related and unrelated variety*
	Low	*3) Specialized regions (with low levels of both related and unrelated variety)*	*4) Regions with a high level of related variety but a low level of unrelated variety*

Fig. 1. The dimensions of related and unrelated industrial variety.

with a high level of related variety, enterprises operate in different industries that share several similarities, whereas in a region with a high level of unrelated variety, enterprises operate in different industries that share *few* or *limited* similarities (Frenken et al., 2007). If we theorize that all the enterprises in a region operate in exactly the same industry, then it is a highly specialized region, with a low level of related and unrelated variety. With reference to related and unrelated variety, we can broadly classify regions into four categories in a 2×2 matrix (Fig. 1): (1) regions with a low level of related variety but a high level of unrelated variety, (2) regions with high levels of both related and unrelated variety, (3) specialized regions (with low levels of both related and unrelated variety), and (4) regions with a high level of related variety but a low level of unrelated variety.

Wixe (2015) has shown that enterprise productivity increases in regions with industrial specialization, but with reference to the concepts of cognitive, organizational, social, and institutional proximity (Boschma, 2005), we will hypothesize that productivity is an inverse function of unrelated variety. Furthermore, with reference to the concepts of technological externalities (Jacobs, 1969) and cognitive proximity, we will hypothesize that related variety has a positive effect on enterprise innovation. In our view, this implies that regions with high levels of related variety and low levels of unrelated variety (Fig. 1, Box 4) optimize enterprise performance by fostering both innovation and productivity. With reference to the concepts of pecuniary externalities (Krugman, 1991) and geographical proximity (Boschma, 2005), we will also hypothesize that regional population density increases enterprise productivity.

Economic-geographical regions can accordingly be studied along a number of dimensions, and here we examine whether related and unrelated variety and population density can foster pecuniary and technology externalities or spillovers at an enterprise level. Density implies that a firm is localized in geographical proximity to numerous other firms realizing economies of scale and pecuniary externalities by serving a large market (Krugman, 1991) and benefiting from relatively abundant access to factor conditions (Feser, 2002; Henderson, 2003; Porter, 2000). Industrial variety can induce technological (Jacobs) externalities or spillovers from resource sharing across branches and foster innovation as knowledge diffuses across industrial boundaries and firms recombine and apply ideas from different perspectives (Carlino, 2001; Jacobs, 1969; Schumpeter, 1934). It can be argued that related industrial variety in particular fosters positive externalities from resource sharing, or knowledge and technology spillovers, because of the relatively narrow cognitive distance between enterprises (Boschma, 2005; Hassink et al., 2014; Nooteboom et al., 2007). Following this line of reasoning, regions with unrelated industrial variety will conversely experience less resource sharing because the cognitive distance between the enterprises is too great. Below, we also argue how unrelated variety is likely to constrain enterprise productivity.

The major aim of this study is to identify regional characteristics that may foster or constrain enterprise productivity and innovation. However, we argue that such knowledge may also have practical implications for policymakers, managers, investors, and other stakeholders in their pursuit of optimized value creation.

The present work is a multilevel study, and the data are generally derived from the Norwegian part of the Community Innovation Survey (CIS) "Innovation in the business enterprise sector, 2010" by Statistics Norway in collaboration with Eurostat. Participation in the Norwegian part of the CIS study is mandatory for selected firms; thus, we avoid potential nonresponse bias in the data. We analyze more than 6500 enterprises nested within a wide range of industries located in 89 distinct economic-geographical regions throughout the country.

To model related and unrelated industrial variety, we apply Shannon's (1948a,b) measure of entropy with reference to enterprises' Standard Industrial Classification (SIC) codes, which correspond to the European Community's Nomenclature of Economic Activities (NACE) codes. The concept of population density is modeled by dividing the number of inhabitants by the geographical sizes of regions (Frenken et al., 2007). The concepts of related and unrelated industrial variety and population density are thus constants for enterprises residing within a particular region, and vary between regions. Other independent variables and the dependent variables for this study, productivity and innovation, are measured at the enterprise level of analysis.

2. Theoretical positioning and hypotheses

Back in 1890, Marshall introduced the concept of agglomeration economies, a term with a connotative association with regional industrial specialization. In 1969, Jacobs introduced the term "urbanization economies," which may be associated with industrial diversity or variety. It has been debated whether specialization or diversity foster local externalities in terms of knowledge or technology spillovers (Beaudry and Schiffauerova, 2009), but we emphasize that industrial specialization is a two-dimensional construct in which a low level of specialization can indicate a region with a high level of related or unrelated industrial variety. We believe that such a distinction can provide a more nuanced picture of how regional industrial characteristics foster enterprise productivity and innovation.

Furthermore, it should be noted that later extensions of Marshall's work on agglomeration and industrial specialization emphasize the role of local rivalry as a catalyst for regional development (for a review and synthesis of Marshal's scholarly work, see Glaeser et al., 1992). The concepts of related and unrelated variety also take account of this issue, in that low variety in terms of these dimensions in fact describes industrial specialization within a region (Fig. 1).

It may also be argued that agglomeration economies can induce pecuniary externalities (Martin and Sunley, 1998) as a function of regional size or population density (Krugman, 1991). In his seminal paper, Krugman (1991, p. 485) asks rhetorically: "how far does a technological spillover spill?" He continues, "if one firm's actions affect the demand for the product of another firm . . . this is as much a 'real' externality as if one firm's research and development spills over into the general knowledge pool" (ibid.). Therefore, studying the concept of population density, along with the concepts of related and unrelated variety, enables us to scrutinize their potential genuine effects on enterprise productivity and innovation.

Because of the historical path creation trajectories of regional industry development and entrepreneurial orientation (Henfridsson and Yoo, 2014; Martin and Sunley, 2006), it may be assumed that some regions have expanded a relatively rich portfolio of related industrial variety, proportionate to their low population density. Conversely, other regions may have experienced a path-dependent "lock-in" effect of continuity or "more of the same" (Hassink, 2010), resulting in a fragmented and unrelated industry structure. Finally, some regions may have developed a highly specialized industry structure. Therefore, to take account of such issues, we emphasize that population density and related as well as unrelated variety are distinct in connotation and merit treatment as genuine constructs, both theoretically and empirically. As a consequence, the following literature review focuses mainly on empirical studies that have explicitly or implicitly addressed the issue of industry-related and industry-unrelated variety in conjunction with population density.

2.1. Literature review

Studies from Italy and the Netherlands show that related industrial variety enhances employment and economic growth (Boschma and Iammarino, 2009; Frenken et al., 2007). Related variety increases productivity growth in Italy (Boschma and Iammarino, 2009), but perhaps surprisingly the effect is negative in the Netherlands (Frenken et al., 2007). Unrelated variety and population density reduce unemployment growth in the Netherlands, yet according to some models employment growth is low in densely populated regions (Frenken et al., 2007). A Finnish study also finds that population density is negatively associated with employment growth, whereas related variety increases employment growth in high-tech sectors, but not in low- and medium-tech sectors (Hartog et al., 2012). Data from Turkey indicate that related variety is associated with regional productivity (Falcioglu, 2011). Research from Spain shows that population density and related variety are associated with regional economic growth, and population density and related variety are also associated with regional employment growth in some models (Boschma et al., 2012). In a Swedish context related variety is positively associated with regional innovation, measured by the number of patent applications (Tavassoli and Carbonara, 2014). Using US patent data, Castaldi et al. (2015) also show that related variety is associated with innovation at the regional level; however, they also find that unrelated variety is associated with breakthrough innovations. In their study of workplaces for the entire Swedish economy, Eriksson and Lindgren (2009, p. 33) conclude that "concentrations of similar related firms do not explain any considerable part of the variations in firm competitiveness." Studies from Canada show that changes in regional population size are negatively associated with changes in labor productivity at the firm level (Brown and Rigby, 2011), and that regional population size is positively, but not consistently, associated with productivity (Baldwin et al., 2008). An Italian study finds firms in densely populated regions and in regions with related variety to be R&D intensive, while firms located in densely populated regions tend to have high levels of exports (Antonietti and Cainelli, 2011). The study also investigates whether related variety, unrelated variety, or population density are associated with innovative output or productivity, but fails to show consistent or significant effects. In fact, the study indicates that related variety has a negative but insignificant effect on innovation and productivity in all the reported models. Finally, Wixe (2015) has shown that population density, measured as the size of the accessible market at the local, intra-regional, and extra-regional levels, has a positive effect on labor productivity, yet the findings are most robust at the local level.

Overall, the literature review may appear to be inconclusive. However, a number of the studies indicate that related variety is associated with regional economic growth (Boschma and Iammarino, 2009; Boschma et al., 2012; Frenken et al., 2007), productivity (Falcioglu, 2011) or productivity growth (Boschma and Iammarino, 2009), employment growth (Boschma and Iammarino, 2009; Boschma et al., 2012; Frenken et al., 2007; Hartog et al., 2012), and innovation (Castaldi et al., 2015; Tavassoli and Carbonara, 2014). Although Frenken et al. (2007) report that related variety is negatively associated with regional productivity growth, their study does not control for initial productivity levels (regions with high productivity at the outset may grow at a relatively slow pace, cf. Solow, 1956). Unrelated variety reduces unemployment growth (Frenken et al., 2007) and is associated with breakthrough innovations (Castaldi et al., 2015). Some studies show negative or partly negative effects of population density on regional employment growth (Frenken et al., 2007; Hartog et al., 2012), whereas Boschma et al. (2012) report the opposite result from some models. Wixe (2015) finds that population density has an overall positive effect on labor productivity.

We were only able to identify a limited number of contributions to the literature that examined whether related or unrelated variety, or population density, had an effect at the firm or enterprise level. Eriksson and Lindgren (2009) find that related variety has limited effects on firm competitiveness, but their study does not measure innovation. In Canada, Brown and Rigby (2011) find that changes in regional population size are negatively associated with changes in labor productivity, which can be explained with reference to the Solow (1956) "effect" (i.e. regions that are growing in population may have high labor productivity at the outset, and labor productivity consequently grows at a slower pace). Moreover, as noted above, Baldwin et al. (2008) find that population size is positively but not consistently associated with productivity. Antonietti and Cainelli (2012) find no significant or consistent effects of population density, related variety, or unrelated variety on productivity and innovation; however, their study had a relatively small sample size and only examined a limited number of industries[1].

Despite somewhat mixed effects at the regional level of analysis, we hypothesize below that unrelated variety and population density are associated with productivity at an enterprise level of analysis. Next, we elaborate how related industrial variety is expected to be associated with enterprise innovation.

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[1] In addition, they modeled related variety by applying the Herfindahl–Hirschman index (Herfindahl, 1950; Hirschman, 1945), instead of Shannon's (1948a,b) measure of entropy, as suggested by Frenken et al. (2007). The Herfindahl–Hirschman index is similar to Simpson's (1949) index of diversity, and Nagendra (2002, p. 178) emphasizes with reference to landscape diversity that the "Shannon index stresses the richness component and rare cover types, whilst the Simpson [or Herfindahl–Hirschman] index lays greater emphasis on the evenness component and on the dominant cover types." Accordingly, we argue that the Shannon index is preferable for measuring the potential effect of related industrial variety on innovation, because the prevalence of *richness* and *rarity* is arguably likely to increase the amount of nonredundant information and other resources in the potential application and recombination of perspectives (cf. Burt, 1992, 2004). Moreover, in other studies, the Herfindahl–Hirschman index has in fact been applied to model diversity and specialization (e.g. Kemeny and Storper, 2015); yet these concepts do not consider that industrial variety or diversity may be related or unrelated. (However, we have also applied the Simpson/Herfindahl–Hirschman index in our analyses, and we report on this issue below.)

2.2. Enterprise productivity as a function of unrelated variety and population density

2.2.1. Unrelated variety and enterprise productivity

A low level of unrelated variety may be aligned with a high level of regional industry specialization (cf. Fig. 1), which enables economies of scale at the regional level and forces competing enterprises to be productive. Similar explanations have been provided by other scholars (e.g. Glaeser et al., 1992; Marshall, 1890; Porter, 2000, 2003). Furthermore, a low level of unrelated variety may be aligned with high cognitive, organizational, institutional, and social proximity, which is developed and reinforced in industries that share many similarities. Boschma (2005, p. 71) asserts that "the different dimensions of proximity co-evolve at multiple spatial scales, shaping the evolution of places over time." Although close proximity along the dimensions described can be detrimental to innovation, because of a lack of novelty and high redundancy in cognition and work practices (Boschma, 2005; Nooteboom et al., 2007), it is not unreasonable to assume that a high degree of proximity can foster productivity, because employees can more easily coordinate their efforts across enterprise boundaries. This may be particularly useful in large-scale projects involving numerous local enterprises that require close collaboration or coordination. For instance, close cognitive proximity implies that actors share a similar knowledge base, which fosters efficient and smooth communication. Close organizational, social, and institutional proximity implies that the establishment of work practices and procedures can be handled smoothly through administrative routines and "the way of doing things." Wixe (2015) shows that industrial specialization increases labor productivity at the plant level (and that industrial diversity has the opposite effect). This may indicate that specialization increases productivity.

A high level of unrelated variety, on the other hand, may preclude enterprise productivity, because enterprises operating in very different industries lack complementarities in factor inputs, and there are low levels of technological spillovers, because of large cognitive distances, or a low degree of cognitive proximity, between enterprises (Boschma, 2005; Nooteboom et al., 2007). A high level of unrelated variety may further induce low organizational, social, and institutional proximity, which is likely to constrain the efficiency of administrative routines at a regional level. An unrelated and fragmented industry structure may finally constrain regional economies of scale and local competition. All these issues are likely to hamper enterprise productivity. We conclude our arguments in the following hypothesis:

Hypothesis 1 (H1). There is a negative association between regional unrelated variety and enterprise productivity. High levels of unrelated variety will decrease enterprise productivity and low levels of unrelated variety will increase enterprise productivity.

It should be noted here that high levels of related variety are also an indicator of low regional specialization (cf. Fig. 1). However, we argue that related variety will not preclude enterprise productivity because it fosters technology and knowledge spillovers (Nooteboom et al., 2007) and complementarities in the efficient deployment of factor inputs. Thus, we assume that the benefits of specialization versus those of related variety will balance each other out.

2.2.2. Population density and enterprise productivity

Krugman (1991) emphasizes that the effect of population density on value creation can be explained purely as a function of economies of scale (beyond an enterprise level of analysis) and low transport costs, and that population density is not necessarily associated with technological spillovers or externalities. In other words, Krugman emphasizes the pecuniary externalities of demand and supply factors in densely populated regions. According to Krugman (1991, p. 487), a region with a large population "will be an attractive place to produce, both because of the large local market and because of the availability of the goods and services produced there." His statement bears a resemblance to the concept of geographical proximity, which Boschma (2005, p. 63) defines as "spatial distance between actors." The costs of transportation from densely populated regions are likely to be lower than those from less populous regions, because the former will tend to be located in geographical proximity to the most direct routes to other markets, with a high volume and high frequency of transportation. Consistent with Krugman's argument concerning access to large local markets, geographical proximity in densely populated regions means that enterprises can serve a market that is locally accessible. This reduces transportation costs and increases potential market size, which facilitates a high volume of sales revenue of products and services assembled at a relatively low cost, because of the economies of scale from serving numerous buyers. A large market and geographical proximity to other markets may also facilitate stability in demand, which will increase productivity in terms of revenue generated per employee. In addition, geographical proximity entails that suppliers and customers can more easily interact in interfirm business-to-business relations, thereby decreasing their transaction costs (Williamson, 1979, 1981).

Densely populated regions also supply a competent labor force of both high volume and variety in geographical proximity. Everything else being equal, this should increase the access of enterprises to well-qualified human capital. Accordingly, the outcomes of deployment of these resources will tend to be greater in densely populated regions. The cost of qualified human capital will also be relatively high, and enterprises in densely populated regions may consequently substitute human capital investments for investments in other assets. This will further increase the de facto productivity of enterprises' stock of human capital.

In summary, geographical proximity in densely populated regions fosters high demand and high supply of qualified labor, low transportation costs, and increased efficiency in interfirm supplier–customer relations, which together will tend to increase enterprise productivity. We have reviewed studies examining the relationship between population density and productivity. Despite the findings not being very conclusive, we refer to Wixe (2015), who shows that different measures of population density, such as the size of the accessible market at the local, intra-regional, and extra-regional levels, have positive effects on average labor productivity at the plant level. We therefore propose the following hypothesis:

Hypothesis 2 (H2). There is a positive association between regional population density and enterprise productivity.

2.3. Enterprise innovation as a function of related variety

We have emphasized that industrial variety can induce technological externalities or spillovers from resource sharing and foster innovation as knowledge and information diffuse across a variety of industrial boundaries, recombining ideas from different perspectives (Carlino, 2001; Jacobs, 1969; Schumpeter, 1934). We have further emphasized that *related* industrial variety in particular may foster positive externalities from resource sharing or knowledge and technology spillovers owing to the relatively narrow cognitive distance between enterprises. Thus, related variety may increase the propensity for enterprise innovation, and we elaborate on this argument in the following paragraphs.

Boschma (2005, p. 64) argues that "a not too great cognitive distance between firms (in terms of competencies and skills) enables effective communication and thus learning, while a not too small cognitive distance avoids lock-in, especially when access to dissimilar bodies of knowledge is required in product innovation." According to Nooteboom et al. (2007, p. 1017), "cognitive distance yields opportunities for novel combinations of complementary resources. However, at a certain point cognitive distance becomes so large as to preclude sufficient mutual understanding needed to utilize those opportunities." Measuring cognitive distance as the technological distance between a focal firm and its alliance partners, Nooteboom et al. find a curvilinear relationship between this concept and innovation. Cognitive distance up to a certain level is positive, but beyond a saturation point, the effect turns negative.

In our study, we do not explicitly study cognitive distance with reference to formalized interfirm alliances, but we argue that related industrial variety captures the concept of cognitive distance "between the extremes," which enables enterprise managers and other stakeholders to identify the potential for resource sharing, recombining resources that are complementary, and providing potential added value. If the cognitive distance is too great, such potential is difficult to recognize, because of a lack of mutual understanding, or simply because potential recombining is difficult owing to technologies or concepts being too different to recombine. If the cognitive distance is too narrow, this may indicate a similar and redundant knowledge base, creating limited potential for innovation (Burt, 1992, 2004). In line with this reasoning Hassink et al. (2014, p. 1298) emphasize that related variety strikes "the right balance between cognitive distance and proximity that allows for innovation and interaction."

It may puzzle the reader that we study regional industrial variety along two distinct dimensions, namely related and unrelated variety. For instance, one may intuitively assume that the concepts are one dimensional, where related variety is between the extremes of no variety at all (i.e. specialization) and a high degree of variety. However, a high degree of *related* variety simply implies richness in the presence of enterprises that operate in very similar industries (whereas a high degree of *unrelated* variety implies a richness of enterprises operating in very different industries). In other words, increasing related industrial variety does not produce a steadily increasing cognitive distance between enterprises. On the contrary, the greater the related industrial variety, the higher the potential to recombine resources, because of the high potential for borrowing ideas and other input factors from numerous and related perspectives.

We have reviewed the literature on related variety, and despite the somewhat mixed findings, we conclude and hypothesize that the concept is associated with innovation at the enterprise level of analysis:

Hypothesis 3 (H3). There is a positive association between regional related variety and an enterprise's propensity for innovation.

3. Methodology

3.1. Research context and data

Norway is divided into 89 distinct economic-geographical regions, as defined by Statistics Norway. The criteria for divisions are based on trade and labor markets. Economic-geographical regions reside within counties and consist of one or more entire local municipalities. In other words, economic-geographical regions do not cross county borders, and local municipalities are not divided into economic-geographical regions. Accordingly, economic-geographical regions are at a spatial level between counties and local municipalities. The concept is analogous to the classification of local administrative units at level 2 (LAU 2) in the European Union, formerly described according to Eurostat by the nomenclature of territorial units for statistics at level 4 (NUTS 4).

As noted above, the data are generally drawn from the CIS "Innovation in the business enterprise sector, 2010" by Statistics Norway conducted in collaboration with Eurostat. The population of enterprises is based upon the Central Register of Establishments and Enterprises, according to Statistics Norway. In Norway, it is mandatory for enterprises with 50 or more employees to participate in the survey. For enterprises with 5–49 employees, random samples were selected from companies in different strata (defined by the size of enterprises in terms of number of employees) for which participation was also mandatory; random samples were taken from 43% of enterprises with 20–49 employees, 25% of enterprises with 10–19 employees, and 19% of enterprises with 5–9 employees (there are a few exceptions to this procedure, explained in Norwegian by Wilhelmsen and Foyn, 2012, pp. 35–36). The total response rate exceeded 95%. The CIS survey is coordinated by Eurostat and harmonized throughout Europe to enable valid cross-country comparisons. Because of the strong presence of small enterprises in Norway, the Norwegian part of the survey includes data from enterprises with 5–9 employees (enterprises with fewer than 10 employees are not commonly sampled in other Eurostat member states). The Norwegian part of CIS survey includes data from 6595 enterprises. The CIS data identify the economic-geographical region in which each surveyed enterprise is located. Statistics Norway also provides additional data on population size in each economic-geographical region as of the first quarter of 2008, and on the geographical size of economic-geographical regions in square kilometers.

3.2. Independent and control variables at the regional level of analysis

3.2.1. Population density

Population density is an independent variable with reference to H2 and a control variable with reference to H1 and H3. The concept was measured by dividing the population size of economic-geographical regions by their geographical size in square kilometers. A similar procedure is followed in other studies (e.g. Frenken et al., 2007).

3.2.2. Unrelated industrial variety

Unrelated industrial variety is an independent variable with reference to H1 and a control variable with reference to H2 and H3. We were able to identify SIC codes for 6589 enterprises (of a total sample of 6595 enterprises) and their location in economic-geographical regions. These SIC codes were used as a baseline to model unrelated and related industrial variety at the regional level.

The SIC codes include a hierarchy of five levels to distinguish the "crudeness" of industrial classes. We first identified each enterprise's SIC code at level two, which represents a relatively "crude" distinction. Next, we applied Shannon's (1948a,b) entropy measure at this classification level for enterprises located within distinct economic-geographical regions. More formally, unrelated variety at the regional level is defined as follows:

$$\text{Unrelated variety(UV)} = \sum_{k=1}^{n} s_{k,i} \ln\left(\frac{1}{s_{k,i}}\right),$$

where $s_{k,i}$ is the proportion of enterprises in class k (SIC code at level two) in region i. If $k = 0$, this implies that $\ln(1/s_{k,i}) = 0$; n is the number of identified SIC codes at level two.

3.2.3. Related industrial variety

Related variety is an independent variable with reference to H3 and a control variable with reference to H1 and H2. To model the concept, we first identified each enterprise's SIC code at level five, which represents the most "fine-grained" distinction of industrial classes. Next, we applied Shannon's (1948a,b) entropy measure at this classification level for enterprises that were located within distinct economic-geographical regions. However, because SIC codes at level five contain information in both "fine-grained" and "crude" industrial classifications, we subtracted unrelated variety (UV) from the equation to take account of this issue. More formally, related industrial variety at the regional level is defined as follows:

$$\text{Related variety} = \sum_{k=1}^{N} l_{k,i} \ln\left(\frac{1}{l_{k,i}}\right) - UV,$$

where $l_{k,i}$ is the share of enterprises in class k (SIC code at level five) in region i. If $k = 0$, this implies that $\ln(1/l_{k,i}) = 0$; N is the number of identified SIC codes at level five. A similar procedure has been applied by researchers such as Frenken et al. (2007).

If we examine the measurements of related and unrelated variety more closely, a likely assumption is that these concepts are associated with population density. A large number of enterprises will be present in densely populated regions; therefore, for algebraic purposes, we can assume that a higher proportion of enterprises would operate in different industries. This therefore suggests an association between population density and unrelated variety. Furthermore, we can assume that the number of enterprises in a region correlates more strongly with entropy measures based on "fine-grained" versus "crude" industrial classification, indicating that related variety is also associated with population density (a "fine-grained" as opposed to a "crude" industrial classification creates a higher number of categories as candidates when measuring Shannon's entropy). Despite the likelihood of correlation, the concepts of related and unrelated industrial variety and population density deviate in connotation and accordingly deserve to be treated as distinct and genuine concepts.

3.3. Dependent, independent, and control variables at the enterprise level of analysis

We have data from 6584 enterprises (of a total sample of 6595 enterprises) that enable us to model dependent, independent, and control variables at the enterprise level of analysis.

3.3.1. Productivity as dependent and control variable

Productivity is a dependent variable with reference to H1 and H2. The concept is measured as enterprise sales revenues in Norwegian Kroner in 2010 divided by number of employees. Huselid (1995) measures productivity in a similar way. Although productivity is not necessarily equivalent to profitability, Huselid reports that human resource management practices yield very similar results for productivity and profitability (measured as net income per employee).

We also use productivity as a control variable with reference to H3. It may be argued that productive enterprises accumulate resources that increase an enterprise's propensity for innovation. This accumulation of resources, through productivity gains, may create slack in the organization, which fosters an innovative potential beyond what may be channeled into formal R&D investments. Productivity gains may provide autonomy, enabling employees to individually or collectively pursue innovative ideas in an environment that is relatively unconstrained in economic terms.

3.3.2. Innovation as a dependent variable

Innovation is a dependent variable with reference to H3. We measure the concept as a dummy variable. The survey respondents were requested to indicate whether the enterprise had product innovations that were new to the market between 2008 and 2010. If the answer was yes, this was coded as an innovation, taking a value of 1 (default value was 0). Bertrand and Mol (2013) apply a similar measure of product innovation.

Many studies use patent data as a measure of innovation, but a drawback of this approach is that patenting patterns vary across industries. Studies also indicate that enterprises patent for strategic purposes, not only as a means of legally protecting innovations (Arundel, 2001; Hall and Ziedonis, 2001). The respondents and the enterprises for this study, on the other hand, are anonymous and have no incentive to overreport (or underreport) enterprise innovation systematically. Finally, it should be noted that other studies have also used data from the CIS project to study innovation (see for instance Ebersberger and Herstad, 2012).

3.4. Other control variables at the enterprise level of analysis

We apply a dummy to control for multidivisional enterprises because they are likely to have operations in subsidiaries across economic-geographical regions. Multidivisional enterprises are coded 1 (and 0 otherwise). In addition, we replicate analyses that exclude multidivisional enterprises from the data (we observe below that there are no substantial differences in the results when multidivisional enterprises are included or excluded from the data).

It should be noted that some industries may be capital intensive, whereas others may be labor intensive. Thus, enterprise productivity may vary across industry boundaries as a function of industry particularities. Some industries may also be more innovative than others, and in Section 4, we elaborate on the way in which we take account of industry heterogeneity when testing the hypotheses.

It is not unreasonable to assume that enterprise size will increase productivity, due to economies of scale. Therefore, we control for enterprise size, measured as the number of employees, when testing H1 and H2. Because large enterprises may have an increased capacity to innovate, we also control for enterprise size when testing H3.

Nor is it unreasonable to assume that enterprise R&D activities are associated with innovation. With reference to H3, we therefore control for R&D intensity, measured as R&D investment per employee. In addition, we control for reported regional, national, or international R&D collaboration. Each of these three variables for R&D collaboration is coded as a dummy, for which 1 = yes and 0 = no. Because this study spans a number of industries operating in a variety of economic-geographical regions, industry and regional heterogeneity has also been taken into account, and we elaborate on this issue in Section 4.

4. Results

4.1. Descriptive statistics

Table 1 reports descriptive statistics. To minimize problems related to nonnormal distributions of continuous variables, we applied Van der Waerden's (1953) method of generating normal quantile values, which minimizes skewness and kurtosis (for further details, see Conover, 1999). Skewness and kurtosis for the transformed continuous variables are reported in Table 1 and all take satisfactorily low absolute values.

In accordance with the previous line of reasoning, we observe that population density correlates strongly with related variety. This may indicate multicollinearity problems in models where both concepts are included, and below we address in detail how we deal with this issue.

Table 1
Correlation matrix.

Mean	SD	Skew	Kurt		1	2	3	4	5	6	7	8	9	10
.000	1.00	.000	−.026	Productivity (1)										
.178	.383			Innovation (2)	.066									
.171	.376			Multidiv. enterpr. (3)	.135	.020								
.005	.984	.102	−.254	No empl. (4)	.174	.044	.510							
.078	.715	1.72	1.81	R&D per empl. (5)	.045	.548	.016	.074						
.085	.278			Reg. R&D collab. (6)	.076	.331	.064	.087	.429					
.074	.262			Nat. R&D collab. (7)	.094	.308	.092	.120	.407	.495				
.077	.267			Int. R&D collab. (8)	.088	.361	.078	.132	.448	.581	.627			
−.023	.944	−.310	−.480	Pop. density (9)	.105	.055	.085	.142	.070	−.003	−.015	.041		
−.008	.976	−.127	−.296	Unrel. var. (10)	.002	.038	.043	.093	.062	.034	.015	.036	.407	
−.023	.944	−.310	−.483	Rel. var	.095	.063	.094	.136	.064	−.002	−.013	.037	.875	.485

$N = 6584$. All correlation coefficients higher than .020 are significant at the 5% level (two-tailed tests of significance).

4.2. *Multilevel regression estimates and hypothesis testing*

4.2.1. *Hypotheses 1 and 2 (H1 and H2)*

H1 suggested a negative association between regional unrelated variety and enterprise productivity, and H2 suggested a positive association between regional population density and enterprise productivity. To test these hypotheses, we conducted a multilevel mixed effects linear regression using Stata 13.1 software (StataCorp, 2013). Table 2 reports both fixed and random effects. Fixed effects represent regression estimates, whereas random effects represent estimated variance components. Residuals represent the estimated standard deviation of the overall error term. We also take account of the corresponding random effect at the regional level. Finally, we take account of the random effect of different industries that are nested within regions. Industries are classified at level two with reference to SIC codes (cf. our previous explanation of SIC codes).

Model 1 includes the following fixed effects regressors: the control variables at the enterprise level of analysis, related variety as a control variable at the regional level, and the independent variables of unrelated variety (H1) and population density (H2) at the regional level. We find that H1 and H2 gain significant empirical support. We also observe that large enterprises (in terms of number of employees) are significantly more productive than small enterprises, probably because of economies of scale at the enterprise level of analysis. The Wald χ^2 is significant in Model 1, and in all reported models in Table 2, which confirms a robust model fit. The likelihood ratio χ^2 is also significant, because of the random effect of different industries nested within regions. The regional random effect is zero and insignificant in Model 1, and in all reported models in Table 2. Zero random effects have been discussed in the literature (Andrews, 1999; Self and Liang, 1987), and in our context it implies that the variation within regions (with reference to enterprise productivity) is not lower than the variation across the whole sample. We have noted that the concepts of population density and related variety are strongly correlated. This may cause multicollinearity problems; therefore, we omit the concept of related variety from Model 2. The effects of the remaining parameters are consistent with estimates reported for the previous model (Model 1).

Table 2
Multilevel linear regression analyses, with productivity as the dependent variable (Model 3 omits multidivisional enterprises).

Fixed effects	Model 1	Model 2	Model 3
Constant	−.045*	−.048*	−.041†
	(.021)	(.021)	(.021)
Enterprise level			
Multidivisional enterprise	.053	.054	
	(.034)	(.034)	
Number of employees	.171***	.171***	.190***
	(.014)	(.013)	(.015)
Regional level			
Rel. variety	.025		.027
	(.035)		(.037)
Unrel. variety (H1)	−.061**	−.057**	−.071**
	(.021)	(.020)	(.021)
Population density (H2)	.102**	.120***	.106**
	(.034)	(.023)	(.035)
Random effects			
Residual	.665	.665	.681
	(.021)	(.013)	(.016)
Regional effect	.000	.000	.000
	(.000)	(.000)	(.000)
Industries within regions	.253	.253	.234
	(.039)	(.018)	(.018)
Wald χ^2 (fixed effects, regressors)	289.6***	289.0***	203.8***
Log likelihood	−8623.1	−8623.4	−7213.6
Likelihood ratio χ^2 (random effects)	1136.4***	1137.9***	810.6***

Dependent variable: productivity. $N = 6584$ (5461 in Model 3); number of economic regions = 89; number of industries within economic regions = 2010 (1852 in Model 3). Standard error in parentheses.

† $p < .10$.
* $p < .05$.
** $p < .01$.
*** $p < .001$, two-tailed tests of significance.

Table 3
Multilevel logistic regression analyses, with product innovation as the dependent variable (Model 5 omits multidivisional enterprises).

Fixed effects	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	−2.24***	−2.36***	−1.83***	−1.83***	−2.30***
	(.070)	(.070)	(.066)	(.066)	(.071)
Enterprise level					
Multidivisional enterprise	.063	.070			
	(.124)	(.124)			
Number of employees	−.059	−.059			−.076
	(.050)	(.050)			(.054)
R&D per employee	1.53***	1.53***			1.60***
	(.056)	(.056)			(.060)
Regional R&D collab.	.564***	.571***			.547***
	(.139)	(.138)			(.157)
National R&D collab.	.287†	.287†			.030
	(.154)	(.154)			(.179)
Int. R&D collab.	.752***	.749***			.688***
	(.159)	(.159)			(.185)
Productivity	.121**	.118*			.178***
	(.046)	(.046)			(.050)
Regional level					
Population density	−.181†	−.128†	−.037		−.233*
	(.098)	(.077)	(.102)		(.103)
Unrel. variety	−.024	.013			−.018
	(.054)	(.051)			(.057)
Rel. variety (H3)	.234*		.234*	.205**	.294**
	(.105)		(.103)	(.064)	(.111)
Rel. variety/Ln(numb. of enterprises)		.161*			
		(.066)			
Random effects					
Regional effect	.000	.000	.006	.008	.000
	(.000)	(.000)	(.024)	(.024)	(.000)
Industries within regions	.287	.284	.986	.985	.176
	(.095)	(.092)	(.152)	(.152)	(.089)
Wald χ^2 (fixed effects, regressors)	1114.2***	1121.1***	10.40**	10.18**	977.9***
Log likelihood	−2186.6	−2186.2	−2966.5	−2966.6	−1766.8
Likelihood ratio χ^2 (random effects)	24.88***	27.30***	207.7***	207.6***	8.33**

Dependent variable: product innovation. $N = 6584$ (5461 in Model 5); number of economic regions = 89; number of industries within economic regions = 2010 (1852 in Model 5). Standard error in parentheses. *p*-Value with reference to related variety (H3) is .026 in Model 1 and .023 in Model 3, two-tailed test of significance. *p*-Value with reference to related variety/Ln(number of enterprises) is .014 in Model 2, two-tailed test of significance.
† $p < .10$.
* $p < .05$.
** $p < .01$.
*** $p < .001$, two-tailed tests of significance.

Although we control for multidivisional enterprises, we cannot rule out all potential noise in the data with reference to this issue. For instance, a multidivisional enterprise may have subsidiaries operating in other economic-geographical regions than where its headquarter is located. Therefore, to address this issue further, we omitted multidivisional enterprises from the data and replicated data analyses from Model 1, and report the replicated estimates in Model 3. We observe that none of the conclusions from our analyses so far is altered. Considering all these findings, we conclude that H1 and H2 gain empirical support.

4.2.2. *Hypothesis 3 (H3)*

H3 suggested a positive association between regional related variety and an enterprise's propensity to be innovative. To test this hypothesis, we conducted a multilevel mixed effects logistic regression using Stata 13.1 software (StataCorp, 2013). Table 3 reports both fixed and random effects. The random effect variables are the same as those reported in Table 2 (multilevel logistic regression does not generate random residual effects).

Model 1 includes the following fixed effect regressors: the control variables at the enterprise level of analysis, and the control variables and related variety (H3) as an independent variable at the regional level. We observe that H3 gains significant empirical support (the *p*-value with reference to related variety, H3, is .026 in Model 1, two-tailed test of significance). Unsurprisingly, we observe that R&D investments per employee and R&D collaboration are positively associated with innovation. Furthermore, consistent with our argument, we observe that enterprise productivity is associated with innovation. Population density has a borderline significant negative effect on enterprise innovation.

The Wald χ^2 statistic is significant in Model 1, and in all reported models, which confirms robust model fit. The likelihood ratio χ^2 is also significant, because of the random effect of different industries nested within regions. The regional random effect is zero and insignificant in Model 1, and insignificant and either zero or close to zero in the other reported models in Table 3. In our context, this implies that variation within regions (with reference to product innovation) is not lower than the variation across the whole sample (cf. Andrews, 1999; Self and Liang, 1987).

As noted above, the concepts of population density and related variety correlate strongly, and this may cause multicollinearity problems[2]. To address this issue, we divide the regional concept of related variety on the natural logarithm of the number of enterprises sampled in each region as a proxy for normalized entropy (cf. Minosse et al., 2006). The correlation between this new concept

[2] In an unreported model, we omit population density as a control variable. The effect of related variety is still positive, but insignificant. The reason for the insignificant effect is probably that related variety and population density have opposite effects on enterprise innovation (see Model 1).

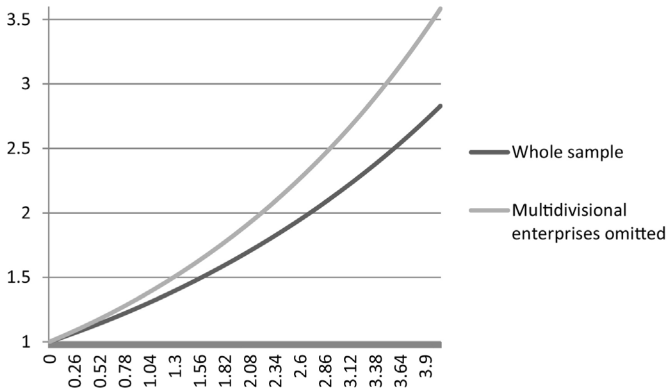

Fig. 2. Odds ratios on innovation as a function of related industrial variety at the regional level. The black line is based on Model 1 in Table 3 (the whole sample) and the gray line is based on Model 5 (the multidivisional enterprises are omitted from the sample).

and population density is .727. Calculating the variance inflation factor (VIF) for the two concepts returns a value of 2.12, which is below the range of critical values between 4 and 10, as suggested in the literature (see O'Brien, 2007 for further readings). Because we have a large sample size, this further increases robustness and decreases the probability of potential multicollinearity problems (cf. O'Brien, 2007). In Model 2 (in Table 3), we substitute this new concept with related variety and find that the effect is positive and significant[3]. The effects of the other parameters in the model are consistent with Model 1, except for a somewhat less negative effect from population density on enterprise innovation.

To take further account of potential multicollinearity issues, we omit all fixed effects regressors in Model 3, except for population density and related variety. In Model 4, we omit all fixed effect regressors except for related variety. We observe that related variety receives significant support in both models (Models 3 and 4). The effect of population density is negative but insignificant (Model 3). The standard error of related variety in Models 1 and 3 (which include population density) is not much higher than that in Model 4 (which excludes population density and all other fixed effect regressors except for related variety). This provides further evidence that multicollinearity is not a major concern in either Model 1 or Model 3. Moreover, it is interesting to observe that related variety receives strong and significant support when all other regressors at an enterprise and regional level are omitted from Model 4, which definitely rules out potential multicollinearity problems.

Although Model 4 does not take account of controls at an enterprise level, it includes enterprises operating in different industries within regions. Thus, Model 4 controls for the potential concentration of particular industries in certain regions (we observe that the random effect of industries nested within regions is unsurprisingly increased in Models 3 and 4 when enterprise fixed-level effects are omitted). Finally, the regression estimates of related variety in Model 4 are only slightly lower than the regression estimates of related variety in Model 1, which includes all the other parameters at both the enterprise and regional levels of analysis.

To take account of potential noise in the data with reference to multidivisional enterprises, we again omitted multidivisional enterprises and replicated analyses from Model 1 (Table 3). We report the replicated estimates in Model 5 and observe that none of the conclusions from our analyses in Model 1 is altered, except that the borderline significant effect of national R&D collaboration is now absent. We also observe that the effect of related variety is stronger, and more significantly robust in Model 5 than in Model 1. Considering all these findings, we conclude that H3 gains empirical support.

[3] The *P*-value of this "new" concept of related variety is .014 in Model 2 (two-tailed test of significance), which is lower than that in Model 1 (.026). The absolute log likelihood value is also marginally lower in Model 2 than in Model 1, which indicates improved model fit.

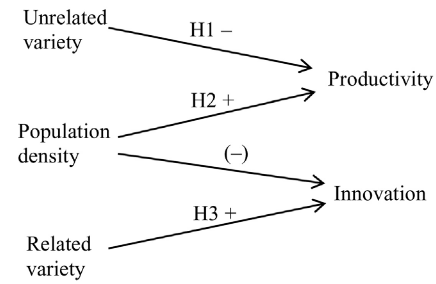

Fig. 3. Empirical model.

To assess further the impact of related variety on the propensity of enterprises to be innovative, we report odds ratios in Fig. 2 (with reference to Models 1 and 5 in Table 3). Fig. 2 shows that the odds ratio takes an approximate value of 3 in the extreme cases of maximum versus minimum related industrial variety.

5. Conclusion

5.1. Discussion of the empirical results

Our study aimed to investigate how regional characteristics influence enterprise performance, and we summarize the major results of the regression estimates and the hypothesis testing in the empirical model in Fig. 3. Unrelated industrial variety has a negative effect on enterprise productivity (H1), whereas population density has a positive effect (H2). Related industrial variety has a positive effect on an enterprise's propensity to be innovative (H3), whereas population density has a borderline negative effect.

We have noted that densely populated regions tend to have more related industrial variety, but population density per se does not suffice to increase the propensity of enterprises to be innovative (indeed we observe a borderline negative effect, which we discuss below). Nor does related industrial variety genuinely suffice to influence enterprise productivity. This study therefore increases our understanding of the role of regional characteristics on enterprise performance by shedding light on the perspectives of pecuniary and technology spillovers as a function of population density and related variety, respectively. Our study illustrates that the propositions of population density fostering pecuniary spillovers (Krugman, 1991) and industrial related variety fostering technology spillovers (Frenken et al., 2007) should not be treated as competitive frameworks, but should rather be regarded as complementary in their explanations of different facets of enterprise performance.

Furthermore, our study found that unrelated industrial variety is negatively associated with enterprise productivity. We have argued that unrelated industrial variety precludes the efficient deployment of complementary factor inputs in the production of goods and services. An alternative or complementary explanation is that a low level of unrelated variety in fact produces a high degree of regional industrial specialization, which enables economies of scale at the regional level and forces competing enterprises to be productive[4].

[4] We substituted the Shannon entropy measure of unrelated variety with the Simpson/Herfindahl–Hirschman measure (by applying SIC codes at level two), and found a positive and significant effect on productivity (see Table A1 in the Appendix).

However, it should be noted that a low level of related variety is also an indicator of industrial specialization, but one that has no effect on productivity (Models 1 and 3 in Table 2). We therefore conclude that unrelated industrial variety precludes enterprise productivity (most likely because there is no efficient deployment of complementary factor inputs) while related industrial variety does not (most likely because it enables the deployment of complementary factor inputs). In other words, the benefits of industrial specialization (economies of scale and local competition) versus related industrial variety (deployment of complementary factor inputs) appear to balance out with reference to enterprise productivity.

It may be puzzling that population density has a direct negative effect on the propensity of enterprises to be innovative in the models that control for enterprise level characteristics (Models 1, 2, and 5 in Table 3). Yet a cautious interpretation of this result is that some regions in Norway with relatively low population density have a long heritage of dynamic and innovative sectors in shipping and other maritime industries, sea farming, and mechanical industries, and later in the oil and gas industries (for a classical case illustrating the foundations of these dynamic environments, see Barnes, 1954; for a more recent case study, see Jakobsen et al., 2005). A complementary or alternative explanation is that the innovative potential increases in regions where the population density is low, because people are relatively knowledgeable about complementary competences and resources that exist in the geographical area. If people tend to know each other throughout the local community, this may increase trust (cf. Fløysand and Jakobsen, 2011; Simmel, 1950), which further fosters the ability to recombine resources in an innovative pursuit across enterprise boundaries.

Enterprise productivity increases the propensity to innovate (Table 3). However, we should be cautious not to overinterpret the result, because we cannot rule out a potential reverse causal effect in that innovative enterprises, at least in the longer run, are likely to increase productivity. Another interpretation is that enterprises with productive employees are inherently more innovative; thus, we can theorize a spurious correlation between the concepts.

Table 1 indicates that the concepts of related and unrelated variety are correlated; however, partialling out the effect of population density, we find that related and unrelated variety are in fact weakly correlated (with a correlation coefficient of .186). This may indicate that regions follow different paths of industrial development, fostering either related or unrelated variety. Reviewing the literature on new economic growth theory, which emphasizes endogenous accumulation of capital and innovative capabilities, Martin and Sunley (1998) argue that the spatial dimension of regions plays a crucial role in explaining such processes. Our contribution has primarily studied how regional characteristics, as exogenous agents, influence value creation at an enterprise level, but it is not farfetched to suggest that there is also a feedback loop in which enterprise productivity and innovation have long-term reciprocal effects on both regional industry and capital structures. In other words, intra-regional endogenous factors may explain value creation whereby regional structures are reproduced and even reinforced. Such endogenous forces may also explain the low genuine correlation between regional related and unrelated variety. In our opinion, the new endogenous growth theory shares many similarities with the paradigm of evolutionary economic geography. Consistent with our argument, Frenken and Boschma (2007) and Martin and Sunley (2010), theorize that the evolutionary process of regional development must be understood as a process in which enterprise-level and regional-level characteristics influence each other.

We have tested whether productivity and related variety are associated with an enterprise's propensity for *process* innovation, but we found no effects (see Table A2 in the Appendix). However, only 5.7% of the enterprises reported having process innovation (those reporting product innovations comprise 17.8%), and it is not unreasonable to assume that such a low number complicates the statistical analyses. Moreover, product innovation is more strongly associated with R&D intensity, and regional, national, and international R&D collaboration, than process innovation (see Table A3 in the Appendix). We can therefore assume that process innovation has lower criterion validity than product innovation (cf. Cronbach and Meehl, 1955)[5]. Nevertheless, one should not generalize our findings beyond the concept of enterprise *product* innovation.

5.2. Policy implications

With reference to the regional concepts of related and unrelated variety (cf. Fig. 1), we summarize our empirical findings in Fig. 4. Regions with low related variety but high unrelated variety constrain both enterprise innovation and productivity (Box 1). They are thus the worst performing regions. Regions where both related and unrelated variety are high foster innovation, but constrain productivity (Box 2). Regions where related and unrelated variety are both low (i.e. specialized regions) constrain innovation, but foster productivity (Box 3). Finally, regions with high related but low unrelated variety foster both innovation and productivity (Box 4). They are thus the best performing regions.

We argue that our empirical findings with reference to related and unrelated variety have practical implications for policymakers, managers, investors, and other stakeholders. For instance, in Norway, there has been a long-standing focus on regional specialization or the cultivation of specialized regional industries to gain competitive advantage and create value in a high-cost society. Our study makes a valuable contribution to this perspective by showing that the concept of regional industry specialization should be understood as a multidimensional construct. The empirical analyses show that regional industry specialization (i.e. low levels of unrelated variety) may indeed foster enterprise productivity (Box 3), but such a regional structure may hamper innovation, which can be obstructive to long-term growth. However, a policy simultaneously focusing on promoting abundant related variety and specialization (i.e. limiting unrelated variety) may enable a region to foster both enterprise productivity and innovation (Box 4).

Another potential implication from this study is the awareness that related industrial variety may facilitate the channeling of competence and labor between industries that share similarities. For instance, many regions in Norway are currently facing challenges because of the low price of oil, but for the same reason, policymakers in these regions are beginning to emphasize that this situation may act as a catalyst for the transfer of highly skilled labor or competence developed in the petroleum industry to other related industries. Sea farming (of codfish and salmon) can benefit from deep-sea instrumentation developed and used in the subsea petroleum industry. Oil platform construction technology (applied at deep-sea levels under extreme climatic conditions) is now being transferred to bridge construction and to the planning of deep-sea tube bridges. Such a supply of resources spilling over from one industry to another, in this case partly as a function of reduced oil prices, may boost innovation in related industries,

(The Simpson/Herfindahl–Hirschman measure is strongly negatively correlated with the Shannon measure.)

[5] However, Table A2 reports that the size of enterprises in terms of number of employees is strongly associated with process innovation. This may further explain why large enterprises are productive, cf. Table 2.

		Related variety — *Low*	*Related variety* — *High*
Unrelated variety	*High*	*1) Regions with a low level of related variety but a high level of unrelated variety:* • A low level of related variety **constrains innovation** • A high level of unrelated variety **constrains productivity**	*2) Regions with high levels of both related and unrelated variety:* • A high level of related variety **fosters innovation** • A high level of unrelated variety **constrains productivity**
	Low	*3) Specialized regions (with low levels of both related and unrelated variety):* • A low level of related variety **constrains innovation** • A low level of unrelated variety **fosters productivity**	*4) Regions with a high level of related variety but a low level of unrelated variety:* • A high level of related variety **fosters innovation** • A low level of unrelated variety **fosters productivity**

Fig. 4. Productivity and innovation effects in economic-geographical regions.

but future research has yet to study this issue in detail. Finally, finding that regional characteristics in terms of related variety, unrelated variety, and population density influence different facets of enterprise performance can enable managers, investors, and other stakeholders to evaluate the potential pros and cons of enterprise localization from a long-term perspective.

5.3. Limitations and future research

This study has emphasized that resources residing beyond enterprise boundaries – in tandem with internal resources – can leverage different facets of enterprise performance, but there may also be some interaction effects between regional characteristics and enterprise strategies in terms of resource deployment. Cohen and Levinthal's (1990) concept of absorptive capacity has received much attention in the scholarly literature, and we speculate here that regional absorptive capacity, in terms of how firms in a region recognize "the value of new information, assimilate it, and apply it to commercial ends" (Cohen and Levinthal, 1990, p. 128) may depend on related and unrelated industrial variety. For instance, future research should aim to investigate the link between R&D investment, innovation, and related or unrelated variety.

We have referred to the finding by Castaldi et al. (2015) that unrelated variety is associated with breakthrough innovations. This may be explained as the result of rare combinations of very different technologies in regions that are rich in unrelated variety. Our study did not show any significant relationship between unrelated variety and innovation at all. One potential explanation of the diverging findings is that our operationalization of innovation does not explicitly capture how innovations differs in their degree of newness (i.e. incremental innovations vs. radical or breakthrough innovations). Thus, it may be that studying breakthrough innovation would yield different results to those reported here, and future studies could examine these issues using a similar research design to ours.

We have emphasized that this is a multilevel study, which has aimed to identify regional industry structures (along with population density) as drivers of enterprise productivity and innovation. This implies that the concepts of related and unrelated industrial variety are modeled as constants for enterprises residing within a particular region. However, one may assume that the industry structure in a region may more or less "fit" enterprises operating (in particular industries) there. For instance, despite that related or unrelated variety are assumed to be identical in two different regions, operating in one particular industry in one of the regions may not be the same as operating in exactly the same industry in the other region. In our study, we have taken account of this issue by controlling for the random effect of different industries that are nested *within* regions; i.e., we do not merely control for an overall industry effect (across regions), but we control for the effect of operating in a particular industry in a particular region. In other words, if enterprises (operating in a particular industry) are in either a favorable or an unfavorable position with reference to their "fit" with the overall regional industry structure, our study accounts for this issue. Having said this, we would encourage future research to address spatial dimensions other than economic-geographical regions. One such spatial dimension is the industry structure. Future research should therefore aim to model entropy measures for different industries to study how they drive productivity or innovation. It could be that industries are not merely innovative or productive, but instead it is the relatedness or unrelatedness within broader classes of industry structures that drives different facets of enterprise performance.

A limitation of this study is that the data are cross-sectional and not longitudinal. However, Wixe (2015, p. 8) argues that "the regional characteristics have a tendency to change slowly over time." Thus, it is reasonable to assume that macro-level regional characteristics will have a stronger effect on micro-level enterprise characteristics (which can change relatively rapidly) than vice versa. Future studies should nevertheless apply a longitudinal research design or apply the appropriate instrumental variables to ensure robust internal validity.

Acknowledgments

This research was supported by grants provided by the Research Council of Norway. We would like to thank three anonymous reviewers for providing constructive comments that helped us to improve the paper.

Appendix A.

Tables A1–A3.

Table A1
Multilevel linear regression analyses, with productivity as the dependent variable.

	Model 1	Model 2
Fixed effects		
Constant	−.045*	−.046*
	(.021)	(.021)
Enterprise level		
Multidivisional enterprise	.052	.053
	(.034)	(.34)
Number of employees	.171***	.171***
	(.013)	(.013)
Regional level		
Rel. variety	.003	
	(.034)	
Simpson/Herfindahl–Hirschman	.052**	.051**
	(.018)	(.018)
Population density	.103**	.105***
	(.034)	(.021)
Random effects		
Residual	.664	.664
	(.013)	(.014)
Regional effect	.000	.000
	(.000)	(.000)
Industries within regions	.253	.253
	(.017)	(.017)
Wald χ^2 (fixed effects, regressors)	288.8***	288.8***
Log likelihood	−8623.5	−8623.5
Likelihood ratio χ^2 (random effects)	1129.1***	1129.5***

Dependent variable: productivity. N = 6584; number of economic regions = 89; number of industries within economic regions = 2010. Standard error in parentheses.
* $p < .05$.
** $p < .01$.
*** $p < .001$, two-tailed tests of significance.

Table A2
Multilevel logistic regression analyses, with *process* innovation as the dependent variable.

Fixed effects	
Constant	−3.62**
	(.114)
Enterprise level	
Multidivisional enterprise	−.196
	(.168)
Number of employees	.470***
	(.073)
R&D per employee	1.01***
	(.076)
Regional R&D collab.	.522**
	(.171)
National R&D collab.	.443*
	(.180)
Int. R&D collab.	.307
	(.193)
Productivity	.012
	(.064)
Regional level	
Population density	−.087
	(.140)
Unrel. variety	−.036
	(.075)
Rel. variety	.013
	(.148)
Random effects	
Regional effect	.000
	(.000)
Industries within regions	.274
	(.155)
Wald χ^2 (fixed effects, regressors)	419.7***
Log likelihood	−1181.4
Likelihood ratio χ^2 (random effects)	6.20**

Dependent variable: *process* innovation. N = 6584; number of economic regions = 89; number of industries within economic regions = 2010. Standard error in parentheses.
* $p < .05$.
** $p < .01$.
*** $p < .001$, two-tailed tests of significance.

Table A3
Correlations.

	1	2
Innovation (product) (1)		
Process Innovation (2)	.373	
R&D per empl.	.548	.288
Reg. R&D collab.	.331	.226
Nat. R&D collab.	.308	.225
Int. R&D collab.	.361	.238

N = 6584. All correlation coefficients are significant at the 5% level (two-tailed tests of significance).

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