Where cities fail to triumph: The impact of urban location and local collaboration on innovation in Norway

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Abstract
The role of cities in fostering innovation has for long been taken for granted. Agglomeration and the knowledge spillovers generated in dense urban environments have been considered fundamental drivers of innovation. This view has, however, become challenged by research questioning the returns to physical agglomeration and local networking, placing instead more emphasis on the importance of interregional and international collaboration, and on innovation in peripheral regions. This paper delves into the debate on the role of cities for innovation by examining the interplay between urban location and local collaboration in Norway. It uses data from the Community Innovation Survey for 2006–2010 to map out the geographical dimension of R&D collaboration in Norwegian firms with a view to assessing whether different types of R&D collaboration in urban and rural locations affect firms’ propensity to innovate. The results show that local collaboration is associated with increased process and organisational innovation, while it does not produce higher levels of product or marketing innovation. Conversely, international collaboration is connected with higher probabilities of product, new-to-market and marketing innovations. Furthermore, location in urban or rural areas makes no difference for most innovation outcomes in Norway when other characteristics are controlled for. Location in cities also does not shape the returns to local R&D collaboration. Hence, the
Cities are widely regarded as the best locations for the brewing of innovation. “Cities, the dense agglomerations that dot the globe, have been engines of innovation since Plato and Socrates bickered in an Athenian marketplace” (Glaeser, 2011, p. 1). Cities bring together innovative actors in dense environments, facilitating the connectivity that some have called “buzz” (Storper & Venables, 2004). Cities also produce positive externalities through their concentration of skills, entrepreneurship and creativity, through the related and diverse firms they contain, and through the trade and cultural exchanges they generate. Proximity to other innovative actors in cities “provides valuable information that can be a wellspring of innovation” (Glaeser, 2011, p. 21). Hence, the general perception is that if firms want to innovate, they have to locate in cities. Firms in cities are more innovative, and the bigger the city, the bigger the potential for a firm to become innovative.

However, this tenet has been increasingly challenged by empirical research looking at where firms get the information that makes them more innovative (e.g., Doloreux & Dionne, 2008; Fitjar & Rodríguez-Pose, 2011; Grillitsch & Nilsson, 2015; Melli, 2018; Rodríguez-Pose & Fitjar, 2013; Tödtling, Grillitsch, & Höglinger, 2012). These studies have emphasized that innovation is more a consequence of internal developments within the firm and of the development of purpose-built networks than of the positive externalities afforded by dense urban environments. Firms in relatively remote environments often compensate for the lack of local externalities by developing more pipelines that bypass the local environment and reach out to other innovative environments, often in distant parts of the world (Grillitsch & Nilsson, 2015; Habersetzer, Grèzes-Bürcher, Boschma & Mayer, 2019; Mayer, Habersetzer, & Melli, 2016). Besides, peripheral regions may offer other advantages, such as quietness or opportunities for secrecy, which can attract some types of innovative firms (Eder, 2019; Mayer & Baumgartner, 2014; Shearmur, 2012; Shearmur & Doloreux, 2016).

Consequently, there is a growing debate about whether local linkages, in general, and local linkages within cities, in particular, actually influence firms’ capacity for innovation. This paper delves into this question by means of a rich data set containing a large sample of Norwegian firms. Norway is an interesting case because of its status as one of the most innovative economies in the world. The presence of highly innovative and productive firms in such a small and remote (albeit rich) country, lacking large urban agglomerations, represents a puzzle in light of the theories that posit that innovation mainly happens in big cities. In addressing how local collaboration in cities shape innovation, this paper provides new empirical evidence, using more extensive and reliable data than most previous research on this topic. The analysis uses three waves of the Norwegian Community Innovation Survey (CIS) between 2006 and 2010 to build an unbalanced panel of more than 6,000 observations. The paper examines the extent to which local R&D collaboration matters more or less for innovation than R&D collaboration at greater geographical distance (both within and outside Norway) and whether the impact of local collaboration on innovation is greater in larger urban areas than in small cities, towns, and rural regions.

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The results challenge the prevailing view that innovation benefits from frequent interaction in close geographical proximity. Local collaboration is only associated with greater levels of process and organisational
innovation, while it seems to be mostly irrelevant for other types of innovation. Product, new-to-market, and marketing innovation rely on other forms of networking and mainly on connections to agents located outside Norway. Moreover, the benefits from collaborating locally, nationally, or internationally in innovation projects are unrelated to the urban or rural location of the firm.

The paper proceeds by reviewing the debate on whether local collaboration and its facilitation in urban environments leads to greater innovation. The methods and data are presented in Section 3, while Section 4 focuses on the empirical analysis. The paper concludes with a summary of the results and some implications for further analysis and policy.

2 | DOES COLLABORATION IN CITIES LEAD TO GREATER INNOVATION?

Recent developments in urban economics have put cities at the heart of the innovative process. Technological change and globalisation, rather than leading to the "death of distance" (Cairncross, 2001) or a “flat world” (Friedman, 2005), have been intrinsically associated with an increasing concentration of economic and innovative activities (Florida, 2005; Scott & Storper, 2007). In particular, ever more innovative processes take place in urban areas (McCann, 2008). Agglomeration in cities facilitate mechanisms that drive such concentration by enticing formal and informal interaction and knowledge exchange between innovative actors (Storper & Venables, 2004; Glaeser, 2011). The bigger the city, the greater the capacity for different types of local interactions, and the greater the innovation and productivity increases (Combes, Duranton, Gobillon, Puga, & Roux, 2012). Hence, to be innovative, firms supposedly need to be in cities, that is they need to "be there" where new knowledge is generated and diffused through intensive local exchanges (Gertler, 2003). Cities, in general, and city size, in particular, thus matter for innovativeness, productivity and economic growth (De la Roca & Puga, 2017; Glaeser & Kerr, 2009; Puga, 2010; Soo, 2018). From this perspective, location in cities—and the bigger city, the better—becomes a must for innovation, productivity, and competitiveness. By contrast, location in more isolated rural areas is deemed to represent a huge handicap for innovation (Soto & Paredes, 2016). Cities are regarded as sites of creativity, innovation, and economic growth; smaller cities and rural areas are not.

Why are cities associated with higher levels of innovation? Several mechanisms can account for this (Accetturo, Di Giacinto, Micucci, & Pagnini, 2018). First, the density linked to cities create positive externalities, which rise with city size. Cities put innovative actors in close geographical proximity and facilitate the development of dense input–output links as well as access to top-level skills and physical infrastructure (e.g., Duranton & Puga, 2001; Ellison, Glaeser, & Kerr, 2010). Knowledge sharing is more efficient among colocated actors as the transmission of tacit knowledge relies on regular face-to-face communication (Storper & Venables, 2004; McCann, 2007). Second, sorting effects mean that innovative workers and firms are drawn to cities, where they are more likely to maximise the use of their skills (Ahlin, Andersson, & Thulin, 2018; Baldwin & Okubo, 2006; Storper, Kemeny, Makarem, & Osman, 2015). Interregional mobility of labor is associated with increases in firm-level innovation and productivity (e.g., Eriksson & Rodriguez-Pose, 2017; Timmermans & Boschma, 2014). Third, cities can facilitate the emergence of complex systems of interpersonal and interfirm interaction that foster innovation systems (e.g., Cooke & Morgan, 1994; Cooke, Gómez Uranga & Etxebarria, 1998; Iammarino, 2005). Finally, tacit knowledge travels with difficulty, meaning that new knowledge is geographically constrained and its expansion beyond cities complicated. There is a strong distance-decay effect in the diffusion of knowledge and innovation, with limited knowledge spillovers at play beyond 80 km from the center cities in the United States and beyond 200 km for the European Union (Crescenzi, Rodriguez-Pose, & Storper, 2007). Cities are thus at the heart of the sharing, matching and learning processes that drive innovation (Duranton & Puga, 2004).

The analysis presented in this paper focuses exclusively on the third and fourth mechanisms that supposedly facilitate firm-level innovation in cities: extra-firm collaborations and the opportunities cities offer for firms to engage in innovation collaboration and form networks. How the geography of the location of firms and of the collaborative networks they generate affects firm-level innovation, in general, and different types of innovation—product,
new-to-market, process, organisational, and marketing innovation—in particular, is discussed on the basis of existing literature for Norway and elsewhere. Three research questions will be tackled: (a) whether local collaboration is associated with more innovation than collaboration at a distance, (b) whether collaboration at different geographical distances affects different types of innovation differently, and (c) whether the association between local collaboration and innovation is larger in urban than in rural regions and in bigger cities than in smaller ones.

The importance of local interaction in cities for innovation and economic growth is at the center of various approaches to regional development. From new economic geography and urban economics to the industrial districts, regional innovation systems, clusters, and innovative milieus literature, it is emphasised that interaction happens most easily in dense and highly institutionalised environments, where trusting relationships resulting from geographic proximity sustain collaboration. In such environments, geographical proximity is considered to produce proximity also in other dimensions, such as social or cognitive proximity (Boschma, 2005).

However, the assumption that innovation is fundamentally an urban phenomenon “sits uncomfortably with empirical work showing that innovation occurs in peripheral regions [...], that openness—at least when measured by the variety and type of external contacts—is not necessarily higher in cities [...], and that firm-level innovativeness is only weakly associated with location across the metropolitan to peripheral small town spectrum” (Shearmur, 2015, p. 424). A growing body of research has tended to stress, first, that interfirm cooperation differs between regions, independent of regional firm characteristics (Fritsch, 2003); second, that geographic proximity between cooperation partners may be less important for innovation than hitherto assumed (Fitjar & Rodríguez-Pose, 2011); and, third, that innovation can happen—and often happens—outside large cities (Eder, 2019; Frick & Rodríguez-Pose, 2018; Shearmur, 2017).

First, even in densely agglomerated areas, innovative actors may depend more on connections to actors in distant places than on local contacts (Huber, 2012). Firms in larger, urban regions have greater access to extra-regional knowledge. Research on the world-city network emphasizes the growing linkages between the world’s largest cities (Beaverstock, Smith, & Taylor, 2000; Taylor, 2001). Indeed, firms located in the Norwegian capital region have more international partners than those located in smaller towns and regions, leading Herstad and Ebersberger (2015) to conclude that place-specific resources also support the development of international linkages (see also Fitjar & Rodríguez-Pose, 2014). Excessive physical proximity may even be harmful. The “proximity paradox” (Boschma & Frenken, 2010) or “Goldilocks principle” (Fitjar, Huber, & Rodríguez-Pose, 2016) notes that while some proximity is necessary for successful knowledge sharing, excessive proximity reduces the scope for learning. Indeed, various contributions have indicated that if the preoccupation with local collaboration becomes too dominant, this may lead to myopic knowledge search and lock-in to established ways of thinking (Amin & Cohendet, 2004; Giuliani & Bell, 2005). As Soløs and Gulbrandsen (2014, p. 24) underline, “many forms of collaboration seem to have little impact on innovation.”

Second, innovative actors outside big cities do not stand still. Lower density makes long-distance interaction a must for firms outside big cities. This implies that knowledge sharing at arm’s length is frequently more common than what the geography of innovation literature has acknowledged (e.g., Andersson, Quigley, & Wilhelmsson, 2005; Doloreux & Dionne, 2008; Fitjar & Huber, 2015; Fitjar & Rodríguez-Pose, 2011; Grillitsch & Nilsson, 2015; Rodríguez-Pose & Fitjar, 2013013; Tödtling et al., 2012). While knowledge gain at close quarters is relatively easy in large urban areas, it becomes much more difficult in more remote or less densely populated regions, where the limited number of actors represents an important handicap for innovation. To cope with this, firms in peripheral regions must compensate by investing more in developing external and, in particular, extra-regional, long-distance linkages and collaborations (Grillitsch & Nilsson, 2015; Jakobsen & Lorentzen, 2015). Through links to urban actors, peripheral firms can access urban knowledge, while retaining potential other benefits of their peripheral location (Mayer et al., 2016). Furthermore, sorting effects may imply that highly productive firms stay in peripheral regions as transportation costs are relatively less important to them (Forslid & Okubo, 2015).

A peripheral location has seemingly not held back Norwegian firms (e.g., Fitjar & Rodríguez-Pose, 2011, 2015; Soløs and Gulbrandsen, 2014), which are much more innovative than the size of the country’s cities would suggest. The roots of Norwegian innovation lie fundamentally in the capacity of its firms to overcome geographical peripherality and establish long-distance partnerships with innovative firms, research centers, consultancies, and
universities, often located beyond the national borders. Firms establishing international connections tend to be more innovative than those relying on domestic linkages (Fitjar & Rodríguez-Pose, 2011, p. 1264). Similar mechanisms to compensate for peripherality have been found in Sweden (Grillitsch & Nilsson, 2015). Swedish firms in more remote environments are more likely than firms in large cities to establish networks—both national and international—outside their local geographical area. Similar results have been reported for Canada (Doloreux, 2003; Doloreux & Dionne, 2008), Belgium (Teirlinck & Spithoven, 2008), and Austria (Tödtling et al., 2012).

Furthermore, the partnerships behind firm-level innovation are mostly purpose-built rather than the result of chance encounters. Purpose-built partnerships are more often associated with long-distance collaborations (Fitjar & Rodríguez-Pose, 2017). “Global pipelines” are relationships in which firms invest considerable time and effort to interact with a partner from which it can gain valuable and non-superfluous knowledge (Bathelt, Malmberg, & Maskell, 2004). This is a more costly strategy, but one that may carry greater rewards. However, due to the costs of long-distance knowledge search, global pipelines may be more viable for larger than for smaller firms (Ebersberger & Herstad, 2013; Grillitsch & Nilsson, 2015).

The jury is, in any case, still out on the mechanisms through which cities sustain learning processes conducive to innovation (Shearmur, 2012). While some highlight the importance of local collaboration, others suggest that long-distance collaboration may be more beneficial. Some research also stresses that different types of innovation may require different geographical settings and different types of collaboration (Doloreux & Shearmur, 2012; Eder, 2019; Lee & Rodríguez-Pose, 2013; Shearmur, 2015; Teirlinck & Spithoven, 2008). As indicated by Fitjar and Rodríguez-Pose (2011) and Shearmur (2015), more radical innovation can happen anywhere, with firms relying either on their own internal capacities or on targeted, often long-distance, connections. Such linkages can be the source of innovations that set firms apart in their markets by providing new knowledge and ideas from outside the local market. By contrast, the adoption and commercialisation of innovation benefits more from local labor, finance and marketing expertise and, therefore, from local interaction, information exchange, and feedback (Shearmur, 2015, p. 428). In particular, changes within the firm, for example, in process or organisational forms, may be more contingent on cultural context and therefore require a local approach. In these cases, being located in cities and clusters can facilitate firm-level learning (Lee & Rodríguez-Pose, 2013, p. 1756).

Overall, this suggests that there is a need for more empirical research on the relationship between firms’ location in urban or rural regions, the spatial scales of their collaboration patterns, and different types of innovation outcomes. This paper makes several contributions to this debate. First, previous studies have not analyzed the interaction between local collaboration and urban location, and hence the view that local collaboration is more beneficial in urban contexts remains essentially an assumption. Second, using panel data from Norway allows for greater control of unobserved firm heterogeneity than the mostly cross-sectional research that approached this question in the past. The richness of the data set also permits us to dodge the problems of nonresponse bias. Finally, the analysis examines several different innovation outcomes, enabling a more nuanced understanding of how collaboration and location may have different implications for different types of innovation.

3 | METHODS AND DATA

We use three waves of the Community Innovation Survey (CIS) for Norway to create an unbalanced panel of firms⁴ and match the firm-level data with Statistics Norway linked employer–employee data from official employment registers used for tax purposes and from official education registers. This enables us to obtain detailed information on the composition of each firm’s workforce.

⁴For detailed information on the three surveys, see Wilhelmsen and Foy (2009), Wilhelmsen (2011), and Wilhelmsen and Foy (2012).
The Norwegian CIS offers, relative to most other innovation surveys, several benefits which are helpful in tackling our research questions. First, it includes information on whether domestic partners are intraregional or extraregional, permitting an analysis of local collaboration. The harmonised CIS does not include this information, although some other countries do. Second, it asks all firms about their collaboration partners in joint R&D and other innovation activities, not just the innovative ones. This is essential for assessing the relationship between collaboration and innovation outcomes. Third, unlike most other countries, participation is mandatory for sampled firms. Nonrespondents are fined. This results in a response rate of 94–97% of sampled firms, almost ruling out the risk of nonresponse bias. Fourth, the sample is designed to be regionally representative at the level of economic regions.

The sample includes the full population of large firms and of R&D intensive firms, as well as a sample of small firms. The final sample contains between 5,980 and 6,532 firms in the three waves considered in this paper, 18,924 observations in total. These represent around a third of firms and two-thirds of all employees in the overall population of Norwegian firms with more than five employees.

The analysis comprises firms which participated in two concurrent waves. The very high response rate and the inclusion of the full population of the largest firms mean that many firms are present in consecutive waves. Of course, this is more often the case for firms with more than 50 employees or smaller firms with R&D activities, where the full population is included. However, around half of all firms in each survey also participate in the next wave. We can therefore exploit the longitudinal structure of the data to measure independent variables 2 years before dependent variables, allowing for better control of possible reverse causality. Consequently, independent variables and controls in 2006 are used to predict innovation levels in 2008, and independent variables and controls in 2008 to predict innovation in 2010. While this does not rule out the potential for endogeneity related to the effects of innovation on collaboration patterns or on firm location decisions, it does at least mean that the outcome is observed after the collaboration project or location decision. From Model 2, we also add a lagged dependent variable that further controls for past innovation. The final data set consists of 6,382 observations. This includes 1,893 firms that were present throughout the period and were measured twice for independent as well as for dependent variables and 2,596 firms that were only present in two consecutive surveys. Appendix Table A1 shows descriptive statistics on the sample.

3.1 Dependent variables

In line with the Oslo Manual, we define innovation as “the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation, or external relations” (OECD & Eurostat, 2005, p. 46). Building on this definition, the CIS includes measures of four dimensions of innovation—product, process, organisational, and marketing—all used as dependent variables in the analysis. In addition, the product innovation dimension contains an indicator of the novelty of innovation—whether product innovations were new to the market—also considered in the analysis. The total number of dependent variables is thus five. All innovation measures are dichotomous variables with a value of 1 if the firm has introduced an innovation in the preceding 3 years (i.e., during 2004–2006 for the 2006
survey) and 0 otherwise. Figure 1 shows the share of firms reporting innovation of each type in the three waves included in the analysis.

**Product innovation** is registered if the firm introduced new or significantly improved goods and/or services into the market. **New-to-market product innovation** is a subcategory of the above, including only innovations that were new to the firm’s market and excluding innovations that were new to the firm but which already existed in the market. **Process innovation** refers to the introduction of new or significantly improved methods for production of goods or services; for storage, delivery, or distribution of goods or services; or new support functions, such as systems for maintenance, procurement, accounting, or IT. **Organisational innovation** is the introduction of organisational changes, such as new business practices for organisation of work or procedures; new methods for organisation of work responsibilities or decision-making within the firm; or new methods for organising external relations to other firms or public institutions. **Marketing innovation** refers to any significant changes in design or packaging of goods or services; the use of new media or methods for promoting products; the use of new methods for product placement or new sales channels; or the use of new methods for pricing goods or services.

### 3.2 Independent and control variables

There are two main independent variables in the analysis. Our first independent variable of interest—**partners**—measures the breadth of the firm’s collaboration with different types of external partners in innovation processes. The CIS asks about collaboration linkages in the preceding 3 years with eight different types of external partners: within the enterprise/enterprise group, with suppliers, clients/customers, competitors, consultants/consultancy firms, commercial laboratories/R&D enterprises, universities/higher education institutions, and public or private research institutes. For each partner used, the firm is further asked to identify the location of the partner. The index is a simple count of the number of different types of partners used at each geographical scale, indicating the breadth of the firm’s network at each scale. Three geographical scales are taken into account: **regional partners** refers to the number of partner types used within the region; **national partners** depicts the number of partner types located elsewhere in Norway; while **foreign partners** is the number of partner types located outside Norway. Figure 2 shows the average number of partner types at each geographical scale in the three periods.

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4The questionnaire defines collaboration as active participation in joint R&D or other innovation activities with other organisations, excluding pure subcontracting.
The second variable of interest—location—indicates the firm’s location in one of four types of regions: Big city regions are regions with an urban center which has a population of 500,000 or above and a high level of services. There is only one such region in Norway: the capital Oslo. Medium city regions are regions with an urban center which has a population of between 150,000 and 500,000 and a high level of services. Three Norwegian regions belong in this category: Bergen, Stavanger, and Trondheim. Small city regions are regions with an urban center with a population of between 19,000 and 150,000 and a medium or high level of services. This category includes a total of 16 regions: Fredrikstad, Drammen, Tønsberg, Skien, Kristiansand, Ålesund, Bodø, Tromsø, Moss, Hamar, Lillehammer, Gjøvik, Sandefjord, Arenal, Haugesund, and Molde. Figure 3 shows a map of the urban regions of Norway. Finally, rural regions are regions without any urban center or with an urban center of less than 19,000 inhabitants or with a lower level of services. Firms located in rural regions are, according to the theories discussed, less likely to benefit from local agglomeration and density and therefore have less potential to innovate. This is therefore the baseline category for comparison with other locations. Table 1 shows the definition of each location category and the number of firms in each category in the three periods. The number of firms is relatively similar across geographical categories (Table 1).

Regions are defined at the level of economic regions, as classified by Statistics Norway. These are regions at the NUTS4 level and correspond in most cases to functional economic regions. The categorisation of different regions is based on Gundersen and Juvkam (2013), who developed a hierarchy of region sizes based on urban population and the level of services in each region. We also merge regions that are functionally integrated into the same labor market based on Gundersen and Juvkam (2013). This division of economic regions is becoming well-established in Norway and has already been used in previous studies of how the geographical location of firms affects innovation (e.g., Aarstad, Kvitastein, & Jakobsen, 2016; Fitjar & Timmermans, 2017; Herstad & Ebersberger, 2015).

The CIS itself uses firms’ official corporate addresses to identify the firm’s location. For multipoint firms, this can be misleading, especially in a study of urban versus rural location. Some firms have their corporate headquarters and official address in one place (often a large city), but most of the actual production and employment take place somewhere else (e.g., in more peripheral locations). To account for this, we draw on linked employer–employee data from tax registers to identify the location of each firm’s main activities as measured by the size of the workforce. We use the municipality listed as the workplace of the largest number of employees as the actual location of each firm.

FIGURE 2 Average types of partners used at each geographical scale by survey period [Color figure can be viewed at wileyonlinelibrary.com]
Four main control variables are included in the analysis. *R&D Expenditure* is the total amount spent on internal research and development activities by the firm in the year of the survey, and is drawn from the CIS. *Number of employees* is the number of full-time employees in the firm. This is a count of people employed in the firm in the year of the survey, based on linked employer–employee data from tax registers. *Share of educated employees* is the percentage of the firm’s workers who have completed a tertiary education degree. This variable is again based on linked employer–employee data, with information on each employee’s education level drawn from the Norwegian education database. This is an official register used by the universities and the student loan authorities. The database includes education at Norwegian universities only, which could underestimate education levels at some firms. As all these three variables are highly skewed, we log-transform them using the natural logarithm. For R&D expenditure and share of educated employees, a constant of 1 was added before log-transforming as several firms had values of 0 on these variables. Appendix Table A2 shows means, standard deviations, and pairwise correlations between the variables. Finally, *industry* is a set of dummy variables for the two-digit NACE industry of the firm,
4 | RESULTS

To examine the relationship between collaboration, location, and innovation, we fit a logit regression model to the data. The model takes the following form:

$$\text{logit} \left( \text{Innovation}_{i,t} \right) = \alpha + \beta_1 \text{Partners}_{i,t-1} + \beta_2 \text{Location}_{i,t-1} + \beta_3 \text{Controls}_{i,t-1} + \beta_4 (t - 1) + \epsilon_{it},$$  \hspace{1cm} (1)

The dependent variable, innovation, refers to the five dimensions of innovation outlined above. We run five models, one for each measure of innovation. The probability of innovation in firm $i$ at time $t$ is modelled as a function of the vectors partners (referring to the three geographical scales outlined above), location (the four categories of centrality outlined above), and controls (the four control variables presented above) at time $t - 1$. In this analysis, $t$ can be either 2008 or 2010, while $t - 1$ is correspondingly 2006 or 2008. In addition, we include the time of measurement of the independent variables as a fixed effect to account for any temporal trends. As some firms are observed twice (at $t = 2008$ and $t = 2010$), we use robust standard errors, clustered over firms.\textsuperscript{5} Table 2 shows the results of estimating this model (which we refer to as Model 1).

Looking first at the odds ratios for the control variables, these go along with expectations and point to the robustness of the analysis. R&D expenditure is strongly and significantly associated with all types of innovation. Firms that invest more in R&D, innovate more, regardless of the type of innovation considered. The share of educated workers is also strongly and significantly associated with innovation, with the exception of process and marketing innovation. Firm size mainly has a strong positive connection with organisational innovation, which will be more relevant in larger organisations. Employment size is significantly (at the 90% level) negatively associated with the likelihood of new-to-market product innovation. The sector in which a firm operates also matters, as expected, for its capacity to innovate.

The location of the firm in an urban environment is linked to a higher likelihood of product innovation (including new-to-market) only. At the 95% confidence level, the only significant odds ratio is for location in big city regions on

\textsuperscript{5}We have also estimated the models with standard errors clustered over counties, with no difference in the results.
product innovation in general. This is associated with a 28% increase in the odds of innovation compared to rural location. However, the difference with firms located in medium or small city regions is smaller and not statistically significant. Reducing the confidence level to 90%, location in medium-sized city regions is also associated with a higher likelihood of product innovation in general, and location in big or medium-sized city regions with a higher likelihood of new-to-market product innovation specifically. For the latter category, the difference between the big, medium-sized, and small city regions is even smaller, but firms in rural regions are less innovative. For other types of innovation, location in urban or rural regions makes no difference for the likelihood of innovation. For process and organisational innovation, firms in big city regions even tend to be less innovative than rural firms, although these differences are not statistically significant.

It is worth noting that this does not imply that there are no differences in innovation levels between urban and rural areas in Norway. If we fit Model (1) following a stepwise approach, location in cities is associated with a higher likelihood
of all innovation outcomes except process innovation, and with stronger odds ratios for location in larger cities. However, for organisational innovation, the differences disappear when controlling for R&D expenditure and firm size, and for marketing innovation, the differences disappear when also controlling for industry. Hence, the higher levels of innovation in urban areas is mostly a function of firms in these areas being larger, more R&D intensive, and with better access to well-educated employees (see also Herstad, 2018; Herstad, Sandven, & Solberg, 2013), as well as of the industry composition of urban areas. When controlling for these characteristics, urban firms perform significantly better only when it comes to product innovation.

The breadth of collaboration with regional partners is associated with a higher likelihood of two types of innovation—process innovation and organisational innovation. The odds of process innovation increase by 8% for every additional regional partner used, while the odds of organisational innovation increase by 14%. However, collaboration with regional partners has no significant effect for product innovation in general, new-to-market product innovation in particular, or marketing innovation. More market-oriented innovation is independent of local collaboration. For these types of innovation, long-distance collaboration instead appears as the main factor behind innovation. Foreign collaboration is associated with a higher likelihood of product innovation, including new-to-market, as well as of marketing innovation. The odds of product innovation in general increase by 13% for every additional foreign partner used, while the odds of new-to-market product innovation increase by 7% and those of marketing innovation by 9%

Process and organisational innovation, in contrast, are not associated with the breadth of foreign collaboration. Hence, two quite different collaboration patterns are connected with the different types of innovation, underlining the need for analyzing them separately: foreign collaboration is more closely related to market-oriented product (including new-to-market) and marketing innovations, while regional collaboration is associated with a higher likelihood of process and organisational innovations. A broader network scope seems required for more outward-, market-oriented, and radical innovations, while an understanding of the local context is more important for innovations within the organisation.

4.1 Robustness checks

While the above analysis has employed the panel structure of the data to measure independent variables before dependent variables, this does not rule out the possibility of reverse causality. If the same firms innovate consistently over time, the level of collaboration of Norwegian firms or the places they source their information from could still be affected by the firm’s level of innovation at an earlier time. To account for this, Model 2 includes a lagged dependent variable as a predictor, taking the following form:

$$\logit (\text{Innovation}_{it}) = \alpha + \beta_1 \text{Innovation}_{it-1} + \beta_2 \text{Partners}_{it-1} + \beta_3 \text{Location}_{it-1} + \beta_4 \text{Controls}_{it-1} + \beta_5 (t - 1) + \epsilon_t$$

(2)

In this model, innovation in one of the five dimensions considered is expected to closely follow innovation in the same dimension in the preceding period. All other independent variables are as in Model 1, including the use of robust standard errors clustered over firms. Variance inflation factors show no signs of severe multicollinearity in the model. Table 3 shows the results of fitting Model 2 to the data.

The results are mostly consistent with those from Model 1. However, and as expected with the introduction of the lagged innovation variable, some associations are weakened. The association between urban location and new-to-market product innovation disappears, while that with product innovation in general is now only significant at the 90% confidence level. For regional collaboration, the association with process innovation also vanishes, leaving organisational innovation as the only outcome significantly positively related to collaboration with regional partners. In addition, there is now a significant negative association at the 90% confidence level between regional collaboration and the likelihood of product innovation. For foreign collaboration, the association with product
innovation in general remains, while the coefficient for new-to-market product innovation and marketing innovation is now only significant at the 90% confidence level. The lagged dependent variable itself is strongly and significantly associated with all types of innovation, indicating that firms that innovate in one period often remain innovative over time. For product innovation in general, having innovated in the preceding period is associated with 281% higher odds of innovation, controlling for other characteristics. The signs of control variables mostly stay the same, although the odds ratios for R&D expenditure in particular are weakened by the introduction of the lagged dependent variable.

Table 4 provides a further robustness check by restricting Model 2 only to firms that are innovation-active. Innovation-active firms are defined as those reporting positive innovation expenditure, collaboration in innovation...

### TABLE 3 Logit regression results, Model 2

| Variables          | (1) Product innovation | (2) New-to-market innovation | (3) Process innovation | (4) Organisational innovation | (5) Marketing innovation |
|--------------------|------------------------|------------------------------|------------------------|-------------------------------|--------------------------|
| Innovation t - 1   | 3.81***                | 3.09***                     | 2.56***                | 2.02***                       | 3.19***                  |
|                    | (0.30)                 | (0.28)                      | (0.19)                 | (0.15)                        | (0.24)                   |
| Regional partners  | 0.95*                  | 0.96                        | 1.04                   | 1.14***                       | 1.01                     |
|                    | (0.03)                 | (0.03)                      | (0.03)                 | (0.04)                        | (0.03)                   |
| National partners  | 0.97                   | 1.00                        | 0.96                   | 1.04                          | 0.96                     |
|                    | (0.03)                 | (0.03)                      | (0.03)                 | (0.03)                        | (0.03)                   |
| Foreign partners   | 1.12**                 | 1.06*                       | 1.04                   | 1.00                          | 1.06*                    |
|                    | (0.04)                 | (0.03)                      | (0.03)                 | (0.03)                        | (0.03)                   |
| Small city         | 1.09                   | 1.13                        | 0.92                   | 1.01                          | 0.95                     |
|                    | (0.11)                 | (0.12)                      | (0.09)                 | (0.10)                        | (0.09)                   |
| Medium city        | 1.21*                  | 1.20                        | 1.00                   | 1.10                          | 1.04                     |
|                    | (0.13)                 | (0.14)                      | (0.11)                 | (0.12)                        | (0.11)                   |
| Big city           | 1.23*                  | 1.22                        | 0.88                   | 0.93                          | 1.00                     |
|                    | (0.14)                 | (0.15)                      | (0.10)                 | (0.11)                        | (0.11)                   |
| Log R&D expenditure| 1.21***                | 1.23***                     | 1.16***                | 1.09***                       | 1.11***                  |
|                    | (0.01)                 | (0.02)                      | (0.01)                 | (0.01)                        | (0.01)                   |
| Log no. of employees| 0.99                   | 0.97                        | 1.04                   | 1.22***                       | 1.04                     |
|                    | (0.03)                 | (0.03)                      | (0.03)                 | (0.04)                        | (0.03)                   |
| Log % of educated employees | 2.44**                  | 2.35**                     | 1.58                   | 1.61                          | 1.58                     |
|                    | (0.75)                 | (0.77)                      | (0.48)                 | (0.52)                        | (0.49)                   |
| Industry FE        | Included               | Included                    | Included               | Included                      | Included                 |
| Time FE            | Included               | Included                    | Included               | Included                      | Included                 |
| Constant           | 0.05***                | 0.03***                     | 0.11***                | 0.04***                       | 0.07***                  |
|                    | (0.02)                 | (0.01)                      | (0.03)                 | (0.02)                        | (0.02)                   |
| N                  | 6,363                  | 6,341                       | 6,378                  | 4,907                         | 5,667                    |
| Pseudo R²          | 0.30                   | 0.27                        | 0.15                   | 0.10                          | 0.15                     |

Note: Odds ratios; Robust standard errors (clustered over firms) in parentheses.

*p < .05

* * p < .10.

**p < .01.

***p < .001.
processes, or any kind of innovation outcome (cf., e.g., Herstad, Aslesen, & Ebersberger, 2014). In total, 3,861 of the original 6,382 observations were classified as innovation-active and included in this section of the analysis.

The restriction of the analysis to innovation-active firms does not change the results in any major way. For regional partners, the results are largely the same as in Table 3: a significant positive coefficient for organisational innovation and a negative coefficient for general product innovation, significant at 90%. For foreign partners, the results are stronger than in Table 3. The coefficients for new-to-market product innovation and marketing innovation are now significant at the 95% confidence level, and there is also a positive coefficient for process innovation, which is significant at 90%. The effects of location are stronger than in any of the preceding analyses, although still only in the area of product innovation, in general, as well as specifically for new-to-market product

**TABLE 4** Logit regression results for innovation-active firms, Model 2

| Variables                        | (1) Product innovation | (2) New-to-market innovation | (3) Process innovation | (4) Organisational innovation | (5) Marketing innovation |
|----------------------------------|------------------------|------------------------------|------------------------|--------------------------------|--------------------------|
| Innovation t - 1                 | 3.26***                | 2.80***                      | 2.25***                | 1.68***                        | 2.78***                  |
|                                  | (0.28)                 | (0.25)                       | (0.18)                 | (0.14)                         | (0.23)                   |
| Regional partners                | 0.95^*                 | 0.96                         | 1.04                   | 1.13***                        | 1.01                     |
|                                  | (0.03)                 | (0.03)                       | (0.03)                 | (0.04)                         | (0.03)                   |
| National partners                | 0.98                   | 1.01                         | 0.97                   | 1.04                           | 0.97                     |
|                                  | (0.03)                 | (0.03)                       | (0.03)                 | (0.03)                         | (0.03)                   |
| Foreign partners                 | 1.14***                | 1.08*                        | 1.05^*                 | 1.02                           | 1.08*                    |
|                                  | (0.04)                 | (0.03)                       | (0.03)                 | (0.03)                         | (0.03)                   |
| Small city                       | 1.11                   | 1.08                         | 0.89                   | 0.94                           | 1.02                     |
|                                  | (0.13)                 | (0.13)                       | (0.10)                 | (0.11)                         | (0.12)                   |
| Medium city                      | 1.34^*                 | 1.31^*                       | 1.06                   | 1.01                           | 1.16                     |
|                                  | (0.17)                 | (0.17)                       | (0.13)                 | (0.13)                         | (0.15)                   |
| Big city                         | 1.31^*                 | 1.24                         | 0.88                   | 0.83                           | 1.05                     |
|                                  | (0.17)                 | (0.17)                       | (0.11)                 | (0.11)                         | (0.14)                   |
| Log R&D expenditure              | 1.20***                | 1.19***                      | 1.14***                | 1.07***                        | 1.09***                  |
|                                  | (0.01)                 | (0.02)                       | (0.01)                 | (0.01)                         | (0.01)                   |
| Log no. of employees             | 0.91**                 | 0.91**                       | 0.99                   | 1.16***                        | 0.98                     |
|                                  | (0.03)                 | (0.03)                       | (0.03)                 | (0.05)                         | (0.04)                   |
| Log % of educated employees      | 1.19                   | 1.57                         | 1.03                   | 1.20                           | 0.93                     |
|                                  | (0.40)                 | (0.54)                       | (0.35)                 | (0.44)                         | (0.32)                   |
| Industry FE                      | Included               | Included                     | Included               | Included                        | Included                 |
| Time FE                          | Included               | Included                     | Included               | Included                        | Included                 |
| Constant                         | 0.08***                | 0.05***                      | 0.16***                | 0.08***                        | 0.10***                  |
|                                  | (0.03)                 | (0.02)                       | (0.05)                 | (0.03)                         | (0.04)                   |
| N                                | 3.842                  | 3.834                        | 3.839                  | 3.084                          | 3.506                    |
| Pseudo R^2                       | 0.23                   | 0.21                         | 0.10                   | 0.06                           | 0.12                     |

Note: Odds ratios. Robust standard errors (clustered over firms) in parentheses.  
^p < .10.  
* p < .05.  
** p < .01.  
*** p < .001.
innovation. The dummies for big city regions and medium city regions are now significantly associated with a higher likelihood of product innovation in general and—for medium city regions—also of specifically new-to-market product innovation. Indeed, location in a medium city region now emerges with the highest odds ratio for all innovation outcomes, even if the differences are in most cases not statistically significant. For the control variables, the share of educated employees is not significantly associated with a higher likelihood of any kind of innovation when only innovation-active firms are considered. This factor is mainly associated with the decision to engage in innovation activities, rather than the outcome of such activities.

Several additional robustness checks have been conducted. Due to space limitations, not all of these are reported. One set of analyses limited the sample to the 4,399 single-plant firms in the data, or, in another set of analyses, to the 5,453 firms where the largest plant employs at least 50% of the firm’s workforce. Even though this excludes many of the largest and most innovative firms, the results are broadly in line with the findings reported above, especially for the latter set of analyses. The results are also robust to the inclusion of firm age as an additional control variable. As firm age is not itself significantly associated with any of the innovation outcomes, it is not included in the analyses reported above.

A particular question concerns the role of R&D, as firms’ R&D expenditure is potentially endogenous: Firms that expect to succeed in their R&D activities are likely to invest more. Appendix Table A4 shows the results for Model 1 when leaving out R&D investments as a control variable. In this model, Partners at all spatial scales are significantly positively related to nearly all innovation outcomes. Firm size and, in particular, education also have stronger positive coefficients. However, the effects of location in a big city region disappear (or turn negative, in the case of process innovation), while location in a medium city region has a somewhat stronger positive effect on product innovation and new-to-market innovation.

We have also added additional regional control variables, such as total regional R&D expenditure per worker, mean regional firm size, or regional population. Including these tends to reduce the effect of the Location variables, while not affecting any of the other variables in the model. We have also estimated the model including regional population size and population size squared instead of the dummy variables for city size. Regional population size has a positive and significant effect only on product innovation (at $p < .05$) and new-to-market product innovation (at $p < .10$), consistent with the findings reported in Table 2. The results for Partners and for the control variables are also consistent. We have also tried dividing Oslo into a central and a suburban part, following Herstad (2018), without finding significant differences between central and less central locations within Oslo.

In an additional analysis, we have estimated the models including county fixed effects (see Appendix Table A5 for the results pertaining to Model 1, other results available on request). In this case, all significant coefficients for location in a big city or medium city region disappear, while the results for Partners and for the control variables are consistent with those reported in the paper. Hence, there could be other spatial county effects, besides city size, that can account for the significant coefficient observed for the location variable. However, as the county fixed effect may also pick up some of the effect of location in a larger urban area—in particular for the largest urban agglomeration in Norway, the Oslo and Viken region—the preferred option remains the model without county fixed effects. Finally, we have run the analyses using sampling weights, without any differences in the findings.

4.2 Local collaboration in cities and rural areas

The analyses so far have examined location and collaboration separately. However, we are also interested in the interaction between them, specifically in whether local collaboration is more beneficial in urban regions. To
TABLE 5 Logit regression results, Model 3

| Variables                      | (1) Product innovation | (2) New-to-market innovation | (3) Process innovation | (4) Organisational innovation | (5) Marketing innovation |
|--------------------------------|------------------------|------------------------------|------------------------|-------------------------------|--------------------------|
| Innovation t - 1               | 3.81***                | 3.10***                      | 2.56***                | 2.03***                       | 3.18***                  |
|                                | (0.30)                 | (0.28)                       | (0.19)                 | (0.15)                        | (0.24)                   |
| Regional partners              | 0.96                   | 1.05                         | 1.10                   | 1.10                          | 1.06                     |
|                                | (0.06)                 | (0.07)                       | (0.07)                 | (0.07)                        | (0.07)                   |
| National partners              | 0.98                   | 1.01                         | 0.97                   | 1.05                          | 0.97                     |
|                                | (0.03)                 | (0.03)                       | (0.03)                 | (0.03)                        | (0.03)                   |
| Foreign partners               | 1.12***                | 1.07*                        | 1.04                   | 0.99                          | 1.07*                    |
|                                | (0.04)                 | (0.03)                       | (0.03)                 | (0.03)                        | (0.03)                   |
| Small city                     | 1.13                   | 1.20*                        | 0.94                   | 1.01                          | 0.97                     |
|                                | (0.11)                 | (0.13)                       | (0.09)                 | (0.10)                        | (0.10)                   |
| Medium city                    | 1.17                   | 1.20                         | 1.03                   | 1.06                          | 1.01                     |
|                                | (0.13)                 | (0.15)                       | (0.11)                 | (0.12)                        | (0.11)                   |
| Big city                       | 1.22*                  | 1.27*                        | 0.89                   | 0.92                          | 1.02                     |
|                                | (0.14)                 | (0.16)                       | (0.10)                 | (0.11)                        | (0.11)                   |
| Reg.partners × Small city      | 0.85*                  | 0.82*                        | 0.91                   | 0.98                          | 0.90                     |
|                                | (0.07)                 | (0.07)                       | (0.07)                 | (0.08)                        | (0.07)                   |
| Reg.partners × Medium city     | 1.11                   | 1.00                         | 0.92                   | 1.14                          | 1.08                     |
|                                | (0.09)                 | (0.09)                       | (0.08)                 | (0.10)                        | (0.09)                   |
| Reg.partners × Big city        | 1.00                   | 0.88                         | 0.97                   | 1.05                          | 0.89                     |
|                                | (0.08)                 | (0.08)                       | (0.07)                 | (0.09)                        | (0.07)                   |
| Log R&D expenditure            | 1.21***                | 1.22***                      | 1.16***                | 1.09***                       | 1.11***                  |
|                                | (0.01)                 | (0.02)                       | (0.01)                 | (0.01)                        | (0.01)                   |
| Log no. of employees           | 0.99                   | 0.97                         | 1.04                   | 1.22***                       | 1.04                     |
|                                | (0.03)                 | (0.03)                       | (0.03)                 | (0.04)                        | (0.03)                   |
| Log % of educated employees    | 2.43**                 | 2.39**                       | 1.58                   | 1.61                          | 1.59                     |
|                                | (0.76)                 | (0.79)                       | (0.48)                 | (0.52)                        | (0.49)                   |
| Industry FE                    | Included               | Included                     | Included               | Included                      | Included                 |
| Time FE                        | Included               | Included                     | Included               | Included                      | Included                 |
| Constant                       | 0.04***                | 0.03***                      | 0.11***                | 0.04***                       | 0.06***                  |
|                                | (0.01)                 | (0.01)                       | (0.03)                 | (0.02)                        | (0.02)                   |
| N                              | 6,363                  | 6,341                        | 6,378                  | 4,907                         | 5,667                    |
| Pseudo R²                      | 0.30                   | 0.27                         | 0.15                   | 0.10                          | 0.15                     |

Note: Odds ratios; Robust standard errors (clustered over firms) in parentheses.

*p < .10.

* * p < .05.

** * p < .01.

*** * p < .001.
examine this, we extend the model to incorporate an interaction term between Regional partners and Location. Consequently, Model 3 is specified as follows:

$$\logit(\text{Innovation}_{it}) = \alpha + \beta_1 \text{Innovation}_{it-1} + \beta_2 \text{Partners}_{it-1} + \beta_3 \text{Location}_{it-1} + \beta_4 \text{Regional partners}_{it-1} \times \text{Location}_{it-1} + \beta_5 \text{Controls}_{it-1} + \beta_6 (t - 1) + \varepsilon_{it}$$ (3)

The results of this analysis are shown in Table 5. Again, we use robust standard errors, clustered over firms. Multicollinearity diagnostics show variance inflation factors around 5.5 for Regional partners in all models and well below 3 for all other variables, including the interaction terms, indicating that multicollinearity is not severe.

The interaction terms between regional partners and location are mostly insignificant and indicate that the impact of regional collaboration is unaffected by the location of the firm. There are only two statistically significant odds ratios in the interaction terms—negative interactions between regional partners and location in small city regions for product and new-to-market product innovation. For location in big city regions, where the most beneficial effects of regional collaboration were expected, the interaction terms mostly have nonsignificant negative odds ratios compared to the baseline of rural regions. Table 6 furthermore shows the average marginal effects of Regional partners for different locations (Williams, 2012). In big cities, collaboration with regional partners is positively associated with organisational innovation only. Regional collaboration also has a positive coefficient for organisational and marketing innovation in medium-sized city regions. In small city regions, regional collaboration has a negative effect on product innovation, both in general and specifically for new-to-market product innovation. Overall, there are significant differences in the coefficients for regional collaboration between small and medium-sized city regions, but this does not extend to big city regions.

### 4.3 | Intensity of innovation

The analyses conducted so far have examined the impact of collaboration and location on whether firms innovate or not. However, the influence of these factors may be seen not only in whether a firm innovates but also in the intensity of innovation. To probe this, Table 7 shows the results of a Tobit regression analysis using the share of the firm’s turnover from new products as the dependent variable. The right-hand sides of the models are identical to Models 1–3 above. We use two versions of the dependent variable. The first indicates the share of turnover from all products new to the firm (equivalent to product innovation in the analyses above), while the second indicates the share of turnover from products new to the market only (equivalent to new-to-market innovation in the analyses above).

The results are largely consistent with the findings in the logit regression analyses for product innovation and new-to-market product innovation. Firms that collaborate with foreign partners earn a significantly higher share of their income from new products (around 2.5 percentage points). For new-to-market product innovation, the coefficient is weaker and only significant at 90% in Models 1 and 3. It is not significant in Model 2, except when

### TABLE 6 Average marginal effects of Regional partners in different regions

| Region          | Product innovation | New-to-market innovation | Process innovation | Organisational innovation | Marketing innovation |
|-----------------|--------------------|--------------------------|--------------------|---------------------------|----------------------|
| Big city        | -0.005 (0.007)     | -0.009 (0.007)           | 0.009 (0.007)      | 0.024** (0.009)           | -0.009 (0.008)       |
| Medium city     | 0.010 (0.008)      | 0.006 (0.007)            | 0.003 (0.009)      | 0.039*** (0.010)          | 0.021* (0.009)       |
| Small city      | -0.026*** (0.007)  | -0.017* (0.007)          | -0.000 (0.008)     | 0.012 (0.010)             | -0.007 (0.008)       |
| Peripheral      | -0.005 (0.008)     | 0.005 (0.007)            | 0.014** (0.009)    | 0.017 (0.011)             | 0.009 (0.010)        |

*a p < .10.
*b p < .05.
**p < .01.
***p < .001.
| Variables                        | Share of income from product innovation | Share of income from new-to-market innovation |
|----------------------------------|----------------------------------------|---------------------------------------------|
|                                  | Model 1 | Model 2 | Model 2, innovation- active | Model 3 | Model 1 | Model 2 | Model 2, innovation- active | Model 3 |
| Innovation t−1                   | 0.49*** | 0.44*** | 0.49***                      | 0.51*** | 0.47*** | 0.50*** |                                           |
|                                  | (0.04)  | (0.04)  | (0.04)                       | (0.06)  | (0.06)  | (0.06)  |                                           |
| Regional partners                | 1.07    | 0.46    | 0.34                         | 0.78    | 0.70    | 0.13    | 0.01                          | 1.83 |
|                                  | (0.70)  | (0.65)  | (0.63)                       | (1.31)  | (0.70)  | (0.68)  | (0.65)                       | (1.33) |
| National partners                | −0.48   | −0.76   | −0.58                        | −0.65   | 0.17    | 0.06    | 0.19                          | 0.17 |
|                                  | (0.65)  | (0.62)  | (0.59)                       | (0.62)  | (0.65)  | (0.63)  | (0.60)                       | (0.62) |
| Foreign partners                 | 2.58*** | 2.41*** | 2.83***                      | 2.45*** | 1.14*   | 1.00    | 1.34*                         | 1.08* |
|                                  | (0.64)  | (0.60)  | (0.58)                       | (0.60)  | (0.64)  | (0.64)  | (0.62)                       | (0.63) |
| Small city                       | 1.66    | 0.76    | 1.52                         | 1.52    | 2.85    | 5.30    | 2.63                          | 4.06* |
|                                  | (2.44)  | (2.26)  | (2.48)                       | (2.28)  | (2.45)  | (2.32)  | (2.54)                       | (2.39) |
| Medium city                      | 4.41    | 3.86    | 6.74*                        | 2.91    | 4.94*   | 4.64*   | 7.52**                       | 4.26 |
|                                  | (2.68)  | (2.49)  | (2.72)                       | (2.59)  | (2.69)  | (2.53)  | (2.77)                       | (2.63) |
| Big city                         | 5.01*   | 4.41*   | 6.15*                        | 4.65*   | 5.29*   | 5.45*   | 7.05*                        | 6.35* |
|                                  | (2.78)  | (2.57)  | (2.78)                       | (2.61)  | (2.85)  | (2.69)  | (2.93)                       | (2.74) |
| Reg.partners × Small city        | −2.00   |         |                              | −3.53*  |         |         |                              | (1.70) |
|                                  |         |         |                              | (1.79)  |         |         |                              |       |
| Reg.partners × Medium city       | 2.47    |         |                              | 0.62    |         |         |                              | (1.95) |
|                                  |         |         |                              | (1.85)  |         |         |                              |       |
| Reg.partners × Big city          | −1.22   |         |                              | −3.05*  |         |         |                              | (1.66) |
|                                  |         |         |                              | (1.59)  |         |         |                              |       |
| Log R&D expenditure              | 6.29*** | 5.09*** | 4.22***                      | 5.08*** | 5.61*** | 5.00*** | 4.16***                      | 4.98*** |
|                                  | (0.29)  | (0.29)  | (0.29)                       | (0.29)  | (0.32)  | (0.31)  | (0.32)                       | (0.31) |
| Log no. of employees             | −4.11***| −2.48***| −4.78***                     | −2.45***| −3.39***| −2.44***| −3.87***                     | −2.44***|
|                                  | (Continues) |
| Variables | Share of income from product innovation | Share of income from new-to-market innovation |
|-----------|----------------------------------------|---------------------------------------------|
|           | Model 1  | Model 2  | Model 2, innovation- active | Model 3 | Model 1 | Model 2 | Model 2, innovation- active | Model 3 | |
| Log % of educated employees | (0.74) | (0.69) | (0.78) | (0.69) | (0.76) | (0.71) | (0.79) | (0.71) | |
|          | 20.14** | 17.48*  | -1.22  | 17.67*  | 19.24* | 18.11* | 6.68   | 18.35* | |
|          | (7.60)  | (7.21)  | (7.56) | (7.21)  | (7.89) | (7.50) | (7.77) | (7.50) | |
| Industry FE | Included | Included | Included | Included | Included | Included | Included | Included | Included |
| Time FE | Included | Included | Included | Included | Included | Included | Included | Included | Included |
| Constant | -64.47*** | -68.23*** | -49.30*** | -69.52*** | -71.30*** | -73.06*** | -60.60*** | -75.02*** | |
|          | (9.26)  | (8.20)  | (8.90) | (8.38) | (9.92) | (8.60) | (9.43) | (8.75) | |
| N | 6,382   | 6,382   | 3,861  | 6,382  | 6,382 | 6,382 | 3,861  | 6,382  | |
| Pseudo-R² | 0.08    | 0.09    | 0.06   | 0.09   | 0.09  | 0.10  | 0.07   | 0.10   | |

Note: Coefficients; Robust standard errors (clustered over firms) in parentheses. Left-censored at 0 and right-censored at 100.

*** p < .001.
** p < .01.
* p < .05.
+ p < .10.
restricting the analysis to innovation-active firms. Regional and national collaboration are still not associated with product innovation. Firms located in big cities also earn a higher share of their income from new products, including products new to the market. However, there is no significant positive interaction between regional collaboration and location in a big city. On the contrary, the interaction term is negative and significant at 90% for new-to-market product innovation.

5 | CONCLUSION

Agglomeration and density have been generally vaunted in the literature as the factors that make cities—and large cities in particular—much more innovative and productive (Duranton & Puga, 2001; Glaeser, 2011). Cities are considered the powerhouses of innovation. Firms that locate in big cities should benefit from various positive externalities, ranging from greater access to pools of talent to the diffusion of tacit knowledge, through countless formal and informal interactions afforded by large cities. Geographical proximity in dense and agglomerated environments supports the formation of networks that promote the picture of cities as the hubs of innovation in a more integrated world.

Yet, despite all the hype about the innovativeness of large agglomerations, many recent studies are paying attention to the capacity of some firms in smaller cities and rural areas to remain innovative (Andersson et al., 2005; Doloreux & Dionne, 2008; Eder, 2019; Fitjar & Rodríguez-Pose, 2011; Shearmur, 2015), notwithstanding being located in places that, according to the dominant views, are far from auspicious for innovation. Innovative firms in smaller cities and far-flung places overcome the disadvantages inherent to their location by superseding geographical distance and networking with other innovative actors beyond their immediate vicinity (Grillitsch & Nilsson, 2015).

This paper has delved into this debate by examining, using a large sample of Norwegian firms for the period between 2006 and 2010, whether local collaboration and urban location are indeed associated with greater levels of innovation, once other factors are controlled for, and, if this is the case, whether local collaboration is more likely to yield innovation in larger cities.

The results suggest that geographical distance matters, but only for certain types of innovation in Norway. Organisational innovation is robustly associated with the number of different types of partners a firm engages with in its immediate geographical milieu. Yet geographical proximity does not make a difference for the generation of more market-oriented types of innovation, such as product and new-to-market product innovation, or marketing innovation. Firms that engage with other economic actors in their immediate vicinity are not better off in terms of innovative capacity. For these types of innovation, long-distance collaboration instead seems to be the main driver of change. Norwegian firms capable of introducing product and marketing innovations in a more integrated economic environment are those that have reached out to the rest of the world to target the specific knowledge needed to make them more innovative.

Moreover, although firms in urban locations tend to be more innovative in product and new-to-market product innovation, this is not due to any greater rewards from reaching out to local partners in urban environments. The benefits of local collaboration in Norway are not related to whether the firm is located in Oslo, in a medium or small city-region, or in a rural area.

These results—robust to different specifications of the model—provide considerable food for thought about how geography, agglomeration, and density shape innovation. In Norway, there is virtually no evidence that its larger cities are drivers of innovation. Innovation is certainly linked to networking and reaching out to partners, but for many types of innovation, these partners do not share the same regional innovation system. They are located at considerable geographical distance and mostly outside Norway. Hence, although it may be the case that agglomeration and density may facilitate interaction, this does not seem to be the type of interaction driving innovation.
This is, of course, a study that concerns only Norway, raising questions about external validity. Norway is in many ways an exceptional case: rich, innovative, remote, and with cities that, even in the case of Oslo, may be too small to benefit from the full range of externalities associated with agglomeration and densities. This makes it hard to assess the extent to which the results can be generalised to other contexts. Moreover, the Norwegian CIS survey concentrates on measuring formal collaborations. It does not register more informal linkages and knowledge sharing and flows that may play a nonnegligible role in firm-level innovation. It also does not consider the role of labor mobility or other mechanisms of knowledge exchange in urban areas. However, if the literature on cities wants to establish the general point that innovation mostly takes place in urban areas, the innovation levels of Norwegian firms pose a puzzle in which this literature should be interested.

Furthermore, although we use panel data, endogeneity issues may remain. The choice of collaboration partners can be endogenous to the innovation process, as more innovative firms may be more willing to invest in external relationships and also have a larger choice of partners willing to work with them. Location could also be endogenous, due to firm sorting across regions. The same goes for several of the control variables, and leaving out, for example, R&D investments or other controls has an impact on the results. Finally, the innovation outputs of firms are to some extent simultaneously determined, as product innovation may, for example, create a need for new processes or new marketing methods. Future research may want to consider these issues in greater depth.

The innovation patterns of firms in Norway challenge a series of well-established views about which are the main sources of firm-level innovation, about how innovation is generated, and about the capacity of cities to create highly favourable environments for the development and absorption of new innovations. The results thus send a request for more research into how connectivity at firm level is generated and which type of connectivity is more conducive to innovation. Cities have been too readily accepted as the right location for innovation. However, our results and an increasing number of others imply that this tenet may require a second look, as innovation does not always seem to be related to where firms locate, but more so to what firms do. Although cities may be more innovative because they contain more firms and more innovative firms, in the case of Norway there seems to be no evidence that the average firm in a large city innovates in a radically different way from those in smaller cities and rural areas.

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## APPENDIX A

| TABLE A1  | Descriptive statistics on the sample |
|-----------|--------------------------------------|
|           | 2006–2008 | 2008–2010 |
|           | N   | %    | N   | %    |
| No. of employees |      |      |      |      |
| <19       | 912  | 28.4 | 655  | 20.7 |
| 20–49     | 707  | 22.0 | 788  | 24.9 |
| 50–99     | 706  | 22.0 | 710  | 22.4 |
| 100–499   | 732  | 22.8 | 842  | 26.6 |
| >500      | 159  | 4.9  | 171  | 5.4  |
| R&D expenditure |      |      |      |      |
| None      | 2,092| 65.1 | 2,016| 63.7 |
| Less than NOK 1 million | 244 | 7.6 | 217 | 6.9 |
| NOK 1–10 million | 678 | 21.1 | 701 | 22.1 |
| More than NOK 10 million | 202 | 6.3 | 232 | 7.33 |
| % of educated employees |      |      |      |      |
| <5        | 564  | 17.5 | 438  | 13.8 |
| 5–10      | 584  | 18.2 | 527  | 16.7 |
| 10–25     | 862  | 26.8 | 898  | 28.4 |
| 25–50     | 505  | 15.7 | 572  | 18.1 |
| >50       | 701  | 21.8 | 731  | 23.1 |
| Industry |      |      |      |      |
| Seafood   | 42   | 1.3  | 41   | 1.3  |
| Mining and quarrying | 98 | 3.0 | 127 | 4.0 |
| High-tech/medium high-tech manufacturing | 381 | 11.8 | 398 | 12.6 |
| Low-tech/medium low-tech manufacturing | 1,054 | 32.8 | 823 | 26.0 |
| El., gas and water supply | 110 | 3.4 | 157 | 5.0 |
| Construction | 206 | 6.4 | 251 | 7.9 |
| Trade     | 233  | 7.2  | 268  | 8.5  |
| Transport and storage | 220 | 6.8 | 218 | 6.9 |
| Information and communications | 438 | 13.6 | 422 | 13.3 |
| Financial services | 163 | 5.1 | 169 | 5.3 |
| Other services | 271 | 8.4 | 292 | 9.2 |
| Total N   | 3,216|      | 3,166|      |
### TABLE A2  Correlation matrix

|                  | Mean | SD  | Reg. partners | National partners | Foreign partners | Big city | Medium city | Small city | Log R&D exp | Log no. empl |
|------------------|------|-----|---------------|--------------------|------------------|----------|-------------|------------|-------------|---------------|
| Regional partners| .25  | .90 |               |                    |                  |          |             |            |             |               |
| National partners| .25  | .95 |               | .41                |                  |          |             |            |             |               |
| Foreign partners | .21  | .87 | .38           | .48                |                  |          |             |            |             |               |
| Big city         | .28  | .45 | −0.00         | −0.02              | .02              |          |             |            |             |               |
| Medium city      | .19  | .39 | .01           | .03                | −0.01            | −0.30    |             |            |             |               |
| Small city       | .29  | .45 | .01           | .03                | −0.39            | −0.31    |             |            |             |               |
| Log R&D exp.     | 1.87 | 3.44| .36           | .41                | .03              | .03      | .03         | .00        |             |               |
| Log no. empl.    | 3.38 | 1.28| .13           | .18                | .19              | .08      | .02         | −0.02      | .24         |               |
| Log % educated empl. | .21 | .20 | .13 | .11 | .14 | .35 | .02 | −0.14 | .32 | .00 |

### TABLE A3  Sampled firms in region by industry

| Industry                      | Big city | Medium city | Small city | Peripheral |
|-------------------------------|----------|-------------|------------|------------|
| Seafood                       | 0.0      | 1.3         | 0.6        | 3.9        |
| Mining and quarrying          | 1.8      | 7.4         | 1.4        | 5.0        |
| High-tech/medium high-tech manufacturing | 8.6   | 11.0        | 17.6       | 10.9       |
| Low-tech/medium low-tech manufacturing | 11.2 | 28.6        | 37.7       | 42.3       |
| El., gas, and water supply    | 1.9      | 3.9         | 4.9        | 6.4        |
| Construction                  | 6.5      | 7.1         | 7.7        | 7.4        |
| Trade                         | 15.3     | 6.2         | 6.1        | 2.2        |
| Transport and storage         | 7.2      | 7.2         | 6.3        | 6.8        |
| Information and communications| 25.7     | 11.8        | 8.0        | 6.7        |
| Financial services            | 8.5      | 4.2         | 3.3        | 4.3        |
| Other services                | 13.2     | 11.4        | 6.5        | 4.1        |
| **N**                         | **1,814**| **1,261**   | **1,827**  | **1,480**  |
| Variables               | (1) Product innovation | (2) New-to-market innovation | (3) Process innovation | (4) Organisational innovation | (5) Marketing innovation |
|-------------------------|------------------------|------------------------------|------------------------|-------------------------------|-------------------------|
| Regional partners       | 1.13***                | 1.12***                      | 1.17***                | 1.20***                       | 1.11***                 |
|                         | (0.04)                 | (0.04)                       | (0.04)                 | (0.04)                        | (0.03)                  |
| National partners       | 1.15***                | 1.14***                      | 1.08**                 | 1.08**                        | 1.04                    |
|                         | (0.04)                 | (0.03)                       | (0.03)                 | (0.03)                        | (0.03)                  |
| Foreign partners        | 1.31***                | 1.22***                      | 1.15***                | 1.10**                        | 1.17***                 |
|                         | (0.05)                 | (0.04)                       | (0.03)                 | (0.03)                        | (0.04)                  |
| Small city              | 1.12                   | 1.18                         | 0.91                   | 1.02                          | 1.02                    |
|                         | (0.11)                 | (0.13)                       | (0.09)                 | (0.10)                        | (0.10)                  |
| Medium city             | 1.28*                  | 1.31*                        | 1.05                   | 1.09                          | 1.12                    |
|                         | (0.14)                 | (0.16)                       | (0.11)                 | (0.12)                        | (0.12)                  |
| Big city                | 1.11                   | 1.09                         | 0.81*                  | 0.89                          | 0.98                    |
|                         | (0.13)                 | (0.14)                       | (0.09)                 | (0.10)                        | (0.11)                  |
| Log no. of employees    | 1.10***                | 1.09**                       | 1.15***                | 1.25***                       | 1.07*                   |
|                         | (0.03)                 | (0.04)                       | (0.03)                 | (0.04)                        | (0.03)                  |
| Log % of educated       | 16.31***               | 15.66***                     | 5.38***                | 4.55***                       | 4.46***                 |
| employees               | (4.80)                 | (4.91)                       | (1.58)                 | (1.29)                        | (1.27)                  |
| Industry FE             | Included               | Included                     | Included               | Included                      | Included                |
| Time FE                 | Included               | Included                     | Included               | Included                      | Included                |
| Constant                | 0.06***                | 0.04***                      | 0.15***                | 0.09***                       | 0.08***                 |
|                         | (0.02)                 | (0.01)                       | (0.04)                 | (0.03)                        | (0.03)                  |
| Observations            | 6.363                  | 6.341                        | 6.378                  | 5.650                         | 6.061                   |
| Pseudo R²               | 0.171                  | 0.157                        | 0.0761                 | 0.0622                        | 0.0860                  |

Note: Odds ratios. Robust standard errors (clustered over firms) in parentheses.

* p < .10.
* p < .05.
** p < .01.
*** p < .001.
### TABLE A5  Logit regression results, Model 1 with county fixed effects

| Variables                | (1) Product innovation | (2) New-to-market innovation | (3) Process innovation | (4) Organisational innovation | (5) Marketing innovation |
|--------------------------|-------------------------|-----------------------------|------------------------|-------------------------------|--------------------------|
| Regional partners        | 0.99                    | 1.00                        | 1.07*                  | 1.14***                       | 1.04                     |
|                          | (0.03)                  | (0.03)                      | (0.03)                 | (0.03)                        | (0.03)                   |
| National partners        | 1.01                    | 1.03                        | 0.99                   | 1.03                          | 0.98                     |
|                          | (0.03)                  | (0.03)                      | (0.03)                 | (0.03)                        | (0.03)                   |
| Foreign partners         | 1.14***                 | 1.08*                       | 1.05*                  | 1.04                          | 1.09*                    |
|                          | (0.04)                  | (0.04)                      | (0.03)                 | (0.03)                        | (0.04)                   |
| Small city               | 1.14                    | 1.14                        | 1.00                   | 0.98                          | 0.97                     |
|                          | (0.14)                  | (0.15)                      | (0.12)                 | (0.11)                        | (0.11)                   |
| Medium city              | 1.17                    | 1.28                        | 0.98                   | 1.22                          | 1.19                     |
|                          | (0.21)                  | (0.24)                      | (0.16)                 | (0.21)                        | (0.21)                   |
| Big city                 | 1.05                    | 1.02                        | 0.82                   | 0.76*                         | 0.87                     |
|                          | (0.18)                  | (0.18)                      | (0.13)                 | (0.11)                        | (0.13)                   |
| Log R&D expenditure      | 1.29***                 | 1.28***                     | 1.20***                | 1.10***                       | 1.14***                  |
|                          | (0.01)                  | (0.02)                      | (0.01)                 | (0.01)                        | (0.01)                   |
| Log no. of employees     | 0.97                    | 0.94*                       | 1.05                   | 1.21***                       | 1.01                     |
|                          | (0.03)                  | (0.03)                      | (0.03)                 | (0.04)                        | (0.03)                   |
| Log % of educated        | 2.51**                  | 2.25*                       | 1.34                   | 1.98*                         | 1.59                     |
| employees                |                         |                             |                        |                               |                          |
|                          | (0.80)                  | (0.76)                      | (0.42)                 | (0.59)                        | (0.48)                   |
| Industry FE              | Included                | Included                    | Included               | Included                       | Included                 |
| County FE                | Included                | Included                    | Included               | Included                       | Included                 |
| Year FE                  | Included                | Included                    | Included               | Included                       | Included                 |
| Constant                 | 0.06***                 | 0.04***                     | 0.14***                | 0.09***                       | 0.09***                  |
|                          | (0.02)                  | (0.02)                      | (0.05)                 | (0.03)                        | (0.03)                   |
| Observations             | 6,351                   | 6,329                       | 6,366                  | 5,640                         | 6,050                    |
| Pseudo R²                | 0.264                   | 0.245                       | 0.129                  | 0.0793                        | 0.116                    |

Note: Odds ratios. Robust standard errors (clustered over firms) in parentheses.

* *p < .10.
* *p < .05.
** *p < .01.
*** *p < .001.