1. What are the local factors driving regional innovation?

Overall, our review of the available studies shows that various sources provide dashboards (e.g., ERC Regional Growth Dashboard) or performance comparisons (BEIS 2015 analysis of UK Innovation Survey or the Longitudinal Small Business Survey) or local strengths (e.g., Science and Innovation Audits) but to our knowledge no study has systematically researched the causal link between local innovation activity (e.g., the R&D investment) and various local drivers that have contributed to it. Below we review some of the representative studies:

Nesta "Firm growth and innovation in UK city-regions" (2013)

The paper examines the impact of city-region characteristics on firm-level innovation and growth.

Authors use of a two-stage model of firm-level innovation and growth which enables them to differentiate very clearly between potential regional effects on innovative performance and regional effects on firm growth. The paper draws on matched data from the Business Structure Database (BSD) and the Community Innovation Survey (CIS).

The paper finds that city-regions are not the most appropriate geographical unit of measurement for testing the effects of industrial structure and urban scale on firm performance.
The results also show that firm growth depends heavily on prior success in innovation which in turn is strongly influenced by the extent and nature of firms' own efforts in developing innovation-related skills and capabilities. The strongest evidence of city-regional effects on innovation success at firm level is found in production sectors. In knowledge-intensive services, it seems likely that city-regions may not capture the geographic scale on which knowledge exchange relevant to innovation takes place.

Limitations

Tests of spatial autocorrelation pointed to significant interdependence between city-regions on the measures of industrial diversity, urban scale and own-industry specialisation which could cause significant bias in the results. Further research would be useful to identify the geographical units of measurement which best capture the regional effects of own-industry specialisation, industrial diversity and urban scale on firm performance.

NESTA "Economic Complexity and the Emergence of New Ideas"
The paper extends the analysis of economic complexity to local economies in the UK, showing the influence of their sectoral composition on growth prospects, and providing evidence about the mechanisms that link economic complexity and development through the emergence of new ideas. The study explores the use of novel datasets to measure economic complexity and how these relate to complexity.

The paper measures economic complexity using Economic Complexity Index (ECI) and a Fitness based measure, which respectively capture a location's specialisation in unique, knowledge intensive sectors, and a weighted measure of economic diversity. Authors use a complex networks approach to topic modelling to detect topics in the websites of businesses and analyse their relation to economic complexity and industrial sectors before going on to measure complexity by looking for novel words in the websites of businesses in different locations and sectors.

The study estimates economic complexity indexes using employment data from BRES (The Business Register and Employment Survey) and IDBR (Interdepartmental Business Register) accessed from NOMIS, an online portal with labour market data for the UK. Authors use 380 Local Administrative Districts capturing local government boundaries in Great Britain as a geographic unit.

The results support the idea that high ECI scores capture specialisation in knowledge intensive, unique sectors such as computing, creative services, finance or research, while Fitness is closer to a weighted measure of diversity.

Limitations
The study has the following limitations: reliance on Local Administrative Districts instead of functional economic areas as the unit of geographical analysis, the risk of noise in geocoding and sectoral classification of the Glass data, and focus on descriptive, bivariate analyses of Glass' cross-sectional data.

CBI "Unlocking regional growth"

The study investigated why regional productivity differences exist and what more businesses and government can do to tackle them.

The study focused on NUTS3 data to analyse what drives productivity at this granular level for all of these regions. For some of the analysis the authors have gone deeper than this, right down to the postcode level (NUTS4).
The study used the Office for National Statistics' (ONS) Virtual Microdata Laboratory (VML), where the authors analysed data from hundreds of thousands of businesses' anonymised responses to official government surveys on how much they are investing, their levels of research and development and whether they are exporters.
First, for each region and devolved nation the study identifies which of the local areas (NUTS3) have increased their nominal GVA per hour the most between 2004 and 2014. This helps the authors identify the 11-star performers across the UK regions and devolved nations. Next, the study establishes a baseline scenario, under which productivity for each local area continues to grow over the ten years to 2024 at the same pace that it did over the ten years to 2014. To account for these factors, authors assume both in their baseline and alternative scenarios that the 20% most productive local areas (NUTS3) improve at the trend rate of productivity growth from 2004 to 2014. This baseline scenario results in the UK's nominal gross value added rising 31% to £2.09tn by 2024. Under the alternative 'reach for the stars' scenario, authors try to gauge what would happen over the next decade if each local area could match the performance of the star in their respective region. In this scenario, authors find that the nominal gross value added of the UK economy would climb 45% to £2.30tn by 2024. The difference between the two scenarios is £208bn.

The analysis has also identified that there are four main drivers of productivity:1. Educational attainment of young people at 16 and skills; 2. Transport links that widen access to labour; 3. Better management practices; 4. A higher proportion of firms who export and innovate. Investment should focus on the levers that will make the most difference in each nation or region. To assist policymakers, the CBI is developing regional scorecards, which highlight where business leaders, devolved administrations, central and local governments leaders should concentrate their efforts.

Crescenzi, Nathan, Rodriguez-Pose (2016); Stoper (2015) "Do inventors talk to strangers? On proximity and collaborative knowledge"

The paper examines the characteristics of the collaborations between inventors in the UK by looking at what types of proximities – geographic, organisational, cognitive, social, and cultural-ethnic – between inventors are prevalent in partnerships that ultimately lead to technological progress.

The study considers both a plausible set of possible pairs – inventors who might have worked together – and the set of actual pairs (those who did collaborate). To do this, authors build a 'synthetic counterfactual' consisting of a feasible set of potential collaborators. Authors then use a case-control strategy, in which they disentangle the characteristics of actual pairs from the feasible possible pairs that might have existed.

The analysis of the features of UK patenting teams shows that a significant part of innovation activities are characterised by organisational proximity. Second, the results show that ethnic and cultural diversity are also important features of inventing teams and that social networks represent the building blocks for collaboration. Third, geographic proximity enters the picture only indirectly: it interacts with other proximities increasing their association with collaborative work. Inventors seem to rely on geographical proximity to form their teams when it is coupled with other forms of "advantage".

Limitations
First, without exogenous variations in the observed proximities, selection effects cannot be controlled for, and results have to be interpreted as associations. Second, patent data can only capture collaborations that lead to a patented output. Authors do not observe unproductive collaborations (or not-yet-productive ones). Third, the study cannot capture collaborations that lead to non-patentable output – for example in the form of process innovation or innovation in services (an important part of UK innovation activity). Finally, the reliance on patent data might lead to an over-estimation of the importance of organisational proximity. The tendency of inventors to share the same applicant inevitably reflects fundamental incentives about disclosure versus secrecy in R&D projects.

Harris, R. (2008) "Models of regional growth: past, present and future"

The paper critically reviews various models of regional growth over the last 40 years. This coverage of model is wide ranging, from Neo-Classical model to the recently popular New Economic Geography Models and the paper helpful concludes with suggestion to overcome limitations of previous research.
From our point the most critical point is the use of aggregate models (such as neo-classic model which assume homogenous firms) which do not discriminate between the factors which are the most important in determining regional growth. These models fail to recognise that plants and firms are heterogeneous and ignoring this hinders our understanding of different mechanisms that drive regional growth.
Furthermore, if the focus of research is on the identification of barriers to innovation and growth at firm level, research should focus on micro-level spatial data, such as intra-regional activities that crucially determine long-run growth (such as knowledge spillovers, labour market characteristics, and other agglomeration effects), the Annual Respondents Database (ARD), the Business Enterprise Research and Development Survey (BERD) data, and the Community Innovation Survey (CIS) data.

J. Aarstad et.al. (2016) "Related and unrelated variety as regional drivers of enterprise productivity and innovation: A multilevel study"

The study examines the concepts of related and unrelated varieties and their impact on firms' productivity and innovation. In a region 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.

The paper tested whether there is a positive association between regional related variety (such as population density, and an enterprise's propensity for innovation[1]. According to the study, by doing so they overcome the drawback of many studies using patent data as a measure of innovation. The drawback is due to varying patenting patterns across industries. The study finds that related industrial variety has a positive effect on an enterprise's propensity to be innovative, whereas population density has a borderline negative effect.

Limitations

The data used are cross-sectional and not longitudinal. Future studies should apply the appropriate instrumental variables to ensure robust internal validity and the authors would encourage future research to address spatial dimensions other than economic-geographical regions. One such spatial dimension is the industry structure.

2. Would a higher innovation lead to a higher productivity / growth?

Overall several studies looked at the role of innovation on economic growth at national level or on the impact of innovation at firm-level performances; however, based on our literature review, there is limited evidence that previous studies look at impact of innovation on aggregate productivity based on firm-level data.

Moreover, this study aims to be more comprehensive and control this estimation for several factors to ensure more robust results.

Paas, T. and T. Vahi (2012) "Economic growth, convergence and innovation in the EU regions"

The paper examined the relationship between regional innovation and economic development in the NUTS-2 level regions across EU. It aggregated several regional indicators of innovation in three overarching indicators with principal component factor analysis technique.

Then the authors test the significance of relationship between economic development indicators such as GDP and the overarching indicators on innovation.

To test this hypothesis basic regression equation is estimated based on the data for 262 EU NUTS-2 level regions.

The paper finds that almost 63.4% of variability in regional GDP per capita can be explained by factors relating to the regional innovation performance. According to the study, three factors explain 80.8% of the variation of the regions' initial innovation indicators – knowledge-based service, human capital and high-technology manufacturing.

Limitation

Whether this study might be useful to identify regional-level indicators for innovation – these tend to be affected by limitations of granular data availability, reliability and completeness, given these are biased towards science-based innovation.

OECD (2012) "Promoting Growth in All Regions"

The study analysed the importance of different factors, among them innovation, driving local growth in different types of regions. The regression results provide little support for a link between innovative activities and regional growth across lagging and top regions. Authors suggests how these conclusions were affected by the indicators employed (investment in

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[1] The study conducted a multilevel mixed effects logistic regression. Innovation is a dependent variable, measured 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).

R&D and patents) which cover forms of innovation activity that are oriented towards cutting-edge, science-based innovation, which is typically concentrated in advanced urban centres. As the paper suggests, it would make sense to try and measure "softer" forms of innovation, as opposed to the ones of science and technology variety, in lagging regions.

Limitation
Whether its conclusions are useful to understand limitations of studies which focus only on patents, as the study suggest, we recommend contractors to capture also "softer" forms of innovation at a more granular level. A future contractor could propose how to address this limitation.

Rodríguez-Pose, A. and R. Crescenzi (2008), "Research and development, spillovers, innovation systems, and the genesis of regional growth in Europe"

The paper tries to further the research on the impact of innovation on regional economic performance in Europe.
To do that, it combines in one model, R&D, spillovers, and variables underpinning the innovation systems (such as education, participation in lifelong learning programmes etc.) to analyse the impact of innovation on regional economic performance in Europe.
The paper's findings point to the importance of local socio-economic conditions to generate and assimilate innovations. It also highlights the importance of proximity for the transmission of tacit knowledge.

Limitation
Whether it is useful framework to capture relationships between innovation and regional levers; the study is based on 10 years old data at aggregate regional level.

ERC regional Growth Dashboard

The purpose is to present a set of growth metrics for start-ups and existing firms across a range of sub-national geographies in the UK with a specific focus on each of the 38 English Local Enterprise Partnership (LEP) areas. Alongside these metrics it provides some other contextual data for each LEP including the changing sectoral composition of local economies over time. The report is designed to simply present the data for others to use and it is not its intention to investigate the reasons for these variations as that can be found elsewhere in the research outputs of the ERC and the wider research and policy literature.

The growth metrics which are used in the Dashboard are:
• 3-year survival rates of start-ups (2014-17)
• Proportion of 2014 start-ups that reach £1m+ T/O (2014-17)
• Proportion of £1-2m T/O businesses born before 2013 which grow to £3m+ T/O (2014-17)
• High-Growth Firm (OECD Definition) Incidence Rate (2014-17) –using both the traditional 20% threshold and the revised 10% threshold.
• Small High-Growth Incidence Rate (2014-17) –a metric adopting a methodology advocated to avoid the exclusion of firms with less than 10 employees from the OECD definition
• Productivity Growth metric (2014-17) –a new metric this year looking at firms who grow both in terms of jobs and revenues but have a faster rate of growth in revenues

The dataset used in the production of the growth and start-up data is the Business Structure Database (BSD). This is a dataset produced by the Office of National Statistics (ONS) and is an annual snapshot of the Inter-Departmental Business Register (IDBR) which is a live register of data collected by HM Revenue and Customs via VAT and Pay as You Earn (PAYE) records.

BIS (2014) Innovative firms and growth

The paper's specific empirical focus is on Highly Innovative Firms (HIFs) and High Growth Firms (HGFs), their relationship to one another, and how their features and behaviour influence their performance.

The research used four waves of the Community Innovation Survey for the UK for the years 2004, 2006, 2008 and 2010, which were linked to the ONS Business Structural Dataset (BSD) to create a panel. The survey was analysed as yearly cross sections and as an integrated panel of all four waves.

The study finds that:
- HIFs have a significantly higher share of employment accounted for by science and engineering (STEM) graduates, and moreover we find that this has a large positive influence on a range of performance metrics. HIFs also tend to be much more internationally orientated than LIFs and more focused on exporting to international markets.
- high levels of growth are not strongly persistent.
- there is a strong persistence in the innovative status of firms, with most HIFs remaining highly innovative and most LIFs remaining less innovative.
- the analysis suggests that the growth process starts with increased employment, which then leads to future increases in R&D spending and New to Market Products, which in turn lead to future increases in Sales.
- HIFs, on average, tend to perceive more barriers to innovation than other firms, even though they do not seem to affect their relative performance compared to LIFs who perceive fewer barriers to innovation.

Limitation
In adopting R&D spending as a measure that captured inputs to innovation, while the share of sales derived from new-to-market products as an output measure of innovation, the authors noted a potential problem. R&D is an input measure, and as such does not actually measure innovation. Moreover, R&D is only an input to a subset of innovations and much innovation in the economy takes place outside formal R&D settings, for example, in design shops, in production or systems engineering departments etc.

R.Harris, J.Moffatt "R&D, Innovation and Exporting" (2011)

This study considers the determinants of whether a firm exports, undertakes R&D and/or innovates, and, in particular, the contemporaneous links between these variables using three waves of the UK Community Innovation Survey (CIS).

Where appropriate, an instrumental variables procedure is employed to overcome problems of endogeneity.

The results show that in both manufacturing and services, being involved in exporting increased the probability that an establishment was engaged in spending on R&D. Spending on R&D in manufacturing had a much larger impact on the probability of exporting which implies that spending on R&D was not simply to boost the probability of producing new goods and services, but also to improve the establishment's knowledge assets which would in turn help it break down barriers to international markets. In non-manufacturing, spending on R&D increased the probability of innovating but had no significant impact on whether the

establishment exported; rather, innovating increased the probability of exporting. Exporting had no direct impact on whether innovation occurred in either sector.

Limitations
It provides a good framework to capture drivers across the heterogeneity of firms to promote innovation and better performances. That said, in our view, a different technique complemented with new data would be useful to estimate the impact of the rate of return in innovation.